TEACHING MECHANICS TO STUDENTS WITH LEARNING DISABILITIES: A CASE STUDY IN GREECE

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Abstract

Mechanics is a basic part of Physics and the main subject of the relevant course in the second grade of Greek high school. The educational implications of the studies in the field of teaching mechanics refer to the instruction of essential concepts such as force, pressure and energy. However there are few research studies of teaching mechanics to students with learning disabilities especially in Greece. In this paper we present a case study of teaching mechanics to students with learning disabilities in the second grade of a general Greek high school. The purpose of this study is to examine the implementation and the efficacy of teaching mechanics to students with learning disabilities of the second grade of a Greek high school by using the conceptual mapping. An experimental teaching procedure took place in a physics resource room for students with learning disabilities of the second grade of a general high school by using the conceptual mapping during a sequence of successive instructions for the concept of energy. A control teaching procedure without the use of conceptual maps was realized in the same resource room during the instructions for the concept pressure in order to compare the two teaching procedures. In both phases, experimental and control teaching procedure, tests were administered before and after each instruction so as to investigate the prior to the instruction knowledge and the learning outcomes after it. The questions of the student with learning disabilities during the instructions were recorded and analysed in order to define his interest in mechanics by using conceptual mapping. The analysis of the collected data yielded several results. The use of conceptual mapping improved the student's performance on achievement tests and contributed to the accomplishment of the teaching objectives. However the use of the maps was not successful in stimulating the student's interest for the concept of energy. We also discuss the implications of our findings to teaching practices and future research in the field of teaching physics to students with learning disabilities.
Key words: *conceptual maps, interest, learning disabilities, performance, teaching mechanics, teaching objectives.*

Introduction

According to the Greek law the teaching of physics in high school should help students comprehend the basic physics concepts, develop psychomotor and research skills, cultivate the cooperation and communication between them and comprehend the correlation between science, technology and everyday life (Greek Government, 2003). For the achievement of these aims the content of the curriculum of physics in the second grade of high school is based on the concepts of mechanics, which include the physical quantities of speed, power, pressure and energy. However the students may have formed a set of personal ideas, opinions and perceptions about these concepts before learning physics in school. These ideas are recorded in the literature as alternative ideas, misconceptions etc. The application of effective teaching strategies in general school usually takes place in order to change the initiative ideas of the students and to adopt views and ways of thinking consistent with the valid scientific model (Driver, Squires, Rushworth & Wood-Robinson, 1994). Although there are several studies on the teaching of mechanics to students of the general physics class, there are very few for students with learning disabilities in the Greek school (Tselfes, Fasoulopoulos, Vavougios & Panteliadou, 2006). In this article we describe a case study on the teaching of mechanics to a student with learning disabilities, who attends the second grade of a Greek high school and the resource room for the course of physics.

Learning disabilities is a heterogeneous group of disorders manifested by difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. Recent research results confirm the hypothesis that the causes of the disorders lay in the dysfunction of the central nervous system. Although learning disabilities may occur with other handicapping conditions such as sensory impairment, mental retardation or with extrinsic influences such as insufficient instruction, they are not the result of these influences (American Speech-Language-Hearing Association, 1998; Hammill, Leigh, McNutt & Larsen, 1981; Rourke, 2005). In alignment with the principles of other countries of the European Union (The Council and the Ministers of Education meeting within the Council, 1990) the Greek state has institutionalized the organization and operation of special education in primary and secondary schools by attempting to integrate students with special educational needs, such as sensor impairments and learning disabilities, in the mainstream school. The resource rooms are the basic structure of this attempt and they are considered by the state and the official education agencies as the best effort for the integration of these students in the general school (Vlachou, 2006). The diagnosis of students with special educational needs and the construction of their individual educational plan were made before the enforcement of the new Greek law (3699/2008) by an interdisciplinary team, which included specialists of the Centre of Diagnosis Evaluation and Support such as special educator, psychologist, social worker etc, (Law 2817/2000). As required by the Greek law (3699/2008) individual instruction or instruction of small groups of students with learning disabilities take place in the resource rooms in collaboration with the teachers of the mainstream school in order to support and assist these students' successful integration in the general school. In this framework and regarding the view that successful integration of students with learning disabilities in the mainstream school is achieved by adaptations to the instruction in relation to their special educational needs (Meijer, Soriano & Watkins, 2003), in this paper we describe a case study on the teaching of mechanics to a student with learning disabilities using the conceptual mapping instructional strategy.

The use of conceptual mapping in the instruction of physics to a student with learning disabilities could be useful in the case of the concepts of mechanics that should be differentiated, for example contact forces from forces at distance. Conceptual mapping is also useful for emphasizing the relation between concepts of physics, for example the relation of the concept of velocity to the concept of distance and time. The structured and hierarchical way to represent concepts, the emergence of relations between concepts and the variety in the presentation of information using a variety of colours, images, shapes, sketches and graphics (Kinchin, Hay & Adams, 2000; Novak & Cañas 2006), could help students with learning disabilities use the conceptual map as a tool for revision, learn the scientific terminology, consolidate the new information on their long-term memory and activate their involvement in the teaching process.

The purpose of our study is to examine the effectiveness of teaching mechanics to students with learning disabilities of the second grade of a general Greek high school using conceptual mapping. The specific research objectives were to answer the following research questions: 1) Does the use of conceptual maps improve the performance of the student with learning disabilities in mechanics? 2) At which level the teaching objectives for mechanics are being accomplished by the use of conceptual maps? 3) Does the use of conceptual maps stimulate the interest of the student with learning disabilities for mechanics?

Methodology of Research

Characteristics of the case study design

The case study was conducted in a mainstream high school of Northern Greece under the supervision of the third author of the paper. In this school resource rooms for students with special educational needs were being operated throughout the whole school year. The resource room of the second grade of high school (eighth grade after the kindergarten) for the course of physics consisted of one student with learning disabilities, Jimmy. The organization of the resource room i.e. the choice of the classroom for teaching, the planning of the timetable of the courses and the support for the collaboration between the teachers of the mainstream classes with the teachers of special education were organized by the first author of the paper together with the principal of the school. The first author acted as an observer during the experimental and the control phase, as she was the teacher of physics in the resource room. The second author acted as her research advisor having several meetings with her for exchanging views about the planning and the accomplishment of the research. The three authors communicated frequently by e-mail and telephone throughout the course of the study. The credibility of the study was addressed a) through the prolonged engagement of the authors; the study lasted one school year, b) by the first author's qualifications; she had attended one year seminar organized by the Department of Special Education in the University of Thessaly in order to be specialized in the instruction of physics to students with special educational needs, c) the cross checking of the administered tests for the collection of data by the authors of the paper and the teacher of physics of the mainstream class.

The research consisted of two phases, an experimental phase and a control phase. During the experimental phase the teacher of physics of the resource room used the instructional strategy of conceptual mapping versus the control phase where she did not use the conceptual maps. The content of the experimental phase referred to the concept of the energy and was divided in four sequences of successive instructions: definition of work, produced work by a constant force, kinetic energy and gravitational potential energy. Correspondingly the content of the control phase referred to the concept of pressure and the three sequences of instructions were: atmospheric pressure, Pascal's law and flotation. The choice of the concept of energy for the instruction by using the conceptual maps was made because of the specific characteristics and the different types of energy. Moreover the different types, i.e. the kinetic energy, the gravitational potential energy and the concept of work, should be discriminated so that the students achieve the teaching aims described in the Greek law (Greek Government, 2003).

Participant

According to the diagnosis of the Centre of Diagnosis Evaluation and Support Jimmy's problems were focused in a) reading, b) dysgraphia with many written orthographic errors, c) achieving an objective, d) social functionalism and e) lack of inventiveness in the materialization of his activities. The proposal of the Centre for Jimmy's integration in the mainstream class was the individualized teaching in a resource room. The diagnosis report was short and did not propose specific educational interventions to the teachers of special education. The teacher of physics of the resource room assembled additional information about Jimmy in the beginning of the school year. The relevant data were collected by informal interviews with teachers of special education of the previous school year and the student's mother. The teacher of special education in Mathematics said that Jimmy was interested in the course although he confronted difficulties in running algebraic operations and solving difficult equations. The teacher of Modern Greek Language of the resource room said that Jimmy had difficulties in writing, in oral expression and in reading. A teacher of special education in primary education claimed that the student tried very hard throughout the years he attended the elementary school in order to overcome his reading and writing disabilities and that he used to read the daily homework from printed notes with bold letters for the basic conceptions. Jimmy's mother described the family surrounding and she claimed that he studied the daily homework alone.

Instructional strategy: Teaching with conceptual maps

The incorporation of conceptual maps in the instruction of mechanics was realized by the active participation of the student in the construction of the conceptual map. With the use of suitable teaching material, blackboard, pictures of the textbook and hands on-experiments the teacher helped the student to construct step by step the conceptual map (figure 1). Therefore the word of the basic concept of teaching (Word A) was connected to the suitable conjunctive words that describe its characteristics (Word 1, Word 2 . . .). In certain cases these words were given by the teacher in a list and the student choose the appropriate one. Afterwards Jimmy constructed the accompanying text (Text 1, Text 2) in collaboration with the teacher. An example of constructing a part of a conceptual map is the following: Force (Word A), is (Word 1), a vector physical quantity (Text 1). Jimmy dictated the accompanying text to the teacher, as one of his problems was the dysgraphia. The student also selected the colour they used in order to emphasize the basic words of the map. In the end of the instruction the teacher printed the final form of the map and fixed it in a stand inside the physics resource room.

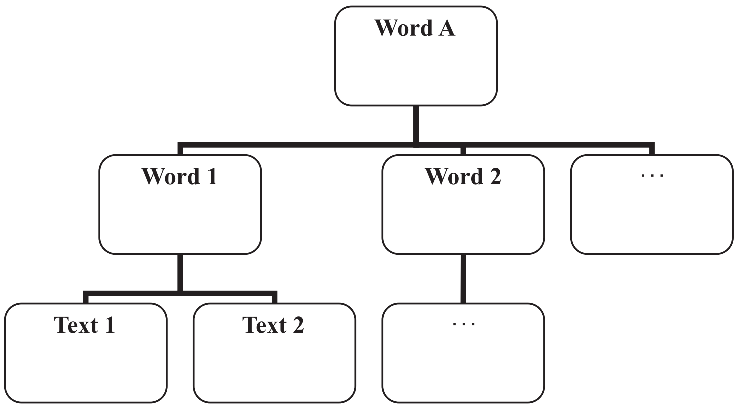

Figure 1. Model of Conceptual Map under Construction.

Collection and analysis of research data

Two tests, a pre-test and a post-test, were administered before and after each instruction in the physics resource room. More specifically four pre-tests and four post-tests were administered before and after the experimental phase respectively, and three pre-tests and three post-tests were administered before and after the control phase. The tests were designated to probe the student's knowledge before and after the instructions and their purpose was to define the student's performance and the level of the teaching objectives that have been accomplished during the experimental phase, and to compare them to the corresponding results of the control phase. The teaching objectives for each one of the phases, experimental and control, were defined according to Bloom's taxonomy (Anderson & Krathwohl, 2001) and they corresponded to the first three levels-categories of the taxonomy i.e. knowledge, comprehension and application. Table 1 presents the teaching objectives of the experimental and the control phase. According to the data of the table the teaching objectives of the different phases of the research were almost equivalent, because 77% of the objectives of the experimental phase corresponds to the percentage of the category of knowledge and comprehension and 23% to the category of application, while the percentages of the control phase are 78% and 23% correspondingly.

Table 1. Categories of the teaching objectives in the experimental and the control phase.

Category	Phases					
	Experimental		Control		Total	
	f	%	f	%	f	%
Knowledge	6	66,7	6	46,2	12	54,5
Comprehension	1	11,1	4	30,8	5	22,7
Application	2	22,2	3	23,1	5	22,7
Total	9	100	13	100	22	100

As for the kind of questions the tests included close-ended and open-ended questions and an exercise or problem regarding the teaching objectives of the specific lesson. Specifically for the blank-space questions the teacher of physics of the resource room gave Jimmy a list of relevant words in order to select the appropriate one. The teacher read aloud the questions and Jimmy answered them orally, and whenever it was necessary he wrote anything that helped him respond, e.g. the symbol of the concept, the unit of measurement, the mathematic formulas and the algebraic operations for the exercises and the problems etc.

Jimmy's responses to the questions of the tests were evaluated by the teacher of physics of the resource room according to the scoring that had been agreed before the instruction with the teacher of physics of the mainstream class. The validity of the scoring was checked by the co-authors of the paper. Jimmy's performance in the pre-tests and post-tests was calculated on the integer scale 0-20 as in the mainstream physics class. The scores of the administered tests were converted to the integer scale 0-100 and the statistical measure of average of descriptive statistics was used in order to estimate Jimmy's performance in every test.

The questions phrased by Jimmy during both phases were recorded by the teacher of physics of the resource room. The questions were analysed by the method of content analysis (Holsti, 1969) and as the unit of analysis was used the theme of each question. The themes of the questions that reflected our research objective about the stimulation of the student's interest for mechanics were a) the concept of physics that was taught, b) the described experimental process during the instruction and c) the application of the concepts of physics to the daily life.

Procedure

The student attended the instructions of the physical phenomenon of movement, of the concepts of force, pressure and energy in the mainstream physics class of the second grade. The teacher of physics in the mainstream class administered experiments in order to explain the characteristics of some of the physics concepts for example, the concept of force. Jimmy made an effort to participate in all the activities that took part in the mainstream physics class and also to solve exercises or simple problems. The teacher of physics of the mainstream class informed the teacher of physics of the resource room about the teaching objectives of each section of mechanics that should be achieved, the activities that were realized during the instructions and the exercises that the students attempted to solve. The teacher of the mainstream class also informed his colleague about the students' results in the short time examinations.

Preparation for the experimental procedure

The conceptual map was used for first time in the resource room at the teaching for the concept of speed. The teacher of physics used a completed conceptual map so that Jimmy can get familiar with its use. The teacher revised the main points of the course such as the relation between the physi-

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cal quantity of speed with the concepts of distance and time, the description of the concept of speed with a vector etc using the conceptual map. Using different colours the teacher emphasised the difference between some conceptions such as the average speed and the average velocity. The teacher also explained Jimmy the possibility of adding pictures in the conceptual charts and the possibility of using it during his study at home.

Afterwards the physics' teacher of the resource room implemented concept mapping during the instruction of the concept of force. According to the teacher of physics in the mainstream class Jimmy could neither draw correctly the vector of a force that acts on an object nor distinguish the contact forces and the forces at a distance. During the instruction in the resource room the teacher constructed together with Jimmy each part of the conceptual map for the concept of force (see figure 2) in a similar way as has been described in the method of the research. Jimmy said that he used the constructed conceptual map while studying at home. The teacher of the resource room used the conceptual map during the revision of the concept of force in the next lesson.

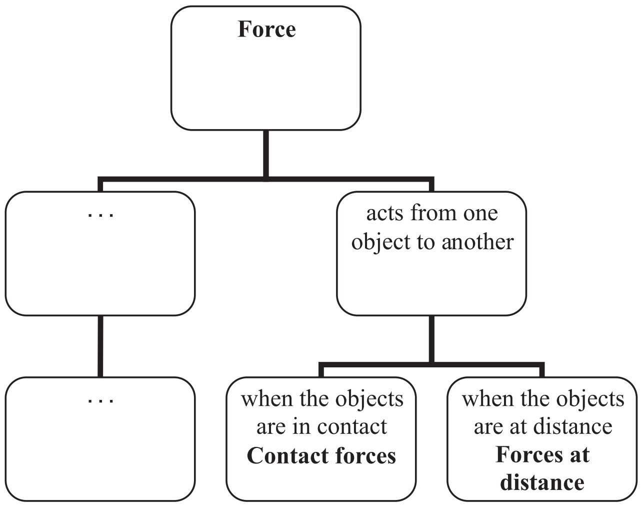

Figure 2. Construction of the Conceptual Map for the Concept of the Force.

Experimental phase

At the beginning of the instruction on the concept of work the teacher of physics administered a pre-test and Jimmy answered its questions. According to the teaching objectives of the specific instruction, Jimmy should a) comprehend the concept of work as a scalar physical quantity, b) connect the concept of work to the concept of transferred energy, c) learn that work and energy have the same unit of measurement. Afterwards the teacher of physics in collaboration with the student constructed the conceptual map as has been described in the section of the method of research. The only modification in the construction of the conceptual map concerned its vertical orientation that was adapted to horizontal (figure 3), because, as has been observed during the instruction of the concept of force, Jimmy was confused with it. At the end of the instruction the teacher read aloud to Jimmy the questions of the post-test. The teacher of physics administered a similar teaching sequence for the concepts of work of a constant force, for kinetic energy and gravitational potential energy, e.g. a pre-test and a post-test and an instruction using conceptual mapping for every concept.

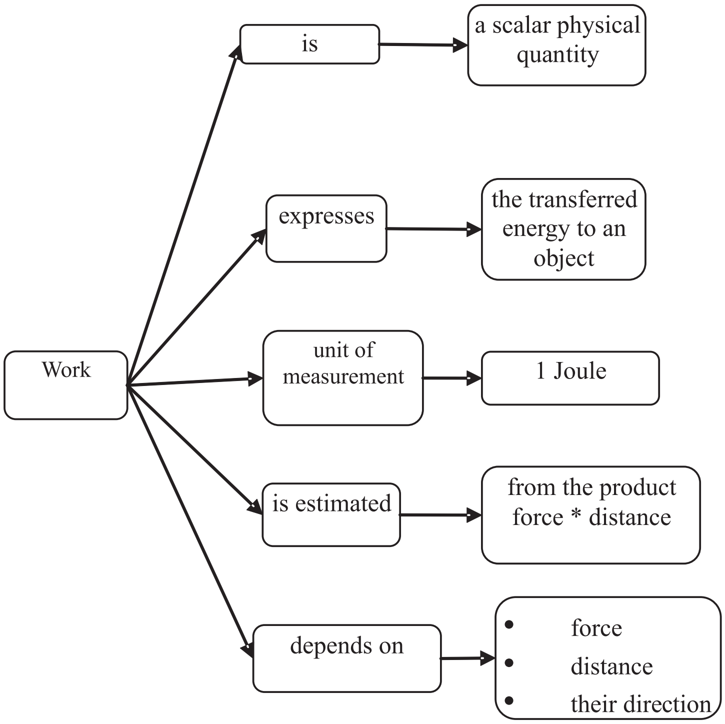

Figure 3. Constructed Conceptual Map for the Concept of Work.

Control phase

At the beginning of the instruction about the concept of atmospheric pressure Jimmy answered the questions of the pre-test. Afterwards the teacher used the suitable teaching material, pictures of the textbook, the blackboard etc so that the student in the end of this instruction would a) know that the atmospheric air is constituted from mixture of gases, b) explain the origin of atmospheric pressure, c) enumerate the factors that determine the atmospheric pressure and describe the relevant mathematic formula, d) know the units of measurement of the atmospheric pressure, e) describe Torricelli's experiment. More specifically the teacher used the pictures of the textbook to describe the affects of atmospheric pressure in daily life, for example the suck of a juice through a straw. As for the enumeration of the basic points of the lesson the teacher used the blackboard. In the end of the instruction the teacher administered the post-test. Similar instructions, without using conceptual mapping, were realized by the teacher for Pascal's law and for the concept of flotation.

Results of Research

Performance in energy and pressure

Table 2 summarises the student's performance in pre-tests and post-tests during the experimental and the control phase. According to the data of the table Jimmy's performance significantly improved after the experimental phase. More specifically the student's performance increased in the tests for the concept of energy from 51% to 95%, while in the tests for the concept of atmospheric pressure, increased from 50% to 60%. It is remarkable that Jimmy's performance improved in every concept of the experimental phase unlike to the control phase, where only in the concept of atmospheric pressure he marked a small improvement (30%). A further analysis of the presented data in table 2 probes Jimmy's high performance in the post-test for the concept of gravitational potential energy, although, the greek word for this kind of energy, "dinamiki energeia", is similar to the greek word for the force, "dinami", and Jimmy's difficulties in the use of language. The effectiveness of the conceptual maps to the improvement of the student's performance seems also to be confirmed by his high scores in the short time examinations for the concept of force in the mainstream physics class.

Table 2. Student's performance in pre-tests and post-tests in the experimental and the control phase.

Content of phase	Performance				
	Pre-test		Post-test		Change
	to 20	to 100	to 20	to 100	%
Experimental phase					
Definition of work	20	100,0	20	100,0	0,0
Work by a constant force	12	60,0	19	95,0	35,0
Kinetic energy	2	10,0	17	85,0	75,0
Gravitational potential energy	7	35,0	20	100,0	65,0
Average	10,3	51,3	19,0	95,0	43,8
Control phase					
Atmospheric pressure	6	30,0	12	60,0	30,0
Pascal's law	4	20,0	4	20,0	0,0
Flotation	20	100,0	20	100,0	0,0
Average	10,0	50,0	12,0	60,0	10,0

Teaching objectives for energy and pressure

Table 3 presents a detailed list of the teaching objectives that had been accomplished before and after the experimental and the control phases, which took part in the resource room. Comparing the percentage of the accomplished teaching objectives in both phases it is obvious that it is much higher in the experimental, 8/9 accomplished objectives (89%) than in the control phase, 1/6 accomplished objectives (17%). The high percentage of the accomplished objectives in the experimental phase is an indication that the use of conceptual mapping in the teaching process is effective for the learning outcomes. Further analysis of the accomplishment of the teaching objectives in the experimental phase shows that Jimmy improved the knowledge and the comprehension of the scientific concepts of work, kinetic energy and gravitational potential energy. The student confronted difficulty only in the application level of Bloom's taxonomy and more specifically in the application of the mathematical formula of kinetic energy in the solution of a physics problem. The difficulty was focused mainly in the realization of the algebraic operations that were necessary for the solution of the problem. Another difficulty, which has been identified from the student's answers to the post-test both in the experimental and the control phase, was that Jimmy did not write the units of measurement next to the arithmetic value of the relevant physical quantity. According to the teacher he added the units of measurement only after her remark except for the unit of measurement of the concept of force (1 Newton) that he used for a long period of time.

Table 3. Teaching objectives in the experimental and the control phase.

Teaching objectives	Instruction	
	Before	After
Experimental phase		
Knowledge		
Work is a scalar physical quantity	☑	☑
Units of measurement of work and energy	☑	☑
Mathematic formula of kinetic energy	x	☑
Factors on which depends the kinetic energy	x	☑
Factors on which depends the gravitational potential energy	x	☑
Mathematic formula of gravitational potential energy	x	☑
Comprehension		
Mathematic formula of work and energy	☑	☑
Produced and consumed work	☑	☑
Zero work	x	☑
Zero gravitational potential energy	x	☑
Application		
Mathematic formula for the calculation of the work	x	☑
Mathematic formula of the kinetic energy	x	x
Mathematic formula of the gravitational potential energy	x	☑
Control phase		
Knowledge		
Air has mass and weight	☑	☑
Factors on which depends the atmospheric pressure	x	x
Mathematic relation for atmospheric pressure $p = \rho g h$	x	☑
Units of measurement of atmospheric pressure	x	x
Torricelli's experiment	x	x
Pascal's law	x	x
Comprehension		
Flotation and sinking a body	☑	☑
Application		
Pascal's law	x	x
Equilibrium in flotation	☑	☑

Interest for energy and pressure

Table 4 presents the categories of questions that had been stated by Jimmy during the instructions of the experimental and the control phase. According to the data of the table more questions (10) were stated during the control phase than during the experimental phase (4). It is remarkable that 9 out of 10 questions of the control phase correspond to the category of application in daily life. For example Jimmy asked about the application of the atmospheric pressure to the barrels, the explanation of the function of a crane according to Pascal's law, about the flotation of a sail etc. In the experimental phase most of the stated questions, 2 out of 4, also belong to the same category of application in daily life, e.g. the effect of the change of a force acted on a see-saw to the produced work.

Table 4. Categories of student's questions during the experimental and the control phase.

	Concept/ Law	Procedure of experiment	Daily life	Total
Experimental phase				
Definition of work	1	-	2	3
Work by a constant force	-	-	-	-
Kinetic energy	-	1	-	1
Gravitational potential energy	-	-	-	-
Total	1	1	2	4
Control phase				
Atmospheric pressure	-	1	3	4
Pascal's law	-	-	3	3
Flotation	-	-	3	3
Total	-	1	9	10

As shown in the previous analysis the use of conceptual mapping in the instruction of mechanics does not contribute to the stimulation of the student's interest for the application of the concepts in daily life. The content of the syllabus itself may be a possible reason for the student's interest taking into account the characteristics of his family that had been described by his mother to the teacher of physics of the resource room. For example Jimmy's interest for the function of an hydraulic press and the application of Pascal's law to daily life may be aroused by his beloved grandfather's profession, who is an owner of fuel-shop, where Jimmy has many times seen the change of lubricant oils in the car engines using the hydraulic press to raise them.

Discussion and Educational Implications

The results of studies evaluating the use of conceptual mapping at high school level in courses of science are contradictory. According to certain studies the students the use of conceptual maps in science classes of eighth-grade has improved the performance of the students on achievement tests (Pankratius, 1990; Willerman & Mac Harg, 1991). This view is reinforced by the research results of a relevant study for tenth-grade students in the course of ecology and genetics (Esiobu & Soyibo, 1995). On the contrary the findings of other studies in classes of science (Fraser & Edwards, 1985) and classes of biology (Lehman, Custer & Kahle, 1985) showed no significant improvement on achievement tests. The analysis of the data of our case study showed that the use of conceptual mapping contributed to the improvement of the performance of the student with learning disabilities on the achievement tests on the concept of energy. On the contrary lack of use of conceptual mapping during the instructions of the concept of pressure did not contribute to the increase of Jimmy's performance. Interpreting the positive results of the student's performance, it seems that the structured way of representing the characteristics of concepts in conceptual maps helped him to comprehend the physical quantity of energy and learn the relevant scientific terminology.

The research findings of previous studies have provided evidence that attest the efficacy of conceptual mapping in an explicit comprehension of physical science concepts (Esiobu & Soyibo, 1995; Okebukola, 1990). The accomplishment of the teaching objectives corresponding to the levels of comprehension and application (Anderson & Krathwohl, 2001) on the concept of energy confirms this efficacy of the conceptual maps. An interpretation of this accomplishment is the possible consolidation of the new information of the physical quantity of energy on the long term memory (Novak & Cañas 2006) of the student with learning disabilities by the use of conceptual mapping.

Previous studies in using conceptual maps for the instruction of science showed that the students' interest had been successfully stimulated (Kwon & Cifuentes 2009; Rice, Ryan & Samson, 1998). We have to admit that our instructional strategy using conceptual mapping in the instruction of the concept of energy failed to stimulate the interest of the student with learning disabilities for the physical quantity and its applications to daily life. The abstract characteristics of the concept of energy and the lack of obvious applications of the different types of energy in Jimmy's environment may be an interpretation of this failure.

The specific limitations of our research, i.e. the realization of the case study to one student with learning disabilities and the use of conceptual mapping only for the specific concept of energy, does not allow any generalisations. However we consider that our research findings could urge researchers of physics and science education to realize investigations about the efficacy of conceptual mapping to students with learning disabilities with similar or different characteristics from those of the present case study and for concepts other than energy. Future investigations could also be designed to compare research results of the efficacy of using the instructional strategy of conceptual mapping for the same physical quantity and employ other interesting themes such as the efficacy of using computer-based conceptual mapping (Anderson-Inman & Horney, 1996; Kwon & Cifuentes, 2009) to students with learning disabilities. Regarding to the limitations of our research we could recommend to the teachers of physics and of science in general to adapt the use of conceptual mapping to the specific needs of the students with learning disabilities, e.g. to the students' preference about the orientation of the conceptual map. Finally we believe that in the case of future confirmation of our research findings the instructional strategy of conceptual mapping could help teachers of physics and of science in general (Rice et al., 1998) to organize and realize instructions that could satisfy not only the specific educational needs of the students with learning disabilities but of all the students as well.

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