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Biology Teaching Strategies for Greek Primary School Students with Learning Disabilities

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The present research examines the impact of teaching strategies, such as structured instruction and ICTs, on the comprehension of biological concepts among Greek primary school students, including those with typical development and learning disabilities (LDs). A preliminary study was conducted with a sample of 20 teachers through semi-structured interviews. The research identified the classes and course units that posed comprehension challenges for primary school students. Interventions were carried out with a sample of 55 6th-grade students, including 13 with LDs. The interventions focused on units related to renewable and non-renewable energy sources, photosynthesis, and the structure of food webs. The first intervention utilized structured instruction with the use of lesson plans and ICTs, such as interactive whiteboards. The second intervention solely relied on ICTs. These groups were compared to students attending traditional lecture-based instruction classes. The results indicated that students with LDs performed less effectively compared to typical development students. Structured instruction proved to be the most effective teaching method for both groups, except for the unit on photosynthesis, where both groups showed decreased performance post-intervention. Students with LDs showed significant improvement in the food webs unit, suggesting that collaborative work enhanced their understanding.

Keywords: biology, learning disabilities, structured instruction, ICTs, primary school

INTRODUCTION

In Greece, the Primary Education Curriculum promotes the engagement of students with scientific and experimental processes (Eurydice, n.d.). The Natural Science Curriculum specifically fosters the development of scientific and technological literacy. Natural Science content in Greek primary school is organized linearly and is divided into subsections, namely Physics, Chemistry, Biology, Geography-Geology, Anthropology, and Astronomy (Pedagogical Institute, n.d.; Institute of Educational Policy, 2021).

Regarding natural science, students grapple with challenging concepts. A lack of scientific knowledge among teachers exacerbates students' comprehension issues,

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particularly those with learning disabilities [LDs] (Dorgu, 2015; Lee & Otaiba, 2015). Children with LDs encounter significant hurdles as they struggle to process information based on pre-existing knowledge, and their memorization abilities are often limited (Fletcher et al., 2019; Young, 2005). Moreover, they tend to have a one-dimensional approach to examining phenomena, leading them to draw incorrect and incomplete conclusions solely based on sensory perception (Taylor & Hord, 2016). As Duda and Adpriyadi (2020) suggested, students' misconceptions about biological concepts, if left unaddressed, can result in poor academic performance and diminished self-esteem. Biology is deemed a particularly challenging subject because it involves processes and concepts that children cannot observe or touch with their senses (e.g., photosynthesis). This challenge is even more pronounced for children with LDs who heavily rely on sensory perception.

On the part of teachers, teaching biology to students with LDs is also challenging, as the subject is not solely based on the development of language or numerical skills. It encourages the implementation of manual activities as well as experimental processes (Vikström, 2008). However, if the teacher is not familiar with those activities and processes, it may be difficult to involve children with LDs during the teaching process effectively. As children with LDs heavily rely on their senses in order to understand phenomena, manual activities and experiments could enhance the comprehension level of students with LDs since they can visualize difficult terms and theories and do not need to express themselves often in writing or orally (McGrath & Hughes, 2017). Furthermore, the involvement of personal effort in such activities facilitates the long-term memory of students and often do not require accessing any pre-existing knowledge (Panagopoulou & Verevi, 2018).

Although structured instruction was initially developed to meet the learning needs of children with autism, its methods can be extended to any kind of LD (Herbert et al., 2016). The key elements of structured instruction include (Williams, 2018): a) structuring the classroom space, b) structuring the daily lesson plan, c) structuring the daily working system, and d) structuring educational activities. Teachers often use a variety of approaches in lesson planning (e.g., constructivist approaches, explicit instruction, etc.), all of which have a positive impact on students' learning outcomes. In the context of science education, pedagogical content knowledge is essential when designing a lesson, as it considers different perspectives during the learning process. Therefore, a well-designed lesson plan can address the diverse learning needs of students and enhance science learning (Großmann & Krüger, 2022). Previous literature indicates that lesson planning has been widely used in special education to promote inclusive classrooms (Searcy & Maroney, 1996; Black et al., 2018; Theoharis & Causton-Theoharis, 2011; Causton-Theoharis et al., 2008; Rahayu et al., 2021). Creating inclusive science education classrooms for children with LDs can also be supported by the use of ICTs, as suggested by previous studies. Visualization through ICT tools can aid in memorization and provide a comprehensive examination of phenomena, in addition to hands-on activities and experiments, as mentioned earlier (e.g., Anagnostopoulou et al., 2021; Chaidi et al., 2021; Chatzivasileiou & Drigas, 2022; Kontopoulou & Drigas, 2020; Sormunen et al., 2019).

Taking the background provided into consideration, structured instruction through lesson plans and ICTs can efficiently tackle both the challenges of teaching difficult concepts of biology and the specific learning needs of children with LDs. Therefore, the aim of the research is to assess the impact of lesson plans and ICTs on the academic performance of Greek primary education students with LDs in the subject of biology. Specifically, the research investigates how the performance of students with LDs compared to students without LDs is affected when lesson plans and ICTs are embedded in the biology classroom. In order to assess the effect of both lesson plans and ICTs, three different interventions were performed: a) an only ICT instruction with the use of interactive board and audiovisual material, b) lesson plans which involved ICTs and traditional instruction (lecture).

To fulfill the aim of the research, the paper is organized as follows: The following section presents the relevant theory. The Method section includes information about the research context, research design, participants, research instruments, and data analysis. Subsequently, the Results from empirical analysis are presented, followed by a discussion and comparison to previous literature. The final section is the Conclusion.

Context and Review of Literature

Characteristics of students with LDs

The characteristics of students with LDs fall in into three different categories. The first is the cognitive category, involving cognitive (knowledge attainment) and metacognitive deficits (critical thinking skills), low academic achievement, poor memory, attention problems and hyperactivity and perpetual disorders, since LDs often present comorbidity with other disorders (Sa'ad & Abdullahi, 2014). The second category involves the affective dimension, i.e poor social skills, poor self-concept, poor motivation, delibating mood states, while the third category is the behavioural dimension, namely adaptive behaviour deficits, disruptive behavior and withdrawal syndrome (Sa'ad & Abdullahi, 2014). Having presented the challenges of students with LDs, the next step is to present the theoretical background of science education in general, i.e the learning theories and respective teaching methods applicable, focusing then on Biology.

Learning theories and teaching methods in science education and Biology

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According to Agarkar (2019), learning theories and relevant teaching methods applicable in science education are behaviorism (transmission of information, remedial instruction), cognitivism (activity-based learning, inquiry methods, and expository teaching), and constructivism (project-based learning, collaborative learning, discovery method). Behaviorism targets adapting the behavior of students through direct reward and punishment and hence is related to the teacher-centered model, i.e., the teacher is the main source of information and responsible for transmitting knowledge (Muhajirah, 2020). Cognitivism's main idea is that individuals learn better when they engage in various activities (Muhajirah, 2020). Constructivism is based on Piaget's and Vygotsky's theories. They both believed that each person has a different way of understanding as they develop different schemas. When exposed to new information, individuals enable the pre-existing schemas to understand and link information (Chuang, 2021). The schemas may or may not change when exposed to new information (Waite-Stupiansky, 2022). The difference between the two versions of the theory is that Vygotsky believes the interactions with the environment are more important compared to the individual during the learning process (Chuang, 2021). Both cognitivism and constructivism are related to the student-centered i.e., students engage actively in the formulation of knowledge, with the guidance of the teacher (Chuang, 2021; Muhajirah, 2020). A structured lesson technique is actually part of cognitivism, as the teacher organizes the content of lessons and has to be as especially efficient in science education, as it the gradual knowledge attainment (Agarkar, 2019). Lesson plans, as part of structured instruction, have been extensively used in science education and Biology (Nawani et al., 2018; Ramdiah et al., 2019), as well as in students with LDs (Lee & Griffin, 2021; Martínez & Porter, 2018; Nagro et al., 2018; Scott et al., 2019). The teacher can design a lesson from scratch, taking into consideration the needs of students with LDs (Aragón et al., ICTs, ICTs on the other hand, are related to the cognitivism and constructivism theories and have also been widely used in science education and Biology. The reason is that difficult concepts and processes can be visualized (Farhana & Sabbir, 2019; Kilag et al., 2022).

Challenges in Teaching and Learning Biology and Teaching Methods

Moving to Biology specifically, previous studies have concluded that regardless of the existence of LDs, some concepts pose challenges in both teaching and learning, leading to misconceptions among students (Del Mar Fernández Fernández & Tejada, 2018; Duda & Adpriyadi, 2020; Firmanshah et al., 2020). Among the units that present the most challenges, photosynthesis is a focal point, as it is a process that cannot be comprehended solely through the senses (Dimec & Strgar, 2017; Jančaříková & Jančařík, 2022; Keleş & Kefeli, 2010; Panijpan et al., 2008; Russell et al., 2004). This issue is linked to another problem mentioned by Zubaidah et al. (2017), which are the relatively low critical thinking skills of students. To address these challenges, numerous recent studies have concluded that organizing information in a structured manner, combined with guided and open inquiry strategies, can effectively alleviate learning difficulties in Biology (David & Nsengimana, 2022; Diem & Hathong, 2019; Emmadiole et al., 2020; Großmann & Krüger, 2022; Owolade et al., 2022; Situmorang, 2019). Another area of focus in the literature is the use of Information and

Communication Technologies (ICTs) to enhance learning and teaching in Biology (Belay et al., 2020; Ghalib, 2019; Kontopoulou & Drigas, 2020; Makuru & Jita, 2022).

Teaching Methods in the Subject of Biology in Primary Education

As for the subject of Biology in Primary Education, which is the focus of the present research, efficient teaching methods include collaborative learning (Jeronen et al., 2016; Tzovla & Kedraka, 2020), project-based learning, inquiry-based methods (Tzovla & Kedraka, 2020), interactive participation (Jeronen et al., 2016), and the use of ICTs (Dewi et al., 2021; Divya, 2023; Tzovla & Kedraka, 2020), with a special focus on interactive blackboard (Divya, 2023). For students with LDs, emphasis is placed on inquiry-based methods (Aydeniz et al., 2012; Chikaluma et al., 2022; Gajić et al., 2021; Heindl, 2019; Kaldenberg et al., 2014; Therrien et al., 2011), along with graphical representation, activity-based learning, inductive thinking stimulation (Brigham et al., 2011; Mehmood et al., 2021; Odutuyi, 2019; Skulmowski, 2024), and self-discovery methods (Aydeniz et al., 2012; Egbes & Ajaja, 2023; Hasairin et al., 2023; Santi, 2023).

Teaching Approach of Biology for Students with LDs in Primary Education

Taking into account the background provided above, the teaching approach of Biology for students with LDs can be broken down into three different dimensions: the cognitive, the post-cognitive, and the behavioral dimension. The cognitive dimension concerns knowledge attainment through traditional instruction, lab experiments, participation in classroom discussions and activities, and the development of problem-solving skills through breaking down the subject's material (Aditomo & Klieme, 2020; Cirino et al., 2013; Grabau & Ma, 2017; Hale et al., 2016; Moll et al., 2014; McGrath & Hughes, 2017; Moutinho et al., 2015; Peng & Fuchs, 2014; Suastra & Ristiati, 2017; Widoretno et al., 2019).

The post-cognitive dimension is related to the development of more complex cognitive and mental skills, such as argumentation skills, concept synthesis, seeking causes, and expression of doubts (Asyari et al., 2016; Chi et al., 2018; Lin, 2016; Moutinho et al., 2015; Nunaki et al., 2019; van Opstal & Daubenmire, 2015; Wagaba et al., 2016; Yousef, 2015). Lastly, the behavioral dimension is associated with providing motivation for discovery, developing values and attitudes, goal attainment, and building self-esteem (Chang et al., 2017; Chen & Wu, 2015; Cheng et al., 2019; Keen et al., 2015; Peng & Fuchs, 2016; Scherer et al., 2016).

METHOD

Research Context

A preliminary study was conducted with a sample of teachers to identify the frequency of comprehension issues in primary school grades and course units, the teaching strategies employed to address these issues, and the LDs commonly found among students. Several recent studies have conducted preliminary research to plan the most effective interventions possible (Akram et al., 2022; Arista & Kuswanto, 2018; Chi et al., 2018; McGrath & Hughes, 2017). The teachers were from primary schools in Athens and Syros Island. The preliminary research was carried out from October 2019 to January 2020. The final research, which involved interventions, was conducted in schools located in three different schools in Agios Dimitrios, Agia Marina in Koropi, and Athens. The final research lasted four months, from October 2020 to January 2021.

Research Design and Participants

For the preliminary research, the descriptive research design was more suitable, since the objective was to identify the most frequent understanding problems, the relevant teaching strategies to overcome them, and the most common LDs teachers deal with. Purposive sampling was employed (Patton, 2014) since it was considered significant to gather information from teachers who have experience in both general and special education. This is a widely used sampling method in educational research when investigating the effectiveness of educational interventions (Hamel & Ahmed, 2020; Holtzhausen & Botha, 2021; O' Brien et al., 2021; Tingey et al., 2020). Twenty teachers participated in the preliminary research. Regarding the demographic information of participants, the majority (*N*=14) are male. On average, they had about seventeen years of service in general education (*M*=16.95) and about ten years in special education (*M*=9.80). In terms of their educational background, thirteen of them participated in seminars, twelve have a master's degree, and three have been retrained. Eleven have taught general education primary school classes; seven have been "shadow teachers", four have taught integration classes, and one has taught special education. Sixteen taught the 3rd, 5th, and 6th grades; fifteen taught the 4th grade; eleven taught the 1st grade, and nine taught the 2nd grade. Twenty taught in urban areas, nine on islands, four in lowland areas, and three in rural and mountainous areas.

The majority of teachers believe that more understanding problems occur in the 5th grade (*N*=15), while others believe that more understanding problems occur in the 6th grade (*N*=12). The most difficult concepts according to them are: a) the structure of food webs (3rd grade), b) the flow of electrons (5th grade), and c) photosynthesis, which is part of the energy unit (6th grade) [40% of cases]. To successfully overcome understanding problems, teachers use ICTs more frequently (*N*=8), audiovisual materials (*N*=8), and experiments (N=7). Regarding the learning disabilities of their students, the most frequent are ADHD (*N*=14), autism (*N*=10), dyslexia (*N*=6), and comprehension deficit (*N*=6).

The researcher considered the results of the preliminary research and decided to implement the interventions in the 6th grade. The rationale behind this decision was the need for all lessons to be interconnected. In the 6th grade, the science curriculum includes a unit on energy, encompassing concepts such as photosynthesis and the structure of food webs. It was deemed crucial to incorporate a lesson on renewable and non-renewable energy sources to introduce the concept of energy transformation, which is essential for understanding photosynthesis.

In the final research, the sample was convenient because it involved teachers willing to implement interventions and students willing to participate in them. Fifty-five students took part in the research, 13 had LDs. The sample of 55 students was divided into groups because three different interventions were used. These three included: a) structured instruction/lesson plans and ICTs (16 students), b) ICTs only students), and

c) traditional instruction (21 students). Further about the interventions is provided below.

Structured Instruction (Lesson Plans)

Renewable and non-renewable energy sources. The latter were discussed in the lesson, which lasted one hour and was a course unit directly from the textbook. The teaching goals included: 1) distinguishing between renewable and non-renewable energy sources; 2) understanding their advantages and disadvantages; and 3) comprehending the consequences of humans using non-renewable energy sources. The key concepts covered were energy, renewable energy sources, non-renewable energy sources, and intensive exploitation. In terms of prerequisite knowledge, energy is part of the natural science curriculum in the 5th grade. Additionally, previous chapters in the 6th grade introduced energy sources like petroleum, mineral coal, and natural gas.

The lesson began with a PowerPoint presentation featuring pictures of various energy sources. Students were tasked with identifying these sources. The teacher then confirmed the correct answers (the initial stimulus). Inductive thinking was further encouraged when the teacher prompted students to identify exhaustible sources. This provided an opportunity to introduce the concept of non-renewable energy sources in the classroom and asked students to identify them. The discussion then shifted to the consequences of the intensive exploitation of renewable sources. The teacher then instructed students to list the potential advantages and disadvantages of both renewable and non-renewable energy sources. Subsequently, specific questions related to the teaching objectives were discussed with the students to pinpoint any areas of misunderstanding.

Generalization and comprehension were enhanced with examples from everyday life. In particular, a PowerPoint presentation included images of various appliances. Students were tasked with identifying the type of energy each appliance used. The numerous appliances that rely on exhaustible energy sources prompted discussions on current energy requirements and strategies to meet them. To conclude the course, the teacher reviewed key concepts and urged students to raise any queries. Since the upcoming lesson would cover photosynthesis, the teacher had to introduce the idea of energy transformation.

Photosynthesis. The lesson lasted one hour and was also based on a course unit from the textbook. Teaching goals were: 1) to highlight the significance and uniqueness of photosynthesis for plants; 2) to explain photosynthesis in simple terms; 3) to understand the role of light and chlorophyll; 4) to comprehend that plants absorb carbon dioxide and release oxygen; and 5) to grasp that this process is the opposite of breathing. The concepts involved were: photosynthesis, chlorophyll, photosynthetic microorganisms, phytoplankton, carbon dioxide, oxygen, and amyl. Regarding prerequisite knowledge, students had already been taught in the previous chapter about living and non-living objects and the energy they require to develop and evolve. Students encountered difficulties in this course unit as they struggled to understand that plants are living organisms despite their lack of movement.

At the beginning of the course, the teacher asked students to name the basic functions of living organisms and noted them on the blackboard (the initial stimulus). Then, they were asked to identify the energy source they needed. The next step was to thoroughly explain the process of photosynthesis. Inductive thinking was stimulated when the teacher performed Priestley's experiment. A PowerPoint presentation at the end of the experiment highlighted the most important concepts involved in photosynthesis. As in the previous lesson plan, the teacher asked specific questions to ensure that students understood the process of photosynthesis completely.

Students were then required to write down the most important concepts involved in photosynthesis. Simultaneously, a PowerPoint presentation illustrated the process of photosynthesis. At the conclusion of the course, the teacher summarized the most significant concepts using a PowerPoint presentation and welcomed questions. Since the upcoming lesson focused on the structure of food webs, the teacher also had to explain the concept of energy transfer between living organisms.

Structure of food webs. The lesson lasted one hour and was based on a course unit from the textbook. The teaching goals were: 1) to understand the concept of food webs; 2) to describe simple food chains and food webs; and 3) to explain the significance of food webs. Key concepts included the food chain, the food web, autotrophic organisms, and heterotrophic organisms. As for prerequisite knowledge, students were already familiar with information about animate and inanimate organisms, plants, and animals from the 5th grade, and had also been taught about photosynthesis in the previous lesson. The teacher asked students to identify the organisms in the textbook. Subsequently, they were prompted to identify potential food sources for each organism (the initial stimulus). The teacher led a discussion on the various food sources and instructed students to categorize the organisms into two columns: autotrophic and heterotrophic. Following this exercise, students were tasked with creating a food chain using these organisms. The teacher introduced the concept of a food web, emphasizing that no organism relies on a single food source, resulting in the existence of multiple food chains. Through a PowerPoint presentation, the teacher visually presented a food web. Students were then prompted to locate themselves within the food chains depicted in this food web.

At this point, the teacher asked specific questions to ensure that all students understood food webs. Generalization and comprehension were established through a classroom collaborative activity in teams of 2–3 students. A PowerPoint presentation included pictures of organisms. Students assigned themselves as those organisms and were then tasked with designing a possible food web. One student from each team presented the teamwork results. At the end of the course, the teacher, using a PowerPoint presentation, summarized the key aspects of the lesson and emphasized the importance of energy transformation into other forms and its transfer from one organism to another. In this manner, the teacher created an association among all three lessons.

ICTs

PowerPoint presentations, including audiovisual materials and interactive boards, were utilized based on the efficiency suggested by previous literature in teaching biology at the primary school level. These same information and communication technologies (ICTs) were integrated into the lesson plans mentioned earlier.

Research Instruments

Regarding the preliminary research, semi-structured interviews were conducted. As for the interview questions, the researcher aimed to find out: a) the units/concepts and the respective grades in the primary school where understanding problems occur most frequently, b) the strategies teachers use to address understanding problems, and c) the most common learning disabilities their students encounter. In the final research, to evaluate the impact of the interventions mentioned above, six different tests were developed for each course unit separately (renewable and non-renewable energy sources, photosynthesis, and the structure of food webs). These tests were administered before and after the intervention. The pre-intervention tests assessed the students' knowledge from the 5th grade or previous units from the 6th grade. The post-intervention tests focused on the concepts and objectives taught during the class. Each test consisted of four questions of equal weight. The scores were normalized to range from zero to ten points. Tests involved both closed-ended true-false questions (e.g., “plants can survive in the absence of light”) and multiple-choice questions (e.g., “choose the right answer: renewable energy sources: a) deplete easily, b) they are environmentally unfriendly, c) have low performance”) and open-ended questions (e.g., “observe carefully the pictures and choose the ones that depict renewable and non-renewable energy sources”, “put the organisms below in the right place, based on their food interrelations”). The tests were validated with the help of the teachers who performed the interventions in the classroom. Furthermore, the tests were administered to a sample of five students (one of them had dyslexia) in order to make any necessary changes. Some questions were modified to be more understandable. Those students were not involved in the final sample.

Data analysis

To analyze the results of the preliminary research, content analysis was performed. In the final research, the dependent variables are the scores in the tests in the three units. The variables were related, since the performance on each subject was measured before and after the interventions. The independent variable is the type of intervention (within-subject factor) and its interactions with the control variables. The control variables that affect the relationship between the dependent and independent variables are the existence of LDs (within-subjects factor), course unit, time (within-subjects factor), and all their possible interactions. The existence of within-subject and between-subject factors suggests the mixed-model ANOVA implementation.

FINDINGS

Mixed-model ANOVA results

The inspection of the table below suggests that among between-subject effects, LDs had a statistically significant effect, *F*(1, 49)=8.88, *p*=.004, η^2_p=.153. Students with LDs had lower score (*M*=5.26, *SD*=.275) compared to students with typical development (*M*=6.19, *SD*=.143). Additionally, the type of intervention had a statistically significant effect, *F*(2, 49)=12.55, *p*<.001, η^2_p =.339. Students who attended the instruction based on lesson plans achieved better scores (*M*=6.87, *SD*=.299) compared to those who attended instruction with an interactive whiteboard only (*M*=5.27, *SD*=.264) and those who attended traditional instruction (*M*=5.032, *SD*=.239).

To continue with within-subjects effects, time had statistically significant effect, *F*(1, 49)=118.49, *p*<.001, η^2_p =.707, as all students performed better in tests after the interventions (*M*=6.32, *SD*=2.35), compared to the scores they achieved before the interventions (*M*=5.48, *SD*=1.95). Furthermore, moving to interactions, the statistically significant interactions are those between time and LDs, *F*(1, 49)=26.01, *p*<.001, η^2_p =.347, between time and intervention, *F*(2, 49)=51.57, *p*<.001, η^2_p =.678, between time and course unit, *F*(2, 49)=9.10, *p*<.001, η^2_p =.157, among time, course unit LDs, *F*(2, 49)=4.82, *p*=.010, η^2_p =.090 and among time, intervention and LDs, *F*(2, 49)=8.29, *p*=.001, η^2_p =.253.

Table 1
Results of mixed-model ANOVA

	df	*F*	*p*	η^2_p
Between-subjects effects				
Learning disabilities	1	8.88	0.004	0.153
Intervention	2	12.55	<0.001	0.339
Learning disabilities x Intervention	2	1.189	0.313	0.046
Error	49			
Within-subjects effects				
Course unit	2	0.3	0.745	0.006
Course unit x Learning Disabilities	2	2.237	0.112	0.044
Course unit x Intervention	4	1.626	0.174	0.062
Course unit x Learning Disabilities x Intervention	4	1.524	0.201	0.059
Error (course unit)	98			
Time	1	118. 49	<0.001	0.707
Error (time)	49			
Time x Learning disabilities	1	26.01	<0.001	0.347
Time x Intervention	2	51.57	<0.001	0.678
Time x Course Unit	2	9.1	<0.001	0.157
Error (time x course unit)	98			
Time x Course Unit x Learning Disabilities	2	4. 82	0.010	0.090
Time x Intervention x Learning Disabilities	2	8.29	0.001	0.253

Despite the presence of LDs, all students showed improvement after interventions, with students with LDs experiencing greater progress. Students who participated in structured instruction outperformed their peers after the intervention. Following the interventions, students performed poorly in the unit on photosynthesis. Students with LDs demonstrated more significant improvement in their scores in food webs compared to typically developing students after the interventions. Conversely, typically developing students showed greater improvement in their scores in energy compared to students with LDs. Both groups of students achieved lower scores in photosynthesis after the interventions.

Last but not least, concerning the interaction among time, intervention, and LDs, students with learning disabilities showed greater improvement in their scores compared to typically developing students after the structured instruction intervention. It is important to highlight that structured instruction proved to be the most effective teaching method for both groups of students. In the other two scenarios, both groups of students demonstrated better performance, but there were not significant differences in their scores after the ICT intervention and traditional instruction. The tables below present all the information mentioned above, including the mean performance by course unit and the presence or absence of LDs.

Table 2
Mean and standard deviation of test scores before and after interventions

Performance		Structured instruction & ICTs		ICT		Traditional instruction	
		M	*SD*	*M*	*SD*	*M*	*SD*
Energy	Before the intervention	5.51	1.50	5.10	1.37	4.69	1.24
	After the intervention	8.23	1.03	6.72	1.07	4.89	1.68
Photosynthesis	Before the intervention	6.52	1.79	5.39	1.64	5.94	1.60
	After the intervention	8.30	1.32	5.97	1.60	5.20	1.13
Structure of food webs	Before the intervention	5.98	1.38	5.40	1.80	5.11	1.61
	After the intervention	7.78	1.62	5.70	1.00	5.25	2.09

Table 3
Mean and standard deviation of test scores before and after interventions, for students with learning disabilities separately

Performance			*M*	*SD*
Energy	Learning Disabilities	Before the intervention	4.00	0.810
		After the intervention	5.94	2.160
	No Learning Disabilities	Before the intervention	5.36	1.360
		After the intervention	6.62	1.840
Photosynthesis	Learning Disabilities	Before the intervention	4.73	1.880
		After the intervention	5.29	2.150
	No Learning Disabilities	Before the intervention	6.26	1.500
		After the intervention	6.65	1.680
Structure of food webs	Learning Disabilities	Before the intervention	4.26	1.088
		After the intervention	6.46	2.310
	No Learning Disabilities	Before the intervention	5.80	1.600
		After the intervention	6.04	1.870

DISCUSSION

To begin with the results concerning the independent variable, i.e., the intervention, the main effect indicated by the mixed-model ANOVA suggests that the group of students who attended structured instruction and ICTs performed the best, while the second-best performance was observed in the group of students who attended the ICTs-only intervention. Students who attended traditional instruction classrooms had the worst performance. Moving on to the interaction of the independent variable with the rest, students who participated in the structured instruction and ICTs, as well as the ICT-only interventions, showed significantly higher performance after the interventions (interaction between time and intervention). This was not the case for the traditional instruction intervention. This finding aligns with previous studies that highlight the benefits of structured instruction (David & Nsengimana, 2022; Diem & Hathong, 2019; Emmadiole et al., 2020; Großmann & Krüger, 2022; Owolade et al., 2022; Situmorang, 2019) and ICTs in the field of biology and science education in general (Belay et al., 2020; Ghalib, 2019; Kontopoulou & Drigas, 2020; Makuru & Jita, 2022). The interaction among time, intervention, and LDs was also found to be statistically significant. Students with LDs showed greater improvement in their scores compared to typically developing students after the structured instruction intervention. Structured instruction proved to be the most effective teaching method regardless of the presence of LDs. For the other two interventions, both groups of students performed better, but there were no significant differences in their scores after the ICT intervention and traditional instruction. This result is consistent with existing literature on the benefits of structured instruction (Searcy & Maroney, 1996; Black et al., 2018; Theoharis & Causton-Theoharis, 2011; Causton-Theoharis et al., 2008; Rahayu et al., 2021) and ICTs for students with LDs (Anagnostopoulou et al., 2021; Chaidi et al., 2021; Chatzivasileiou & Drigas, 2022; Kontopoulou & Drigas, 2020; Sormunen et al., 2019).

Moving to the results by the other variables, all students performed better after the interventions, and this was expected since tests administered before the interventions assessed prerequisite knowledge from former grades or course units in the same grade.

The assessment of performance took place right after the interventions, and it was easier for students to recall relevant information. In general, children with LDs had lower performance compared to typical developmental children. However, as regards the interaction between time and LDs, students with LDs seemed to improve their performance more compared to typical development students after the interventions. For the interaction among time, course unit, and LDs, students with LDs improved their scores in the structure of food webs after the interventions compared to typical development students. Typical development students improved their score more compared to the students with LDs in the unit of energy after the interventions. All students achieved a lower score in photosynthesis after interventions. Photosynthesis continues to be a challenge for both teachers and students, as previous studies suggested (Dimec & Strgar, 2017; Jančaříková & Jančařík, 2022; Keleş & Kefeli, 2010; Panijpan et al., 2008; Russell et al., 2004). More interventions for this course unit are necessary.

Overall, it seems that structure is helpful irrespective of the existence of LDs, but especially in the presence of them, the improvement in the academic performance of those students is higher compared to typical development students. This result is even more intense in the structure of the food web unit. ICTs also contribute to the improvement of academic performance, but they yield better results when embedded in lesson plans. The fact that the best performance from students with LDs occurred in the unit of the structure of food webs suggests that while previous literature emphasizes the inquiry-based method (Aydeniz et al., 2012; Chikaluma et al., 2022; Gajić et al., 2021; Heindl, 2019; Kaldenberg et al., 2014; Therrien et al., 2011), here the focus is instead on collaborative learning, as the students worked in teams (Jeronen et al., 2016; Tzovla & Kedraka, 2020). On the other hand, typical development students were more benefited from other efficient methods referred to for primary education's biology, i.e., the inquiry-based method (Aydeniz et al., 2012; Chikaluma et al., 2022; Gajić et al., 2021; Heindl, 2019; Kaldenberg et al., 2014; Therrien et al., 2011), interactive participation (Jeronen et al., 2016) and the use of ICTs (Dewi et al., 2021; Divya, 2023; Tzovla & Kedraka, 2020), activity-based learning, inductive thinking stimulation (Brigham et al., 2011; Mehmood et al., 2021; Odutuyi, 2019; Skulmowski, 2024), and self-discovery-methods (Aydeniz et al., 2012; Egbes & Ajaja, 2023; Hasairin et al., 2023; Santi, 2023). Of course, students with LDs also benefited from those teaching strategies, but the collaboration made a collaboration made a great difference in their performance. Although experiments are part of activity-based and self-discovery methods, they did not assist in the unit of photosynthesis. Actually, in this unit, all possible methods were used, apart from collaboration. Maybe collaboration could affect the performance of all students.

Although this research sheds light on the understanding of biological concepts on the part of students with LDs, it remains an open question how comprehension can be achieved in difficult course units, i.e., in the unit of photosynthesis. Furthermore, although there is indication that interventions develop biological literacy, it is not clear which dimensions and aspects of biological literacy are enhanced. Maybe if tests developed after interventions involve questions directly associated with biological literacy dimensions and characteristics, this association will become clearer. When it comes to both the sample of the preliminary research and the sample of the final research, they were not representative of the population under study, and hence the results cannot be generalized. Last but not least, the researcher relied solely on teachers to recruit the final sample of students and did not have the ability to focus on specific LDs. Maybe the effectiveness of interventions is dependent on the type of LD. Hence, in the future, more research is needed in this area.

CONCLUSION

The results of the present research revealed that structured instruction is the most efficient teaching method among primary school students, although despite the type of intervention, students improved their scores. However, the improvement in the score of students with LDs is greater compared to the improvement observed in typical development students. This is especially true for the structure of food webs, as in the unit of energy, typical development students reported greater improvement. In the unit on photosynthesis, both categories of students performed worse after interventions.

Based on the results of the research, it is important for teachers to implement lesson planning in primary education's biology because it benefits all students, especially students with LDs. As they are aware of the characteristics of their students with LDs, they can efficiently design how they can teach the concepts involved in each lesson. During the lesson, various strategies need to be incorporated, along with ICTs that assist in the visualization of biological processes. Collaboration should also be involved, since it benefits students with LDs. Engagement in various activities and self-discovery through interactive participation and asking questions, as well as the use of interactive blackboards and presentations, can also improve understanding of difficult concepts in biology. Overall, structure is needed in general and specifically to include children with LDs. A more holistic approach is needed by teachers, ensuring the maximum participation of all students during the learning process.

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