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Science Education Adaptations for Non-Textbook Instruction to Students With Learning and Other Disabilities: A Chronological Literature Review

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Special education is a challenging area of education, as traditional instruction strategies need to be appropriately adjusted to match the individuals' needs resulting from various types of learning and other disabilities (LD). Among a range of subjects, the paper focuses on science education for LD students and it elaborates on two groups of adaptations frequently discussed in the literature, which involve materials alternative to textbook. We have carried out a literature review by using a pool of review articles from the "Bibliography Observatory" database developed by the University of Thessaly, Greece. We herein present the sum of the research activity primarily from the past decades (post 1980s), pertaining to technology assisted adaptations and hands-on activities/laboratory instruction. This analysis has shown that there is an increasing research interest in such adaptations both chronologically and most importantly provides evidence of the advantages these adaptations offer to LD students.

Keywords: special education, science education, learning disabilities, database, science laboratory, computer technology

Introduction

Many pupils with learning and other disabilities (LD) are being included in general curriculum classes, and therefore, there is a need for them to achieve a level of proficiency comparable to that of the students without LD. Science is one of the fields which requires multiple skills, and therefore, improving the performance in these subjects is an important aim for educators. Students with LD exhibit a range of disorders and comorbid disabilities related to poor performance in science which are among others difficulty in memory, written and oral expression, behaviour, and attention, etc. Science instruction is often challenging to teachers and poses limitations to students due to its need for complex cognitive skills involved in the process of learning

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(Vaughn & Linan-Thompson, 2003). At the same time, though it is the nature of the subject that permits the use of hands-on activities and laboratory instruction to teach the necessary information and pass the knowledge on. LD students are thought to be benefitted from these teaching approaches, because including objects from the lab in science courses is what increases science comprehension as the need for reading and writing is lessened. It has been reported that in studies where textbook approaches were compared to activities, students have shown significantly higher performance in the immediate assessments and post-tests, when hands-on learning is applied (Cawley & Parmar, 2001).

The Purpose of the Study

The paper is based on the analysis of a pool of articles recorded in the "Bibliography Observatory" (Kaliampos, Verevi, Panagopoulou, Papalexopoulos, & Vavougios, 2017). This is a database developed at the Department of Special Education at the University of Thessaly (Greece) after collecting and processing articles from the English-language literature on the topic of science education for students with learning difficulties. The purpose of this database is to provide an assistive tool for researchers of education, teachers, and education students. The articles of the database are either experimental, that refer to empirical researches, or review articles, that refer to reviews of the research studies.

We scanned review articles from the database (approximately 55 accessible full articles) to locate keywords pertaining to: computers, software, technology, hands-on activities, laboratory, and practical work. After analysing critically these shortlisted publications, we identified sub-categories within the general subjects of either computer-assisted or hands-on instruction and we herein present these, keeping a chronological order (from past to most recent). Some trends and figures have been drawn from the number of articles referring to each type of adaptation, to better illustrate the researchers' interest in the field throughout the years. Subsequently, these results can indicate the areas towards which research could be potentially orientated in the future. Some teaching strategies appeared in more than one articles, suggesting that there are common points which most authors consider, usually by discussing them not as sole methods, but within sets of adaptation strategies. The most frequently mentioned teaching adaptations are presented in Figure 1.

According to Figure 1, hands-on activities and laboratory, as well as computer-assisted adaptations are two distinctive categories which are not based on textbook approaches, in contrast to other popularly mentioned strategies. The literature reflects the advantages of the non-textbook strategies, because most of the articles analysed from our database refer to practical work adaptations and software and computer special instruction (see Figure 2 and 4).

Based on this finding, we conducted a literature review on these two methods of teaching science to LD students to generate a useful reference to researchers in the field, pre-service and certified teachers. The reason why we only went through review articles for this project is that experimental articles mainly focus on a limited variety of adaptation strategies, whereas reviews contain more information about the research having been conducted the previous years.

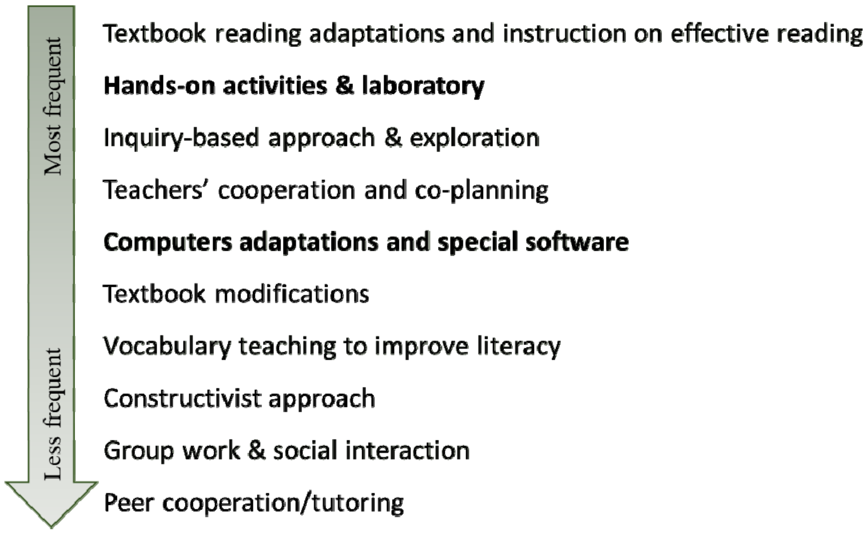

Figure 1. Frequency of teaching adaptations that are described in the review articles.

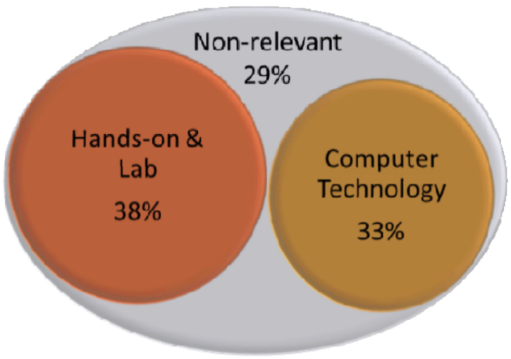

Figure 2. Percentage distribution of the review articles as to their content.

Adaptations on Laboratory and Hands-on Instruction

Hands-on adaptations have been discussed in the relevant literature since 1998 (as referenced in our pool of articles) when it was proposed that activities can mitigate the learning difficulties caused by the lack of literacy and engagement skills, as students reportedly understand a concept more easily through hands-on activities (rather than reading about it) and they enjoy this type of learning. It is pointed out, though, that it is more meaningful for LD students to combine activities with coaching and inquiry (Scruggs, Mastropieri, & Boon, 1998). Similarly, laboratory instruction is a major part of science learning, as the students can look into science from the perspective of a laboratory scientist. Moreover, through experiential learning, students can put the theory they have learned into practice.

The trends in the literature review indicate that the significance of such type of science teaching, as 21 out of 55 review articles of our database refer either to hands-on or to lab-based instruction. Within the general category of hands-on and laboratory instruction, we note that special education researchers discuss the first to a greater extend compared to laboratory instruction techniques (see Figure 3).

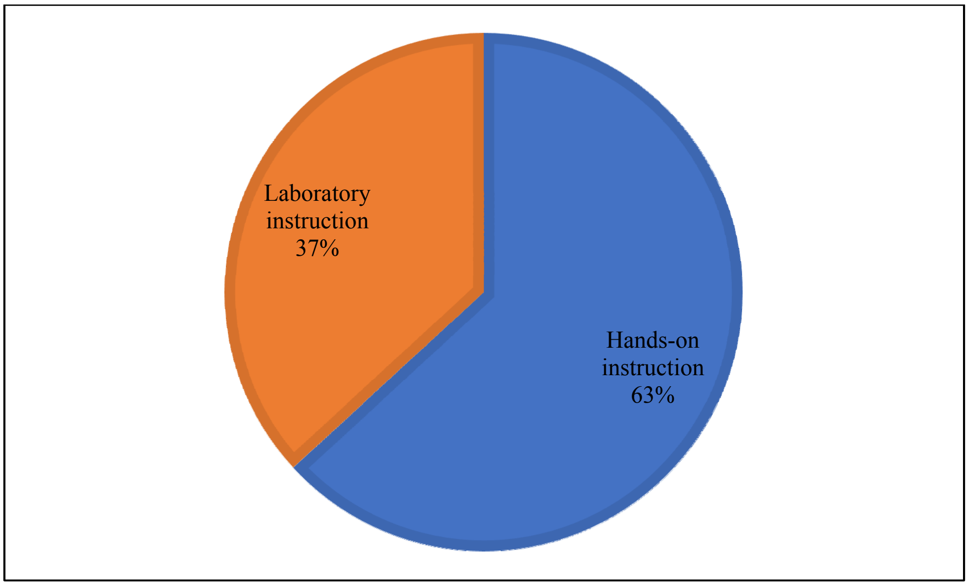

Figure 3. Percentage distribution of review articles that refer to laboratory instruction adaptations and hands-on adaptations.

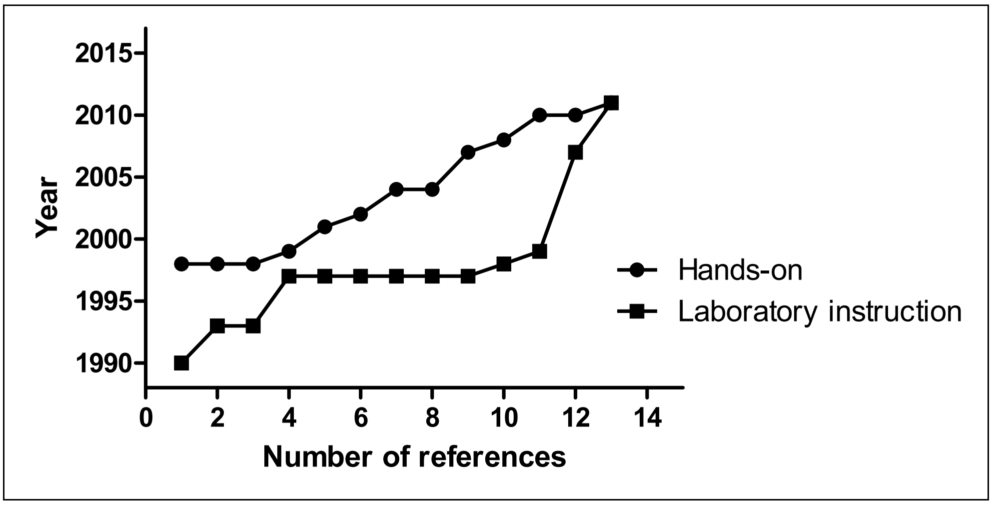

Figure 4. Numerical distribution of references on hands-on and laboratory adaptations as referred in the review articles.

Laboratory Instruction

In the first reference of our pool of articles (L. E. Davis, Eves, & J. H. Davis, 1990), researchers discussed a specific topic within the context of laboratory geology classes for students with spatial and perception weaknesses. The nature of this subject required understanding distances or even differentiating left and right, which might often cause frustration to most students. To relieve those difficulties educators could use three-dimensional maps, where the students can feel the distances by using their hands. Thus, they learn to rely on the sense of touch by working on computers as well, or even memorising information, while walking or listening to lectures on their way to the class. Later on, Kucera (1993) and Burgstahler (1997) presented a more detailed list of laboratory interventions specifically designed for different types of learning disabilities. According to the researchers, students with attention deficit disorders require explicit description of the task in a non-stressful environment, so that they can fully understand the instructions before the task experiment begins.

It was also essential to avoid stressful situations, as they could easily become frustrated and respond poorly, and to ensure they are encouraged to seek for help when it was necessary. In the case of learning disabilities, several adaptations were suggested, such as giving clear notes on the task with explicitly labelled equipment. Overhead projectors could display the protocols more clearly, or colour coding on the materials would help the students understand what they would use during the laboratory activities.

Another dimension of laboratory classes that researchers mentioned for LD students was the physical requirements, since lab work dictates the use of equipment or hazardous materials, while spatial awareness is required by the users (when, e.g., working on a bench, using a sink next to it, or being aware of the nearest fire exit). Instructors need to try to overcome these physical barriers and also ensure that no student is exempt from being able to act appropriately upon laboratory accidents and emergencies (Kucera, 1993). Extra time was the next point that should be offered to LD students in order to complete and return lab reports, prepare the next experiment or analyze the results. Stress and peer pressure should also be avoided by allocating individual working spots to the students.

It is worth noting that according to the review articles students' active participation was often characterized by lack of opportunities to plan experiments or interpret their results, while traditional approaches of instruction still appeared to be the most popular methods among teachers. On the contrary, inquiry-based collaborated activities instruction could reveal more information and promote students' enthusiasm in the laboratory setting. Villanueva and Hand (2011) showed how participation in lab work as a collaboration-based activity has a positive effect on LD students' learning and how it increases their engagement and lessens the frustration related to textbook reading.

Hands-on Instruction

In 1998, Sterling and Goor argued that there is added complexity in teaching science to LD students due to the need for general and special teachers to collaborate. The educators need to become familiar with the practice of co-teaching and science in general, since it is a field that often finds them unconfident and requires time to set up for hands-on activities. Preparation and management of this instruction method was the reason that prevented most schools from implementing it (Brownell & Thomas, 1998). Matkins and Brigham (1999) espoused also the premise that LD students are generally assisted by co-teaching when teachers collaborate successfully. At the same time, in 1999, Jarrett claimed that activities involving action and simulation could help students with conceptualizing basic maths and physical quantities. For example, quantities could be represented by grouping students in the classroom and moving them accordingly, or by using objects (e.g., bottle caps). Paper-and-pencil drawings could be useful in higher grades, too (Jarrett, 1999). Two years later, Alexakos (2001) discussed the kinaesthetic adaptations to explain and demonstrate physical phenomena and gave the example of friction, where the students could understand the phenomenon simply by rubbing their hands to produce heat and correlating this to everyday experience in sports, for instance. A few years later, Melber (2004) argued that the use of a wide range of materials was also necessary (shells, backyard critters, flowers, and plants) and a science lesson with the active engagement of the students could be planned, according to the 5-E Model, consisting of five phases: engagement, exploration, explanation, elaboration, and evaluation. In 2008, Linz, Heater, and Howard espoused on the interactions between special and science teachers, where the mutual understanding of each discipline's requirements played a major role in successful collaboration.

Two years later, Rupley and Slough (2010) described the combination of textbook approaches and hands-on activities and suggested that science learning is particularly effective through a strong theoretical and practical support with the use of textbooks alongside practical activities adapted to the needs of every student. This mainly applied to a range of LD students who fall into some of the categories defined by the authors such as language learners, breakthrough learners (i.e., students who use both reading and activities to acquire knowledge) and conceptual learners. The next article related to the topic of textbook incorporation into activities comes from Brigham, Scruggs, and Mastropieri (2011) that focused on different approaches for LD students' performance enhancement. Textbook learning mainly described by individual studying, lecture attending, and worksheet filling is presented alongside hands-on activities which involve learning through experience, supporting inductive thought processes (by the need for reasoning about physical phenomena and reasoning with prior knowledge). The authors argued that although verbal learning and text processing are generally of secondary significance in hands-on activities, they reduce the frustration of LD students when they are appropriately combined. For example, the instruction of ecosystem and pollution could be presented by an activity where students could have two simple plastic bottles that simulate the pollution of two ecosystems (e.g., by fertilizers and acid rain). Students could observe the differences of their impact and draw conclusions which will help them understand the meaning of the ecosystems. In this case, combining textbook material with hands-on activities would improve not only students' performance on the subject, but their vocabulary as well, especially when pedagogical tools, such as graphic organizers are used.

Adaptations on Computer-Assisted Instruction

As a large part of the literature referred to a greater or lesser extent to computer and technology adaptations, we considered this area worth studying furtherly. In brief, this strategy involves the use of computer technology and special software adaptations promising to both enhance the comprehension of science for students and increase teachers' efficiency in science instruction. As technology has rapidly evolved in the past few decades, it is interesting to go through the relevant literature following chronological order and observe how suggestions for adaptations change over time. The presentation of information on screen can bring scientific concepts across more effectively and surfing creatively, the net is also thought to have an impact on the relation between self-efficacy and performance in science. Generally, the integration of technology in science instruction via special software is a need for all students, especially the LD students (Marino, 2010; Kumar & Wilson, 1997).

In the first reference on the use of technology for science instruction to LD students in the articles included in the database some specific tools were introduced (Songer, 1989). More specifically, micro-computers were integrated into laboratory instruction as they helped the students develop graphical representation and data processing skills that are often necessary for lab work. Science telecommunications also offered networking opportunities for students to communicate their data on a national/international level and share knowledge about experiments, while promoting collaboration and inquiry. According to the authors, these platforms could help LD students as the emphasis on non-verbal images improved their attention on the task and could also be used to promote communication and collaboration. Fitting the approaches described above in the instruction process needs careful planning to ensure all students are included. The selection of areas to apply should not be replacing the teachers (The teacher should rather be an "idea coach" instead of an instructor), but only supporting their work. In addition, all interventions would be more efficacious when adjusted to individual needs, while they would require active involvement of the student in the task and interactions between small groups. At the same time (early 1990's), Kucera (1993) supported that chemistry instruction and especially laboratory practice dictated the use of software via simulation, because the instrumentation and data acquisition methods were becoming more complex.

The following year, Lovitt and Horton (1994) argued that computer-based approaches could take the form of interactive hypertext format and additionally offer access to data stores or data bases. It was reported that students achieved higher scores on earth and physical science and biology when graphics tutoring was used with verbal and visual material incorporated in design components. Vocabulary exercises where students had to complete tasks involving word sets on the computer resulted in an improved learning experience as well. It was suggested, however, that software and hardware adaptations need further development. A few years later, Scruggs et al.'s (1998) hypermedia versions of books including activities on computers was argued that could also improve textbook efficacy.

Later on, the use of graphic organisers in science instruction was adapted to the appropriate software. When the software was used in a classroom, it was evident that the students quickly gained confidence in it, contrary to the teachers who appeared less flexible in handling the platform (Mastropieri, Scruggs, & Graetz, 2003). At the same time, Horejsi (2003) presented a more technical perspective of how hardware and software could be modified in order to serve the unique characteristics of LD students. Special hardware included input devices: mice, touch screens, and keyboards, all designed for the special needs of the students enabling the selection of various accessibility modes and output devices with sight and sound adjustments to overcome related disabilities.

A few years later, Marino and Beecher (2010) described the aims to aid the process of learning in Science, Technology, Engineering, and Mathematics (STEM) courses for secondary school LD students. They supported that the games were not to replace instruction, but to complement it by providing independent practice opportunities to individual students depending in their needs. At the same time, a real-time management interface is available for teachers to monitor the students' progress no matter how familiar they might be with special education. Two years later, text-to-speech (TTS) software was introduced, as a compensatory strategy for text reading and understanding. TTS was an auditory and visual platform that converted written text into spoken speech and it seemed that it contributed to the improvement of vocabulary as well (Roberts, Takahashi, Park, & Stodden, 2012).

Moreover, the rapid development of computer technology during the last decade offered to LD students the opportunity to create simulations of physical phenomena in virtual reality. This process offered a more multisensory experience that could be combined with mobile learning applications which involved the use of media, for instance by capturing videos and extracting data of them (Israel, Maynard, & Williamson, 2013). A more recent version of e-textbooks and multi-touch tablets (MTT) was described by Rupley, Paige, Rasinski, and Slough (2015) that could serve as alternative adaptations for reading enhancement. According to this approach, students could read more efficiently when they use encoding systems, the graphic/visual, and the text. Technically, such digital books resemble smartphone apps, as they have touch-screen functions, hyperlinks, videos, animations, and 3-D models. These especially adapted e-textbooks give a reading experience that combines visual features with the relevant text, and therefore, assist struggling readers comprehend, as they mainly rely on pictures.

Discussion

According to the analysis of the review articles presented in this paper, there are plenty of non-textbook tools that could be exploited in science education for students with LD either in daily teaching practice or in the research field. We noted that researchers moved from general to more specific and elaborated lab interventions. For example, the materials used, the lab as a "working place" for students, the available time for the completion of each task, LD students' feelings, while they learn in this context, and so on. Therefore, teachers may find guidance in their teaching by using this pool of review articles when they focus on improving one or several aspects of lab instruction. Moreover, teachers have used hands-on activities including action, simulations, drawings, or a variety of materials either on their own or in collaboration with a special educator. They have also used computers for virtual reality simulation, to present information on a screen, to gain access to actual data, to facilitate a creative use of graphic organizers, to provide some accommodations that a student with LD need (e.g., text-to-speech software), etc. Hands-on activities, computers adaptations, and special software have helped students with several types of learning and other difficulties achieve higher grades, understand better different subject matters (e.g., physics, geology, chemistry, etc.) and improve their behavior (e.g., on task behavior), while minimizing reading and writing.

We consider that categorization and chronological presentation of these papers could help candidate teachers and in service teaching staff choose the appropriate tools in order to plan and carry out the instruction effectively regarding the needs of students with LD. Presenting the review papers on the adaptations on lab and hands-on instruction in a chronological sequence that keep pace with the advances in computer-based instruction may help teachers select a strategy, a teaching practice, or a tool that the school setting may support; when a teacher works at a school with low-quality infrastructure facilities or poorly integrated information and communication technlology (ICT), they could use teaching strategies suggested in the literature review in the past decades, before the era of technology-infused education. Regardless of the instructional strategies that may actually be put into practice, we believe that, especially for the researchers of science and special education, presenting the development of tools in line with the development of technology could depict the trends in special education research and reveal new areas of interest. And last but not least, we hope that our analysis of these articles could motivate students of the Department of Special Education at the University of Thessaly (in Greece) to actively participate to the update of the "Bibliography Observatory" and the relevant research programs.

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