

The investigation of the effectiveness of the criteria for the construction of a physics text for students with dyslexia: The case of the electric current

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Abstract

In this paper we have studied the effectiveness of the writing criteria that are proposed to be applied during the construction of physics texts so that students with dyslexia do not confront reading difficulties with them. The effectiveness of the criteria has been assessed by the accomplishment of an investigation among students with and without dyslexia. A physics text that was constructed according to the writing criteria and referred to the concept of the electric current was given to read by all students. Twenty two questions were used in order to assign the recognition of the physical phenomena, the physical quantities, the relations between the physical quantities and the units of measurement by all the students. The results of the investigation showed that the writing criteria helped the students with dyslexia not to have difficulties with the physics text about the “electric current”. The only area that students with dyslexia had some difficulties compared to the students without dyslexia was the recognition of the units of measurement.

Keywords

Physics education, physics text, students with dyslexia

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Introduction

Developmental dyslexia is defined as a specific impairment in reading and spelling abilities. According to the discrepancy definitions, the reading achievement of students with developmental dyslexia falls substantially below that generally expected for the students' chronological age, intelligence, and learning opportunities (Critchley, 1970; World Health Organization, 1993; American Psychiatric Association, 1994). The oral reading of students with developmental dyslexia is characterized by distortions, substitutions or omissions. In general, the oral or silent reading is characterized by slowness and errors in comprehension (American Psychiatric Association, 1994). Over the last twenty years, researchers have converged on the idea that developmental dyslexia (henceforth, dyslexia) results from a specific impairment of phonological representations (Bradley & Bryant, 1983; Padelidiadou, 2000; Snowling, 2000). According to the "phonological" theory, a dysfunction in some peri-sylvian areas of the left hemisphere of dyslexic individuals is the cause of a deficit of phonological representations or processes, which provokes difficulty with the learning of grapheme-phoneme rules, hence with reading. However, parallel work has emphasised that dyslexics may have more general deficits in the auditory, visual and motor domains. This work gave rise to a temporal auditory processing theory of dyslexia (Tallal, Miller & Fitch, 1993), a visual/magnocellular theory (Stein & Walsh, 1997), and an automaticity/cerebellar theory (Nicolson, Fawcett & Dean, 2001), respectively. The above mentioned theories are compatible with the idea that a phonological deficit is a direct cause of dyslexia, but challenge the specificity of such a deficit. It is hypothesised that the phonological defect itself results from a more general auditory impairment (Tallal et al., 1993) or from a motor (articulatory) dysfunction (Nicolson, Fawcett & Dean, 2001); the visual deficit is also proposed as an additional source of reading difficulties (Demb, Boynton & Heeger, 1998; Livingstone, Rosen, Drislane & Galaburda, 1991; Stein & Walsh, 1997; Vidyasagar, 2004). The above hypotheses support a biological cause for dyslexia while according to previous research children with dyslexia in conjunction to phonemic difficulties present a number of other difficulties in skills related to the velocity of elaborating information, movement, memory, orientation, balance, measurement of time and visual processing especially form discrimination and visual processing speed. These difficulties could explain the visual difficulties such as unstable binocular vision and unsteady fixation when reading and might result in visual confusion of letter order, which can lead to poor memory of the visual form of words (Vlachos, 2002).

In general, the characteristics of adolescents with dyslexia, ages 13-17, are different and vary from quite simple to more complicated ones (Moragne, 1997). As children

approach adolescence they may learn to read words accurately, but they will not be fluent or automatic because their phonological deficit still exists. Although these older students may recognise the words, their reading is less automatic, more effortful and slower (Shaywitz & Shaywitz, 2005). The results of various studies (Moats, 1996) indicate that the adolescents with dyslexia make the same errors during the reading process as younger students do. According to an investigation (Goulandris et al., 2000) about the dyslexia as a form of specific language impairment, adolescents with dyslexia perform as well as those with persistent oral language impairments. Other investigations (Fawcett & Nicolson, 1995) on students with dyslexia (ages 8, 13 and 17) found that their achievement in sound categorisation and phoneme deletion is significantly worse than that of students without dyslexia. As for the memory of children with dyslexia, ages 8-14, the results of an investigation (Nelson & Warrington, 1980) showed specific deficit in the short-term memory storage, the long-term memory storage and the semantic memory storage (this term refers to the memory of meanings, understandings, and other generalized knowledge that does not involve memory of a specific event). Moreover, experiment results (Brady, 1986) showed that the developmental and individual differences in verbal memory span are related to the phonological processes. Other research evidence (Ackerman & Dykman, 1993) from testing children, ages 7-12, showed that the differences between readers with dyslexia and adequate readers in running memory span and serial memory span are distinguishable. Recent analyses conclusions (Howes et al., 2003) support that serial memory and abstract visual-spatial memory performance of students with dyslexia is poorer than that of students without reading disabilities.

Levine (1990) states that abstract/verbal concepts and ideas are the most difficult kinds of concepts for dyslexics because they are thought about in words instead of pictures and cannot be seen, touched, heard, tasted, or smelled. According to Shaywitz, persons with dyslexia have “a reliance on context to discern the meaning of what is read” (Shaywitz, 2003). Since the automatic route to reading is unavailable to the person with dyslexia the act of decoding one word relies heavily on its relationship to all the surrounding words. Consequently, if she/he is to identify many of the words on the page, she/he must pause and rely on the support of her/his higher-level thinking skills. She/He must survey the context and get to the word’s meaning by this slower and more indirect pathway (Shaywitz, 2003).

In the light of the above it seems that the reading process of adolescents with dyslexia is not automatic and their mnemonic ability is poorer than the students without dyslexia. This means that they may have problems retaining the meaning of text when reading at speed or fail to recall learned facts. Therefore the physics texts

should be written in such a way as to be read without any difficulties by students with dyslexia. The following four criteria have been proposed (Papalexopoulos et al., 2006) in order to be applied to the construction of physics texts.

Criterion 1: The verbal part of the text should include words that are familiar to students with dyslexia in order to recognise them easily and overcome their poor memory abilities (Ornstein & Carstensen, 1991; Nelson & Warrington, 1980; Howes et al., 2003).

Criterion 2: The information of the verbal part should be contained in the pictorial part as well, so that both hemispheres of the brain of students with dyslexia to be stimulated (Bakker, 1992). In the case of words that symbolise difficult physical concepts, the optical representation of the basic elements of these concepts is a proposed solution (McCoy, 1988).

Criterion 3: The pictures of the text should be simple and explicit so that students with dyslexia not to encounter reading problems (Reid et al., 1983; Seitz & Scheerer, 1983; Rakow & Gee, 1987). The pictures should have the following characteristics: a) The rough drawing is preferred instead of the photos and it should explain the information that is included in the verbal part of the questions (Drewniak & Kunz, 1992). b) The difference between dimensions of the represented objects and those in nature should be minimum (Newton, 1984). c) The symbols of physical quantities that represent more than one meaning should be clear (Stylianidou et al., 2000).

Criterion 4: The organisation and presentation of the information included in the verbal and the pictorial part of the text should have the following characteristics: a) Information should be organised in such a way as to emphasise the basic concepts of the text; therefore, the students' brain keeps the concepts in the long-term memory as high important information (Ornstein & Carstensen 1991; Fields, 2005). b) If possible, the information should be represented in alternative forms such as tables of data, diagrams, and so on (McCoy, 1988; Trott, 2003).

The above mentioned writing criteria have been applied to the construction of a physics text (Papalexopoulos et al., 2006) concerning the theoretical description of the physical quantity of electric current which is taught in the 11th grade. The information included in the text refers to the physical quantity of the electric current, the units of measurement of the electric current and the electric charge, the ampere-meter, its operation and connection in an electric circuit, the electric charge conservation principle, the concepts of node and branch in an electric circuit, the Kirchoff's 1st rule and its experimental verification. The verbal part of the text was constructed according to Criterion 1, (i.e. using words familiar to students with dyslexia). This

was achieved by using already mentioned words in previous sections of the “electric current” in the school textbook. The words that were taken into account were the “term-words”, (i.e., words with a special meaning in physics different than in everyday life). The text was written by using “term-words” that could be found quite frequently in the school textbook. As for the design of the pictorial part of the text, the parts of the text that were accompanied by pictures were chosen according to Criterion 2. The parts of the text that described basic physical quantities were accompanied with pictures because the physical phenomena are studied by the use of these quantities (Serway & Jewett, 2004). The parts of the text that included “term-words”, which were difficult for the students to understand, were accompanied with pictures too. The designation of the pictures was done in such a way as to represent the objects according to Criterion 3, (i.e., the dimensions of the objects, the symbols of the physical quantities etc). The organisation and presentation of the information that was included in the verbal and pictorial part of the text were realised by using Criterion 4. Concepts that describe the “electric current” did not seem appropriate to be presented in alternative forms like tables and diagrams; therefore, the way of presenting the information in the verbal or pictorial part of the text has not been modified. The changes made into the text related to the emphasis of the basic concepts that described the physical phenomenon of the electric current and the relevant physical laws, considering that bold letters in the text enable students with dyslexia to read without difficulties (Ornstein & Carstensen, 1991; Fields, 2005).

Research questions

This preliminary study aimed to assess the effectiveness of the above mentioned writing criteria in physics text about the electric current, ensuring that it was readable and easily understood by the students with dyslexia. The effectiveness was assessed through an experimental research regarding students with and without dyslexia in order to identify the specific problems students in the two groups encountered with the particular text.

The lack of previous research results did not help us to form particular hypotheses in this study; instead, we phrased the following research questions: a) Do students with dyslexia recognize the physical phenomena which are described in the constructed physics text, in the same level as students without dyslexia? (*Question I*). b) Do students with dyslexia recognize the physical quantities which are described in the constructed physics text in the same level as students without dyslexia? (*Question II*). c) Do students with dyslexia recognize the relations between the physical quantities which are described in the constructed physics text in the same level as students

without dyslexia? (*Question III*). d) Do students with dyslexia recognize the units of measurement of the physical quantities which are described in the constructed physics text in the same level as students without dyslexia? (*Question IV*). e) Are there any differences among students with dyslexia in recognizing the physical phenomena, the physical quantities, their relations and the units of measurement and do the students with and without dyslexia have difficulties in recognizing these categories? (*Question V*).

Method

Participants

Three students with dyslexia (two boys, Manolis and Leo, and one girl, Christine) and three students without dyslexia (two boys, Apostolis and Costas, and one girl, Helene) participated in this study. Students with dyslexia were matched with students without dyslexia in terms of age, sex, IQ, and their previous achievement in physics from their school teachers. The participants were attending the 11th grade. Manolis, Leo and Christine were diagnosed as having dyslexia by a group of specialists in a psycho-medical childhood centre in Athens, Greece. The mean chronological age of the students with dyslexia was 16.6 (SD=0.2) and their average IQ, according to the Greek version of the WISC-III test, was 100.80 (SD=1.7). The average chronological age of the students without dyslexia was 16.4 (SD=0.1) and their average IQ, according to the Greek version of the WISC-III test, was 101.35 (SD=1.6).

Procedure and evaluation instruments

As we have stated above, the characteristics of adolescents with dyslexia vary from simple to complicated (Moragne, 1997). Preliminary systematic observations were conducted in order to define difficulties between students with and without dyslexia in terms of reading and understanding a physics text. The observations occurred during the instruction of physics at the 10th and at the 11th grade until the conduction of the procedure that related to the reading and understanding of the constructed physics text. We assigned students comprehension of the physics textbook according to their answers to the relevant questions of the textbook. These questions examined: a) recognition of physical phenomena (12 questions), b) recognition of physical quantities (36 questions), c) recognition of relations between the physical quantities (21 questions), and d) recognition of units of measurement (7 questions). An example of a sheet of observations and some examples of questions that examined the recogni-

tion of the physical quantities, the relations between the physical quantities and the units of measurement are presented in Figure 1.

	Questions	Manolis	Leo	Christine	Apostolis	Costas	Helene
Recognition of the physical quantities							
1	Write two examples which show that force is a vectorial physical quantity						
2	Write the direction of the resultant of two forces with opposite directions						
3	An object moves along a straight direction having a constant velocity. What are the characteristics of the resultant of the forces acting on the object						
Recognition of the relations between the physical quantities							
4	Write the relation that describes the second law of Newton						
5	The acceleration of an object produced by a force is a) proportional to the square of the force, b) proportional to the force, c) independent of the force, d) inversely proportional to the force						
Recognition of the units of measurement							
6	Write the units of measurement of the physical quantities presented in the second law of Newton						
7	The unit of measurement of a force is a) 1kg m/s, b) 1kg m/s ² , c) 1kg m, d) 1kg s ² /m						
	Total						

Figure 1. Sheet of observations for definition of the students' comprehension of the theory of forces in the physics textbook

The results of the observations (see Table 1) show that the students with dyslexia in comparison to the students without dyslexia had difficulties in recognising successfully the physical phenomena, the physical quantities, the relations between the physical quantities and the units of measurement of the physical quantities that were described in the text of the physics textbook. More precisely, according to Table 1, from the 228 questions (76 questions of the physics textbook x 3 students) students with dyslexia correctly answered 80.3% in contrast to the 94.7% of the students without dyslexia. The students with dyslexia had more difficulties in recognising correctly every category of the physics text than the students without dyslexia (see Table 1). For example, in recognising the physical quantities, 39.5% of the students' with dyslexia gave correct answers, while the students without dyslexia achieved a percentage of 44.7%.

Table 1. Distribution of the students' correct answers to the questions of the physics textbook as to the categories of recognition

Categories of recognition	Students' with dyslexia correct answers		Students' without dyslexia correct answers		Questions of the physics textbook	
	f	rf (%)*	f	rf (%)*	f	rf (%)
Physical phenomena	30	13.2	36	15.8	72	15.8
Physical quantities	90	39.5	102	44.7	216	47.4
Relations between the physical quantities	48	21.1	57	25.0	126	27.6
Units of measurements	15	6.6	21	9.2	42	9.2
Total	183	80.3	216	94.7	456	100.0

* The relevant frequencies have been estimated as to the total number (228) of the questions of the physics textbook (76 questions of the textbook x 3 students) that were used to find the students' difficulties in recognising the defined categories.

Students' reading of the physics text occurred two weeks before teaching of the subject in the science class. The procedure of reading was decided to be implemented prior to teaching in order to avoid the development of any knowledge related to the subject matter of the text. Besides this, the procedure took place as close to the date of teaching the subject matter so that the students would not have any questions about the content of the text that related to prerequisite knowledge.

In order to examine the comprehension of the physics text by the six students we have developed a series of questions. The purpose of the questions was to examine students' comprehension of the physics text. Therefore students were told that they could read the text while answering the questions. The 22 questions examined the recognition of i) the physical phenomena (7 questions), ii) the physical concepts (8 questions), iii) the relations between the physical concepts (3 questions) and iv) the units of measurement of the physical quantities (4 questions). We also read the questions aloud to the students with dyslexia in order to avoid any misunderstanding. The following question is indicative of the questions used in order to examine students' recognition of the unit of measurement of the electric current "1 ampere (A)". "Is the following true or false question: *1 A is the electric charge that flows through a cross-section of a metallic pipe in 1 sec in case that the electric current is 1 A.*"

Results and discussion

Table 2 presents the distribution of students' wrong answers to the questions of the constructed physics text as to the categories of the recognition. As can be seen in the table, only one student with dyslexia (Leo) did not answer correctly one of the questions that examined the recognition of the physical phenomenon of the electric

Table 2. Distribution of the students' wrong answers to the questions of the constructed physics text as to the categories of the recognition

Categories of recognition	Students with dyslexia		Students without dyslexia		Total number of answers/Questions	
	Wrong answers/Questions*		Wrong answers/Questions*			
	f	rf (%)	f	rf (%)	f	rf (%)
Physical phenomena	1/21	4.8	0/21	0	21	31.8
Physical quantities	3/24	12.5	1/24	4.2	24	36.4
Relations between the physical quantities	1/9	11.1	3/9	33.3	9	13.6
Units of measurements	4/12	33.3	1/12	8.3	12	18.2
Total	9/66	13.6	5/66	7.6	66	100.0

* The frequencies of the answers for every category of recognition corresponds to the total number of the relevant answers for all the students with dyslexia or for all the students without dyslexia e.g. 3 answers which examine the students' recognising of the relations between the physical quantities x 3 students with dyslexia = 9

current which flows through a metallic pipe. As for the students without dyslexia, we noticed that all participants answered correctly the relevant questions about the physical phenomena. According to this data, the answer to our first research question is that the students with dyslexia recognised the physical phenomena described in the physics text equivalently with the students without dyslexia.

As far as the students' with dyslexia ability to recognise the physical concepts described in the physics text concerns, we noticed that Christine did not answer correctly two of the questions that examined the procedure of measuring the electric current. Manolis also did not answer the question concerning the definition of branch in an electric circuit. Within the students without dyslexia, only Costas failed to answer the question concerning the cross-sections of a metallic pipe. We consider that these wrong answers of the students with and without dyslexia do not imply a reading difficulty or difficulties in recognising the physical quantities described in the text. Taking into account the data of Table 2 (12.5% wrong answers by the students with dyslexia and 4.2% wrong answers by the students without dyslexia), the answer to question II is that the students with dyslexia recognised the physical quantities described in the physics text in an analogous level as the students without dyslexia.

The analysis of the students' with dyslexia answers concerning the relations between the physical quantities which describe the relevant physics phenomena indicated that Christine did not answer correctly only one question. The specific question about the conservation of the electric charge during its flow through the cross-sections of a metallic pipe was not also been answered correctly by two students without dyslexia, Costas and Helene. Helene did not answer correctly the question about the stability of the electric current across a metallic pipe as well. According to this (11.1% wrong answers by the students with dyslexia and 33.3% by the students without dyslexia), the answer in our third research question is that the students with dyslexia recognised more relations between the physical quantities than the students without dyslexia did. Although this seems to be paradoxical, we consider that the small number of questions related to the recognition of the relevant category does not allow any claims for generalisations. The high (88.9%) percentage of correct answers students with dyslexia gave suggests that those students identified effectively the relations between the physical quantities described in the physics text.

Concerning the recognition of the units of measurement of the physical quantities by the students with dyslexia, our analysis showed that Leo did not answer correctly most of the relevant questions (3 wrong answers to 4 questions). Manolis also did

not answer correctly one of the questions about the units of measurements. On the contrary, only one student without dyslexia, Apostolis, did not answer correctly one of these questions (see Table 2). Consequently, the answer to the fourth research question is that the students with dyslexia have more problems recognising the units of measurement compared to the students without dyslexia.

The fifth research question concerned possible differences among the students with dyslexia in recognising the categories of the constructed physics text such as the physical phenomena, the physical quantities, the relations between the physical quantities and the units of measurement. According to Table 2, their wrong answers are only 13.6% of the total answers. This low percentage suggests that the specific physics text which was constructed according to the aforementioned writing criteria restricted the reading difficulties. As Figure 2 shows, both Christine and Manolis had difficulties in the category of the physical quantities and both Leo and Manolis had difficulties in the category of the units of measurement. Every student with dyslexia had difficulties in more than one of the categories of recognition, (i.e. Leo confronted difficulties in the physical phenomena and in the units of measurement). The data show that the three students with dyslexia had some difficulties in recognising the physical quantities and the units of measurement of the physics text. Taking into account the fact that the wrong answers for the units of measurement are 33.3% of the total answers of the students with dyslexia while the corresponding percentage for the physical quantities is only 12.5% (see Table 2), we consider that students with dyslexia mainly confronted difficulties in recognising the units of measurement.

Analysing the data for students' difficulties in pair (i.e., a student with dyslexia to a student without dyslexia of the same gender, age, IQ, and the same achievement in physics), it seems that both Manolis and Apostolis had difficulties in the recognition of the units of measurement, both Christine and Helene had difficulties in recognising the relations between the physical quantities, but Leo and Costas did not have any common difficulties (see Figure 2). According to this data, we consider that the students with and without dyslexia in pair confronted similar difficulties. This evidence implies that the two specific categories, i.e., the units of measurement and the relations between the physical quantities, created the main difficulties in recognition for both students with and without dyslexia. A possible interpretation for this effect is the presentation of these two categories in the constructed physics text. Eventually, taking into account the small number of the questions which refer to the category of the relations between the physical quantities, we consider that the presentation of the category of the units of measurement needs to be further studied.

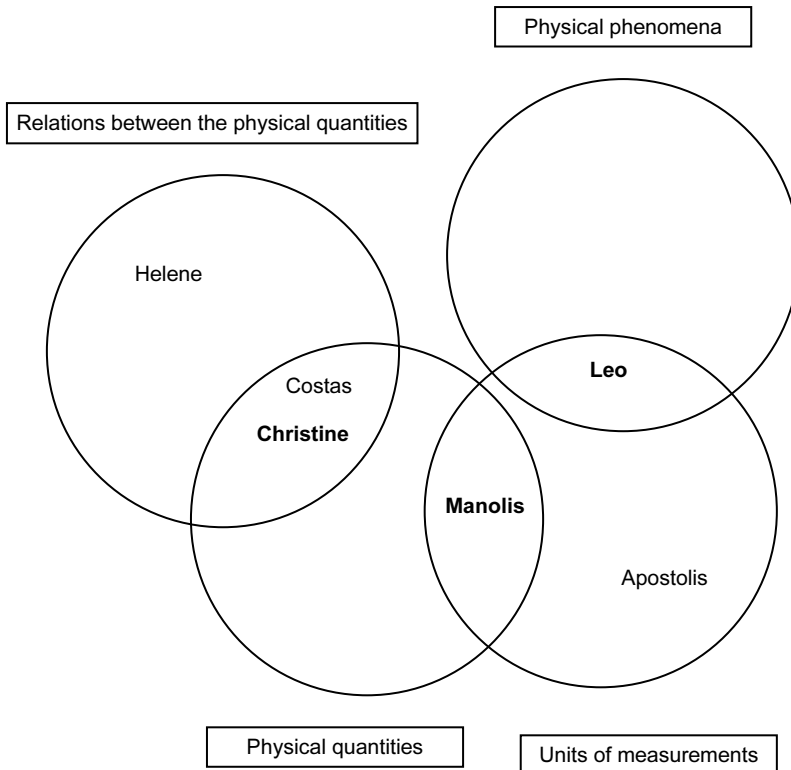


Figure 2. Categories of the physics text that the students with dyslexia (**bold letters**) and the students without dyslexia (**unbold letters**) have difficulties in recognising them

Another noticeable result, that is seen both in Table 2 and Figure 2, is that the category of the physical phenomena created very few difficulties to students with and without dyslexia. A possible interpretation is that the physical phenomena constitute the primary approach of physics for the description of the phenomena of nature. The other three categories, (i.e. the physical quantities, the relations between these quantities and the units of measurement), constitute the necessary tools for physics in order to describe and explain explicitly the physical phenomena; therefore, it is expected to be recognised with enhanced difficulties. However, we consider that this discrimination and hierarchy of the categories constitutes a new research question for further investigation.

The answer to the fifth research question is that students with dyslexia have difficulties in recognising the units of measurement and the physical quantities. As for the comparison of the difficulties in pair (students with dyslexia to students without dyslexia) we consider that they have equal difficulties in recognising and understanding the various categories of the physics text such as the physical phenomena, the physical quantities, and so on.

Summing up the analysis of students' answers to the questions about the effectiveness of the writing criteria, we conclude that the application of these criteria helped the students with dyslexia to encounter fewer difficulties during the reading of the physics text compared to the students without dyslexia. However, we have to notice that the presentation of the units of measurement in the physics text has to be studied further because students with dyslexia confronted with difficulties to understand them.

Conclusions

In this study we assessed the effectiveness of the criteria that have been proposed for the construction of physics texts for adolescent students with dyslexia so that these texts do not create reading difficulties. More precisely, we attempted to assess the effectiveness by the accomplishment of a preliminary research for students with and without dyslexia. The two groups of students read the constructed physics text that had been written according to the writing criteria and we assigned the students' comprehension of the text by analysing their answers to specific questions. The results of the analysis showed that the students with dyslexia recognised the physical phenomena, the physical quantities and the relations between the physical quantities that are described in the constructed physics text at least in the same level as the students without dyslexia did. On the contrary, the students with dyslexia had some difficulties in recognising the units of measurement compared to the students without dyslexia. According to these results we consider that a physics text which a) includes words familiar to the students with dyslexia, b) includes pictures containing information of the verbal part and having specific characteristics (rough drawing and so on), and c) emphasizes the basic concepts, could help students with dyslexia to overcome reading difficulties. The physics text that has been constructed according to these criteria seems also to activate adolescent students' with dyslexia and poor mnemonic function in reading, and help them to comprehend the content at the same degree compared with the students without dyslexia. In general, the results of the research showed that the writing criteria helped the specific students with dyslexia to have few difficulties with the physics text about the electric current that had been con-

structured according to these criteria. However, we consider that further research on the writing criteria could improve their effectiveness in order to reduce students' understanding of the units of measurement.

The nature of the learning disabilities and the unique characteristics for every student with dyslexia restricts any generalization without a preceding definition of students' characteristics and a systematic analysis of the content that the relevant constructing text would refer. However, we consider that the criteria, which have been proposed for the writing of a physics text, may be used by the authors of school-textbooks and the teachers of physics who wish to provide further written material to their students with dyslexia. Moreover, we think that the writing criteria should be adjusted by the specialists and the teachers to the specific content and to the characteristics of the specific students with dyslexia that would read the text. We also consider that the criteria could be applied to the writing of science texts, which would be read by children with other kinds of intellectual disabilities in condition that they would be adjusted to the specific characteristics of these children. Overall we believe that every student with special educational needs has his own "needs" and "strengths" and every teacher has to be critical (Carr & Kemmis, 1988) in order to have successful educational results.

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