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Leveraging Technology to Break Barriers in Public Health for Students with Intellectual Disabilities

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Abstract: A key goal of inclusive education is to enhance health literacy skills, empowering students with intellectual disabilities (IDs) to access critical information needed to navigate everyday challenges. The COVID-19 pandemic, for example, highlighted unique barriers to preparedness for people with IDs regarding social behavior and decision-making. This study aimed to examine students' awareness and understanding of pandemic outbreaks. Using an inquiry-based approach supported by Digital Learning Objects (DLOs), the research assessed students' knowledge and perceptions of viruses, modes of transmission, and preventive measures. An in-depth visual analysis within a single-subject research design demonstrated that interdisciplinary educational scenarios on infectious diseases can be effective for students with ID, especially when DLOs are integrated with targeted instructional techniques.

Keywords: technology; intellectual disabilities; public health; science literacy

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1. Introduction

One of the most prevalent global challenges is the lack of science education, particularly regarding health content, for students with intellectual disabilities (IDs) to cope with a multitude of information on daily life issues and increase their participation in social dialogue [1–3].

During the COVID-19 pandemic outbreak, the ongoing information storm (the so-called "infodemic") created overload and significant barriers in identifying reliable information [4–7]. To overcome disinformation or misinformation, health literacy skills may facilitate navigating across various public health issues, such as infectious diseases [8]. In this direction, people with ID should develop health literacy skills at an adequate level of readiness to foster equally critical thinking, make decisions, and adopt prevention behaviors in periods of epidemic or pandemic outbreaks [9–11].

By engaging students with ID as well as their caregivers in scientific practices, they experience increased service provision [12,13] and acquire science skills to equally participate in emerging challenges in various aspects of daily life [14]. Effective implementation in science classrooms involves activities such as asking questions to solve problems, planning and conducting investigations, analyzing and interpreting data, constructing explanations, using arguments, evaluating, and communicating findings [14,15]. Specifically, inclusive lessons based on inquiry-based learning can enhance comprehension for students with ID, helping them stay focused, reduce memory challenges, and improve attention [16].

Reviews on teaching science to students with ID recommend the connection between basic science content and daily communication using adapted instructional practices in suitable learning environments [17,18]. Systematic instruction with supplemental task analysis techniques, prompting, and time delay constitutes an effective teaching package based on behaviorism to address students' individualized needs [18]. The literature reports that students develop higher cognitive skills from constructivism approaches and especially inquiry-based learning in science classes; nevertheless, few studies have focused on this approach for students with IDs [18,19].

Furthermore, integrating various digital solutions into the teaching process can enhance students' academic performance. These include video-based instruction [20], Computer Assisted Instruction (CAI), video prompting for teaching scientific terminology [21], and adapted e-texts with multimedia and hyperlinks to enhance comprehension [22]. Additionally, immersive technologies promise engagement, motivation, and positive learning outcomes in teaching scientific concepts to students with ID [23]. Incorporating Digital Learning Objects (DLOs) into teaching can enhance vocabulary acquisition while sustaining high levels of student engagement [24,25].

A Digital Learning Object is defined as a "small, self-contained, reusable, and pedagogically complete structure of learning content. . . aimed at delivering learning experiences" [26] (p. 257). DLOs' key characteristics include reusability, granularity, discoverability, accessibility, interoperability, adaptability, durability, generativity, and manageability, and they are stored in online repositories [27]. Several studies have highlighted the positive impact of DLOs in special education and inclusion [28–30]. Recently, Mallidis-Malessas and colleagues [25] investigated the impact of DLOs from the Hellenic open repository Photodentro on learning grade-aligned Physics concepts, specifically transverse waves and the simple pendulum concept. The study revealed improved learning outcomes and positive student experience.

Given the limited literature on health literacy for vulnerable populations, this study focuses on designing an empirical investigation to support digital health literacy among students with ID, helping them navigate health-related challenges in everyday life. This work contributes to the "key steps to equity and inclusion in education" proposed recently by the Organization for Economic Co-operation and Development (OECD), particularly by supporting teachers in developing essential competencies and knowledge areas, as well as fostering and monitoring students' progress [31].

This study employed a single-subject design [32,33] to investigate the contribution of a digitally supported educational intervention on students with ID through a series of lessons on the cognitive and affective determinants of health during an epidemic or pandemic. Students' achievements included the acquisition of scientific terminology related to infectious diseases and their characteristics. The following research question was posed: What is the effect of the digitally supported educational intervention on students' ability to acquire health literacy content on infectious diseases, focusing on the COVID-19 pandemic?

2. Materials and Methods

2.1. Participants and Setting

Twenty students from a public special vocational high school in a northern city of Greece participated. Eleven male and nine female students aged 18–25 years were chosen from 10 special education classrooms (each classroom accommodated three to eight students). Students' inclusion criteria were: (a) a diagnosis of ID from a government agency, (b) adequate visual discrimination to select words from an array on the computer screen, (c) motor ability to independently use a computer mouse to select stimuli from an array on a computer screen, and (d) verbal response. All 20 participants followed an individualized education program to increase their vocabulary, reading fluency, and comprehension. The students required prompting and oral guidelines to complete the activities. Regarding the participation protocols, informed consents were obtained from the parents. To safeguard the privacy of all participants, pseudonyms were assigned. An information sheet was provided for participants, which contained information about the research team, the objectives of the study, and the rights and responsibilities assumed through participation. Students were also informed about their voluntary participation, the possibility to withdraw from the study at any time, and the anonymity of the questionnaires used.

All sessions were conducted in the computer lab by one of the authors, the students' Physics teacher, in a one-to-one format. Additionally, two members of the teaching staff helped students collect reliability data.

2.2. Materials

The intervention was based on the educational scenario titled "Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities" found at the open access Photodentro PAFSE repository (https://photodentro.pafse.eu/handle/8586/176?&locale=en (accessed on 20 August 2024)). The scenario is supported by four Digital Learning Objects, which can also be found in the open repository Photodentro PAFSE. Additionally, the scenario involves other open digital educational resources, such as videos, which have been retrieved from open online resources (A Day at School, Unicef: https://www.unicef.org/greece/en/stories/day-school-during-covid-19 (accessed on 20 August 2024), or All about Coronavirus: A Video for Kids and Their Families | University of Michigan School of Public Health: https://www.youtube.com/watch?v=6lJQ123_4e8 (accessed on 20 August 2024)). The authors developed both the scenario and the DLOs as parts of the HORIZON 2020 "Partnerships for Science Education—PAFSE" project (https://pafse.eu/ (accessed on 20 August 2024)). Table 1 shows the structure of the scenario.

The DLOs included three interactive concept maps and one interactive infographic. To ensure content validity, the DLOs were designed and developed according to the principles of the Universal Design Framework, confirming accessibility for all students with ID [34,35]. The concept map "COVID-19" aimed to teach students with ID to apply vocabulary regarding coronavirus (Figure 1). This DLO consists of three propositions presented successively, incorporating task analysis steps to align with this instructional technique for students with disabilities. Students select the given words or phrases to complete each proposition. As each proposition is completed, the DLO provides immediate feedback and reinforcement.

The two other concept maps also followed the same design principles (Figure 2). Their content concerns the symptoms (http://photodentro.pafse.eu/handle/8586 /41 (accessed on 20 August 2024)) and the transmission of COVID-19 (http://photodentro.pafse.eu/handle/8586/42 (accessed on 20 August 2024)), respectively.

The fourth DLO is an interactive infographic titled "COVID-19" (Figure 3), which focuses on measures to slow the transmission of infectious diseases, emphasizing the COVID-19 pandemic. It also aims to enhance decision-making skills during a pandemic outbreak. The infographic consists of twelve frames, colored in green (protective measures) or red (measures against protection), aligned with corresponding images. Students have to select the images to complete the frames and receive feedback and reinforcement.

Table 1. The structure of the educational scenario.

Scenario Title Main partner responsible Overview/context Scientific content and its relevance to public health education Estimated duration
STEM content Content glossary Pedagogical glossary
Competences/learning goals Classroom organization requirements Prerequisite knowledge and skills
School research project Teacher guidance notes/ professional development actions Assessment activities
Digital Learning Objects (DLOs) I. Concept map COVID-19 (http://photodentro.pafse.eu/handle/8586/40 (accessed on 10 August 2024)) II. Concept map of symptoms COVID-19 (http://photodentro.pafse.eu/handle/8586/41 (accessed on 10 August 2024)) III. Concept map of the transmission of COVID-19 (http://photodentro.pafse.eu/handle/8586/42 (accessed on 10 August 2024)) IV. Infographic COVID-19 (http://photodentro.pafse.eu/handle/8586/43 (accessed on 4 June 2023)) **Supplementary educational resources (SERs)** https://www.rch.org.au/ccch/covid-19/ (accessed on 10 August 2024) (translated infographic about COVID-19) https://www.youtube.com/watch?v=MVvVTDhGqaA (accessed on 10 August 2024) (translated video about COVID-19, Eurac Research) https://www.unicef.org/greece/en/stories/day-school-during-covid-19 (accessed on 10 August 2024) (video A Day at school, Unicef) https://www.youtube.com/watch?v=6lJQ123_4e8 (accessed on 10 August 2024) (All about Coronavirus: A Video for Kids and Their Families | University of Michigan School of Public Health) https://www.youtube.com/watch?v=GFm45J8d7HI (accessed on 10 August 2024) (video about viruses)
Teacher–learning activities Principal target
Training phase Lesson 1 (Baseline: orientation phase) Lessons 2, 3 (Intervention: main inquiry—conceptualization—investigation) Lesson 4 (Intervention: applying new knowledge and skills) Lessons 5–6 (Open schooling event: applying new knowledge and skills—conclusions)
Supplementary learning activities I. Video watching and discussion II. Handcrafting
Indicative literature

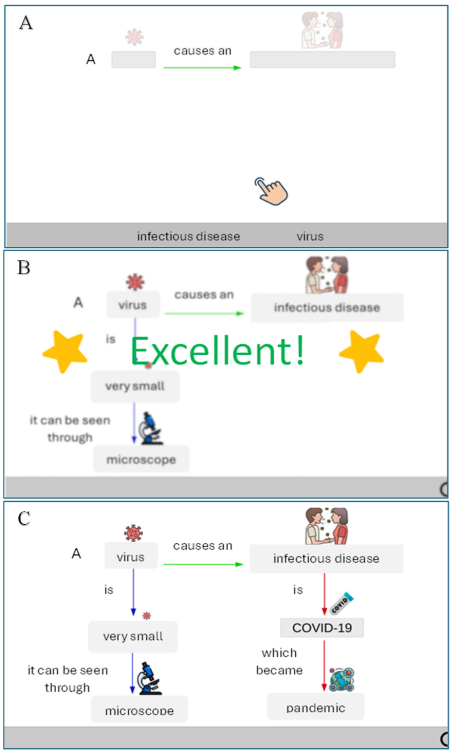

Figure 1. Screenshots (**A**–**C**) of the COVID-19 concept map made with Unity (http://photodentro.pafse.eu/handle/8586/40 (accessed on 20 August 2024)). Reinforcements include yellow star response prompts.

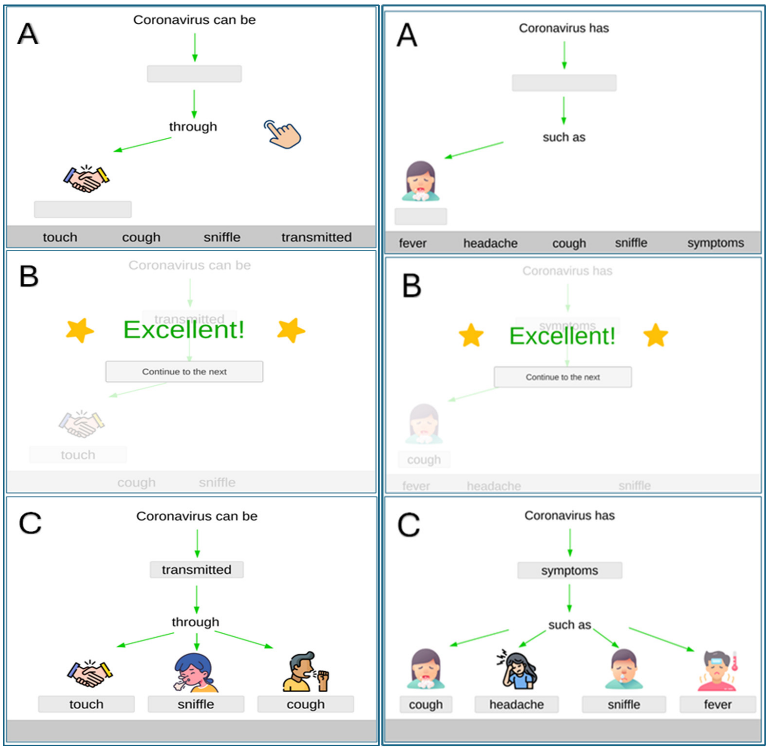

Figure 2. Screenshots (**A**–**C**) of the COVID-19 transmission concept map (**left**) (http://photodentro.pafse.eu/handle/8586/42 (accessed on 20 August 2024)) and COVID-19 symptoms concept map (**right**) (http://photodentro.pafse.eu/handle/8586 /41 (accessed on 20 August 2024)) made with Unity. (**A**–**C**) The COVID-19 concept map was made with Unity (http://photodentro.pafse.eu/handle/8586/40 (accessed on 20 August 2024)). Reinforcements include yellow star response prompts.

Figure 3. Screenshots (**A**–**D**) of the COVID-19 interactive infographic made with Unity (http://photodentro.pafse.eu/handle/8586/43 (accessed on 20 August 2024)). Reinforcements include yellow star response prompts.

2.3. Procedures

2.3.1. Experimental Design

An AB single-subject design was employed to investigate the effects of the inquiry-based intervention on students' performance. "A" refers to the baseline phase, while "B" represents the intervention phase, allowing for the documentation of causal or functional relationships between independent and dependent variables [36]. Experimental control was demonstrated by a clear increase in level and trend from baseline to intervention phases, observed across all students. Figure 4 describes the training, baseline, and intervention phases. Each phase consisted of four sessions to determine the existence of a functional relation between the intervention (independent variable) and student performance (dependent variable). The last session, the open schooling event, acted as a generalization phase.

The AB single-subject design is considered to be suitable for examining individualized intervention effects, particularly in diverse populations, such as students with intellectual disabilities, where variable characteristics in response to interventions are common. This research design enables a detailed assessment of each participant's progress, providing a more precise understanding of how the intervention may impact individual learning outcomes [32,33,36]. Through visual analysis, the risk of overlooking important individual differences can be reduced. Given the heterogeneity within the intellectual disabilities population, a single-subject design, such as an AB design, is particularly valuable for capturing the intervention's effects on each participant. Although the sample of this study is small (20 students), the intra-individual differences of the participants may lead to significant results, even to generalizable findings, and provide replicability.

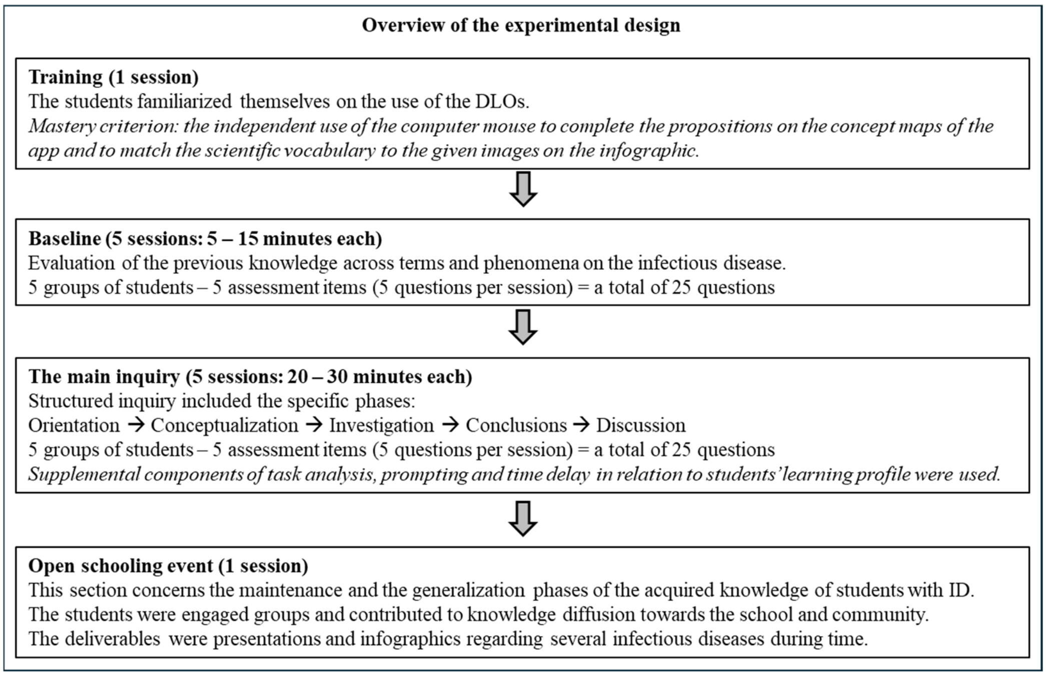

Figure 4. The procedure followed in the empirical study.

2.3.2. Training Phase

A training session was conducted to assess whether students met the mastery criterion for using the DLOs. Simple task analysis steps were implemented to observe students' ability to (a) complete the propositions on the concept maps and (b) match scientific vocabulary to the corresponding images. The researcher confirmed each student's mastery of the DLO and explained how the feedback functions. Within 15 minutes, all students demonstrated proficiency in following the task analysis steps and completing the prepositions on the computer screen.

2.3.3. Baseline Phase

The researcher gathered baseline data over five sessions to assess the prior knowledge of the 20 students. The baseline phase ended when all sessions covering infectious disease descriptions, symptoms, and prevention measures were completed. Oral task directions were provided to each student with identical verbal prompts, such as "choose the correct answer", without providing any additional prompting or feedback.

2.3.4. Digital Technology Supported Inquiry-Based Intervention Phase

Following the baseline phase, the intervention sessions began and lasted for five weeks, with one session per week. Each session lasted from 20 to 30 minutes, depending on each student's level of engagement in the inquiry process. When students entered each session, the researcher launched the Photodentro PAFSE repository, and the students sat in front of their screens. The students interacted with the DLOs and received immediate feedback. Probe sessions with assessment sheets were conducted after the completion of each intervention session. The targeted scientific terminology included terms like virus, infectious disease, incubation time, vaccine, symptoms, and precautionary measures. The main steps of the inquiry process (i.e., orientation, conceptualization, investigation, conclusion, and discussion—applying new knowledge and skills) were designed to help students construct new knowledge as active learners regarding the infectious disease [37–39].

Students received explicit instructions and verbal directions at each step of the structured inquiry to support their learning. The main question, "What is an infectious disease?"

guided the orientation step. Additionally, two brief videos on the COVID-19 pandemic were presented (https://www.youtube.com/watch?v=MVvVTDhGqaA (accessed on 4 June 2022), https://www.unicef.org/greece/en/stories/day-school-during-covid-19 (accessed on 4 June 2022)).

2.4. Data Collection and Dependent Variables

The researchers assessed the effects of the independent variable (i.e., the intervention) on the dependent variables (i.e., the number of correct responses) during the probe sessions. After interacting with the DLOs and following verbal guidelines based on task analysis steps within the structured inquiry, students answered 25 application questions (five per session) related to infectious diseases, their description, and protection measures. Students' responses were collected on data sheets during the probe sessions. Only correct responses were plotted on the graph (Figure 5). Table A1 shows the evaluation sheets used to assess students' acquisition of basic vocabulary and their responses to application questions about infectious diseases. Each student should identify the structure of a virus, recognize key risk factors, define relevant concepts, and understand the importance of vaccination in tracking the progress of a pandemic. Additionally, they had to characterize the relationship between precautionary measures and infection and apply their new knowledge in decision-making scenarios.

Interobserver Agreement

Interobserver agreement (IOA) data were collected from the students across all phases. The second observer was trained to collect IOA data during three sessions in the baseline as well as three sessions in the intervention. Agreement was recorded when the researcher and the second observer provided identical responses regarding the implementation of the intervention. IOA was determined by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. IOA was 100% for all the students.

2.5. Data Analysis

Six features assess changes in outcomes in an AB design: level ("mean score for the data within a phase"), trend ("slope of the best-fitting straight line for the data within a phase"), variability ("standard deviation of data about the best-fitting straight line"), overlap ("proportion of data from one phase that overlaps with data from the previous phase"), immediacy of effect ("change in level between the last three data points in one phase and the first three data points of the next"), and consistency of data patterns in similar phases ("consistency in the data patterns from phases with the same conditions") [40]. Experimental control is demonstrated when the design documents at least three demonstrations of the experimental effect at three different points in time with a single participant [33].

To express the change in academic performance between the baseline and intervention phases, we calculated the Percentage of Nonoverlapping Data (PND) effect size, which determines the effectiveness of the inquiry-based intervention [41]. PND >70% means effective interventions, 50–70% partial effectiveness, and PND <50% shows an ineffective intervention.

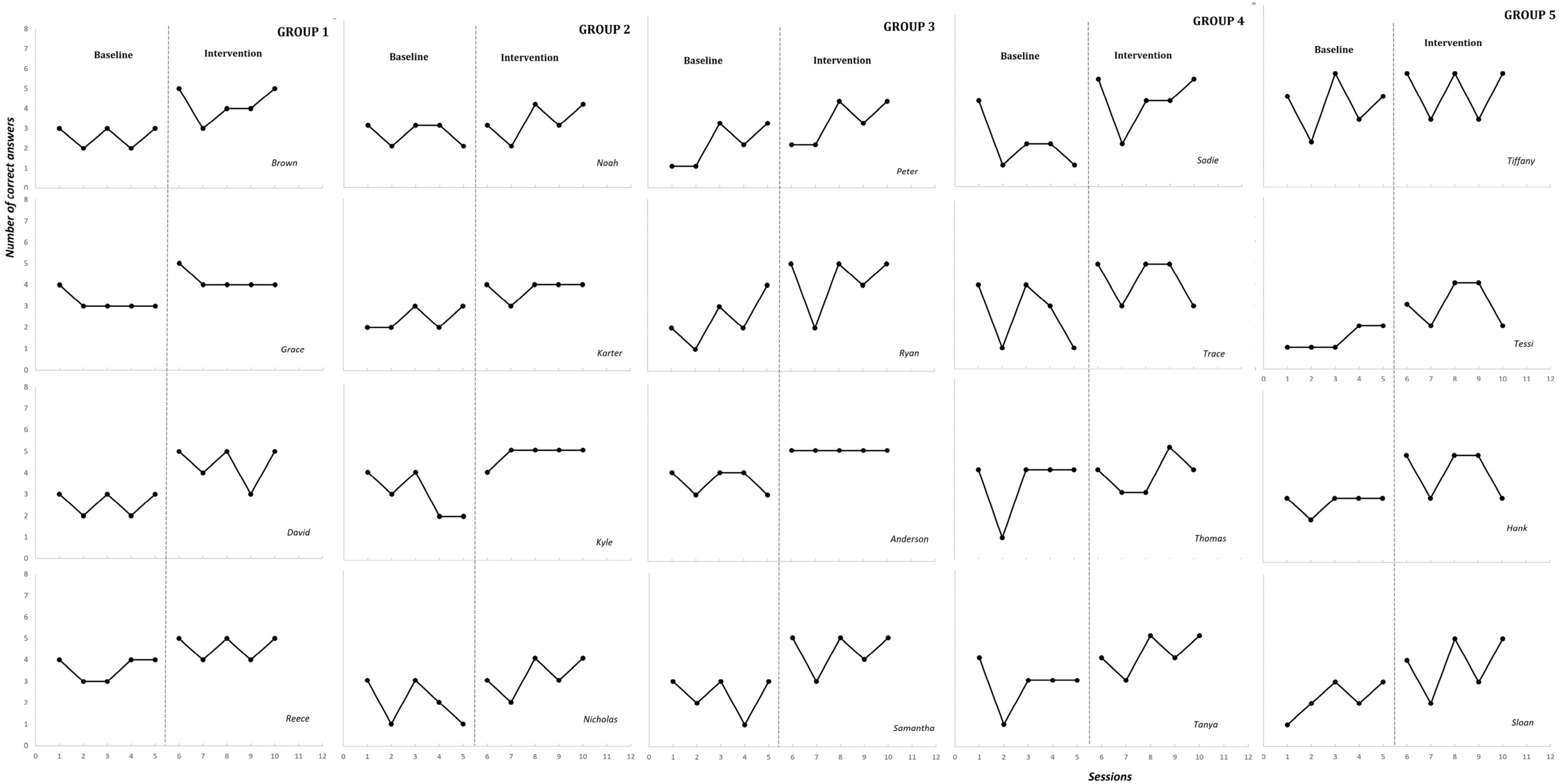

Figure 5. Number of correct responses for the students of the 5 groups participating in the probe sessions. Baseline: 0–5. Intervention: 6–10.

3. Results

Learning Outcomes Across Baseline and Intervention Phases

The visual inspection of the baseline scores indicated that for all students, baseline levels were very low to low and quite variable, with indicative decelerating or stable trends prior to beginning intervention (Table 2 and Figure 5). For example, Brown, David, Noah, Karter, and Anderson had similar data paths during baseline and intervention with the DLOs. For these students, baseline data show initially variable trends in Sessions 1 to 5 (Figure 5), stabilizing or decelerating before intervention. The data of Peter, Ryan, Anderson, Samantha, Sadie, Trace, Thomas, and Tanya showed variability and overlapped the baseline data by 1 to 2 data points (except for Anderson). Grace, Nicholas, Thomas, and Tiffani had almost similar data patterns in the baseline phase and during intervention using DLOs, and the effect sizes for their performance ranged between 0 and 20%. Ryan, Sadie, Trace, and Tanya had distinct data patterns, as their baseline data patterns were variable, ranging from one to four correct answers (Table 2 and Figure 5), and their intervention data patterns changed level; however, they remained variable. Sophie had fewer overlapping data points, while Anderson had no overlapping data points from baseline to intervention conditions.

The 20 students showed increased learning outcomes during the inquiry-based instruction. The functional relationship between dependent and independent variables was robust for most of the students (PND ranged between 60 and 100% for 12 students). The visual analysis of the students' graphs (Figure 5) reveals an upward trend and increased level in the number of correct responses following the introduction of the inquiry-based intervention, compared to the baseline. However, there were data patterns with high variability.

During intervention, 18 students experienced an immediacy of effect and showed an increase in correct responses. All students reached the mastery criterion (completing the basic phases of an inquiry circle). Brown, Grace, David, Reece, Noah, Karter, Kyle, Nicholas, Peter, Ryan, Anderson, and Samantha showed positive learning outcomes at the same rate (Figure 5). When the intervention began, the data were variable yet accelerating or were already stabilized. Brown, David, Karter, Kyle, Anderson, and Samantha had more distinct data patterns. These students had fewer overlapping data points from the baseline phase to the intervention for all sessions than other students. Unlike most students, Anderson began intervention with higher levels (five correct answers in all five sessions). Noah, Nicholas, and Tanya also had distinct data patterns in intervention. In addition, unlike other students, Trace, Hank, and Tessi had distinct data in intervention sessions.

Table 2. Effectiveness data.

Student	Baseline			Intervention			Effect Size
	Mean ± SD (Correct Answers)	Range (Correct Answers)	Visual Analysis (Level, Trend, Variability)	Mean ± SD (Correct Answers)	Range (Correct Answers)	Visual Analysis (Change, Level, Variability)	PND (%)
Brown	2.6 ± 0.5	2–3	low, variable with a slight decelerating trend	4.2 ± 0.8	3–5	abrupt and immediate change in performance, overlapping and variable data	80
Grace	3.2 ± 0.4	3–4	low with a stable trend	4.2 ± 0.4	2–5	immediate change in performance with a stable trend	20
David	2.6 ± 0.5	2–3	low, variable with a stable trend	4.0 ± 1.4	3–5	immediate change in performance overlapping and variable data	80
Reece	3.6 ± 0.5	3–4	low, variable with an overall decelerating trend	4.4 ± 0.9	3–5	variable and overlapping data	60
Noah	2.6 ± 0.5	2–3	low with a stable trend	3.2 ± 0.8	2–4	overlapping data with a slight increasing trend	40
Karter	2.4 ± 0.5	2–3	very low with a stable trend	3.8 ± 0.4	3–4	initial decelerating trend, change in performance, and stable trend	80
Kyle	3.0 ± 1.0	2–4	low, variable with an overall decelerating trend	4.8 ± 0.4	4–5	abrupt and immediate change in level, data with a stable trend	80
Nicholas	2.0 ± 1.0	1–3	very low, variable with an overall decelerating trend	3.2 ± 0.8	2–4	variable data with a slight increasing trend	20
Peter	2.0 ± 1.0	1–3	very low, variable with an increasing trend	3.0 ± 1.0	2–4	variable and overlapping data	40
Ryan	2.4 ± 1.1	1–4	very low, variable with an increasing trend	4.2 ± 1.3	2–5	variable and overlapping data with a slight increasing trend	60
Anderson	3.8 ± 0.8	3–5	low level, with a slight decelerating trend	5.0 ± 0	5–5	very high data with a stable trend	100
Samantha	2.4 ±0.9	1–3	variable	4.4 ± 0.9	3–5	variable and overlapping data with a slight increasing trend	80
Sadie	2.0 ± 1.2	1–5	very low with a decelerating trend	4.0 ± 1.2	2–5	variable and overlapping data	40
Trace	2.6 ± 1.5	1–4	variable with a decelerating trend	4.2 ± 1.1	3–5	variable and overlapping data	60
Thomas	3.4 ± 1.3	1–4	variable with an abrupt change in stable trend	3.8 ± 0.8	3–4	variable and overlapping data with a stable trend	20
Tanya	2.8 ± 1.1	1–4	variable with an accelerating trend	4.2 ± 0.8	3–5	variable and overlapping data with a slight increasing trend	40
Tiffany	3.6 ± 3.6	2–5	variable	4.2 ± 1.1	3–5	variable and overlapping data	0
Tessi	1.4 ± 1.4	1–2	very low with a stable trend	3.0 ± 1.0	2–4	variable and overlapping data	60
Hank	2.8 ± 0.4	2–3	low with a stable trend	4.2 ± 1.1	3–5	immediate change in level, variable data with a stable trend	60
Sloan	2.2 ± 0.8	1–3	very low with an accelerating trend	3.8 ± 1.3	2–5	overlapping data with a slight increasing trend	60

4. Discussion

The purpose of this study was to teach basic content on infectious diseases to students with IDs to acquire health literacy and help them understand the impact of the COVID-19 pandemic on people's lives. Twenty students with mild IDs participated in a structured inquiry intervention supported using DLOs. The results assessing the impact of the intervention on the acquisition of targeted terms and their application showed an increase in the number of correct responses during probes. The twenty students, the teacher, and the two members of the teaching staff agreed that the intervention was effective and expressed a desire to continue using DLOs from the PAFSE Photodentro repository in their teaching process.

The visual analysis of the students' responses revealed that during the baseline phase, all students demonstrated low performance, struggling with the challenging content in Biology and Health Sciences. However, upon entering the intervention, most students exhibited an immediate change in level and demonstrated improved achievements. A functional relationship between the dependent and independent variables was established for 12 students by comparing their performance during the baseline phase with their outcomes after the intervention.

Our results are consistent with previous studies on the contribution of DLOs to teaching academic content in special education [25,28,29,42]. Enhancing the health literacy of students with ID provides a fundamental context for developing meaningful understanding, adopting social behaviors, and communicating ideas related to daily life situations [15,19,21,43].

Regarding students' inquiry skills, an open schooling event with the engagement of students, teachers, parents, and other experts was organized one month after the intervention. The event was used to assess knowledge generalization and communication. Prior to the event, students navigated the provided web resources to identify information on infectious diseases. The researcher encouraged students to pose questions, search in line with their concerns, and explain the process they had to follow (e.g., what will you explore? Define your objective. What do you need to find out? How will you carry out your investigation?). Under these conditions, students were asked to generalize the content they learned by focusing on other infectious diseases. They followed the steps of a simple inquiry process and presented content regarding infectious diseases other than COVID-19. The students communicated the results of their collaborative work. For example, they presented basic information, such as the definition, symptoms, and transmission of Ebola, Yellow Fever, Flu, Cholera, Zika virus, and other pandemics in the past. The majority of the students developed inquiry skills across five dimensions: asking questions, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, and obtaining, evaluating, and communicating information. Specifically, each student (who demonstrated a high PND effect size) could propose certain actions to promote public health, communicate the adoption of choices by others, demonstrate values and adopt individual attitudes that lead to public health, select appropriate information to describe the progress of public health during a pandemic outbreak, identify the community challenges in relation to pandemic outbreak, connect them with social behavior, and find the relevant resources to address them. The other students (Grace, Noah, Nicholas, Peter, Sadie, Thomas, Tanya, and Tiffani presented low scores in PND effect sizes: 0–40) were supported by the teachers and their classmates in order for them to be involved in the inquiry process.

The students agreed that they enjoyed the intervention and reported that the DLOs were easy to use and helped them engage in the learning process. Some indicative comments were: "I liked the lessons about viruses, I will remember this information!", "I liked that we talked about diseases and how we can avoid them", "I liked that we learned about the coronavirus and the differences between the viruses", "I liked that we could express our opinion about various diseases".

This study demonstrates the possible benefits of our approach for students with IDs. Inquiry-based learning may provide a motivating experience for students with IDs, including student-centered tasks, supported by content adaptations and visual scaffolding that transform the activities accessible to them and improve achievement.

To conclude, this study adds to prior evidence that digital technology makes scientific content accessible for students with IDs and contributes significantly to inquiry skills (science skills or practices, problem solving skills, cognitive and metacognitive skills) that are strengthened during the educational process, especially the inquiry circle [21,43,44]. Considering the specific characteristics of mild ID, the use of DLOs helped students to increase their understanding of infectious diseases. The concept maps consisted of prepositions based on easy-to-read methods, designed to facilitate students in highlighting basic content. The sequential presentation of prepositions on the computer screen, based on task analysis steps, helped students minimize memory overload and process information about the infectious disease [45]. Several visual stimuli (i.e., gestures, such as the pointing finger, Figures 1 and 2) prompted students to choose the given words and complete the propositions. The reinforcements (yellow star response prompts, Figures 1–3) motivated students to sustain their interest and follow the task by reducing the attention deficits or giving up the attempt [16]. Our results are consistent with previous findings showing that students who used DLOs remained engaged and showed strong involvement in the teaching process [46].

Overall, this study agrees with the findings of previous studies [47,48], underlines the significance of health literacy, and draws attention to the importance of increasing the availability of instructional methods such as inquiry-based learning to support students with IDs and improve science and health literacy.

Inclusion is a key implication of this study. Students with IDs can use DLOs developed according to Universal Design principles, follow an educational scenario, and communicate health issues with their fellow students, teachers, and family members, as demonstrated during the open schooling event.

One limitation of this study is that all students entered the intervention phase simultaneously [49], as the completion of an inquiry circle was used as the mastery criterion. A second limitation relates to the varying levels of technical proficiency. The participants were selected based on specific inclusion criteria, such as adequate visual discrimination, motor skills, and verbal responsiveness. A third limitation of this study concerns the variability in baseline data. As observed in Tiffany's results, if baseline data are highly variable, the established threshold (highest or lowest point) may be unrealistic or misleading. This variability could affect the interpretation of intervention effectiveness.

Future studies could explore alternative research designs, expand to include individuals with other disabilities, and investigate different DLOs. For example, future research could complement the findings of this study with a group design to examine broader trends and generalizability. Future research should examine the effectiveness of the DLO intervention across a broader spectrum of technical proficiency, with particular attention to the integration of assistive technology tools to support diverse learner needs. In addition, future research should address the third limitation by collecting additional baseline data to ensure it accurately represents the true pre-intervention state.

Digital health literacy enhances preventive measures and adherence to a healthy lifestyle, boosts skills development, and allows individuals to engage in health-related decisions. We believe that this work contributes to a reduction in educational inequalities as proposed by the OECD's "Equity and Inclusion in Education" [31] and UNESCO's "Education For All (EFA)" (https://unevoc.unesco.org/home/TVETipedia+Glossary/show=term/term=Education+for+all (accessed on 20 August 2024)).

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Appendix A

Table A1. Questionnaire on infectious diseases.

1. What is a virus? (A) A microscopic plant. (B) A microscopic infectious agent. (C) A small animal.
2. A known virus is coronavirus. Write another virus you know:
3. Why can't we see a virus? (A) Because a virus is very small. (B) Because a virus is always hidden. (C) Because a virus moves very fast.
4. How can we see a virus? We can see a virus through: (A) glasses. (B) a magnifier. (C) a microscope.
5. When someone is under a disease, they appear
6. Recognizing a disease is called
7. Which of the following is an infectious disease? (A) asthma. (B) cancer. (C) COVID-19.
8. How can we call people who get a virus?
9. What are the transmission ways?
10. When a virus causes a disease, this virus is called: (A) pathogenic. (B) infection. (C) host.
11. The incubation time of the virus is the time until (A) the first symptoms appear. (B) go to the doctor. (C) take medicine.
12. The incubation of a disease can take even a few days. True—False
13. A virus cannot be transmitted (A) through air. (B) through physical contact. (C) through a healthy person.
14. When a virus has infected too many people around the world, it is called: (A) an epidemic. (B) a pandemic. (C) nothing like that.
15. Droplets created when someone coughs are a way of transmission. True—False
16. A disease which is spread all over the world is called
17. A lot of viruses come from animals.

Table A1. *Cont.*

18. Fighting a disease is called (A) treatment. (B) prevention. (C) immunity.
19. The defense system of an organism is called: (A) lymphatic. (B) immune. (C) cardiovascular.
20. Which could be symptoms of a virus? (A) sniffle and cough. (B) fever and headache. (C) all of them.
21. How do vaccines work? (A) they strengthen the body's defence/immune system. (B) they cause other diseases. (C) they last forever.
22. How can you protect yourself from being infected by a virus? (A) being vaccinated. (B) visit the doctor. (C) you cannot protect yourself whatever you do.
23. What are the precautionary measures? (A) a doctor diagnosis for a disease. (B) some acts that help prevent diseases. (C) the symptoms of a disease.
24. How can you make decisions to prevent the spread of an infection? (A) social distancing. (B) by the law. (C) there is nothing you can do.
25. An example of social distancing is (A) a pharmacological intervention. (B) a party in a crowded place. (C) hand washing.

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