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Graph/Chart Interpretation and Reading Comprehension as Critical Thinking Skills

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ABSTRACT: In contemporary academic literature and in many national curricula, there is a widespread acceptance that critical thinking should be an important dimension of Education. Teachers and researchers recognize the importance of developing students' critical thinking, but there are still great difficulties in defining and assessing critical-thinking skills. The multiple definitions of critical thinking indicate the need for further clarification of the concept. An important attempt for clarifying the concept was the "Delphi Report" (Facione, 1990a), where a qualitative research methodology, known as the Delphi Method, was used to develop a unified theoretical framework. The core critical-thinking skills identified in the "Delphi Report" as essential elements for workplace and educational success are targeted in the assessment tool entitled "The Test of Everyday Reasoning (TER)" (Facione, 2001). TER was translated from English into Greek and standardized for Greek population. TER has a series of questions engaging the participant in the interpretation and reasoning relating to the information provided in charts and graphs as well as to the accompanying them textual description. This paper presents the results from the standardization of TER in terms of graph/chart interpretation and reading comprehension skills. Implications for science education in Greece are also discussed.

KEYWORDS: Science education, Test of Everyday Reasoning (TER), visual literacy

Critical Thinking and Education

In current educational research, there is a widespread acceptance that critical thinking should be an important goal of education (Coles & Robinson, 1989; Ennis, 1987; Garnett & Tobin, 1984; Krusse & Preseissen, 1987; McGuinness & Nisbet, 1991; Meadows,1996; Paul, Binker, & Weil, 1995; Perkins, 1993). This acceptance is clearly stated in the European Union's "White Paper on Education and Training," where it is acknowledged that "School must not only allow for critical faculties to be developed at all levels among both pupils and teachers, but it must also encourage it" (European Union, 1995, p. 12). In Greece, the "Cross Thematic Curriculum Framework for Compulsory Education" and the new Curricula for elementary and secondary education clearly state that critical thinking is an important educational aim and that education should be committed[1] "...to provide opportunities for personal growth, nurturing in pupils personal qualities, such as, self-awareness, emotional health, critical thinking, and communication skills ... to assist the development of a critical attitude towards new information and communication technologies..." (p. 10), to "...develop the abilities of critical thinking and decision making on the basis of personal values and needs..." (p. 11), and to "... promote the development of critical thinking..." (p. 22). "Emphasis is placed on the development of critical thinking, the encouragement of collective effort and the acquisition of general knowledge" (p. 25). The "goals therefore are set to assist personal fulfillment through the development of a critical, analytic, synthetic, and creative attitude, which in turn will foster creative action on a personal and collective level" (p. 23).

The Definition and Assessment of Critical Thinking

Despite the need for developing student's critical thinking as it is proposed by academics, researchers and educators, there is a great difficulty in defining what critical thinking is, and consequently how to assess its development. The concepts advanced by Ennis (1987), Paul (1990), Lippman (1991), Siegel (1988), and Sternberg (1985a, 1985b, 1987) were prominent and influential. In the relevant literature, critical thinking is conceptualized according to where emphasis is put on each time. Nevertheless, these conceptualizations did not lead to a coherent view regarding critical-thinking theorizing, but rather they revealed its different and often contradictory aspects. Since critical thinking is conceptualized according to where emphasis is put on each time, there are many different approaches for assessing it – for example as logical fallacies (Dreyfus & Jungwirth 1980; Jungwirth, 1987; Jungwirth & Dreyfus 1990), as formal reasoning processes or skills (Blair & Johnson 1980; Lawson 1982; 1985; Obed, 1997), as scientific reasoning in general (Friedler, Nachmias, & Linn, 1990) etc.

A historical benchmark in conceptualizing critical thinking was the consensus of a panel of 46 leading theoreticians, teachers, and critical-thinking assessment specialists from several disciplines. This consensus statement is widely known as the "Delphi Report" (Facione, 1990a). This consensus described critical thinking as "purposeful, self-regulatory judgement, which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgement is based." (Facione, 1990a, p. 3).

Based on the Delphi conceptualization of critical thinking, a series of psychometric instruments have been developed, including the "Test of Everyday Reasoning" (TER). The construct validity of the TER is grounded on its correspondence to the Delphi conceptualization of critical thinking and on the results of related research indicating that TER and the "California Critical Thinking Skills Test" (CCTST) are strongly correlated, r=0,766 (Facione, 1990b, 1990c, 2001; Facione, Facione, Blohm, & Giancarlo, 2002;). "The TER was developed out of the CCTST" (Facione 2001, p. 14), a tool which has been used in

1. Translated from the Official Gazette issue B, nr 303/13-03-03 and issue B, nr 304/13-03-03 by members of the Greek National Pedagogical Institution.

scientific studies involving over 7900 students from 50 colleges and universities (Facione, Facione, Blohm, & Giancarlo, 2002, p. 5). Furthermore, TER is a product of longitudinal research and constant development from 1992 until today (Form A, Form B, Form, 2000). In the present research, TER was translated into Greek and was also standardized. The sample of this study consisted of 350 persons, including primary school students, secondary education students, and undergraduate students.

Graph/Chart Interpretation and Reading Comprehension

Literacy in the twenty-first century means educating for "the skills necessary to effectively construct and comfortably navigate multiplicity, to manipulate and critique information, representations, knowledge, and arguments in multiple media from a wide range of sources, and to use multiple expressive technologies including those offered by print, visual, and digital tools" (Williams, 2001, p. 22). Students are continuously exposed to a broad range of information, but educational systems seem to have failed to take seriously and to adequately respond to the fact that so much information exists in visual form. The traditional core of educational aims focusing on reading, writing, and arithmetic is considered incomplete without visual literacy that involves the interpretation of visual representations. All students, and not only during "composition, speech or language" classes, should be educated in visual rhetoric, and it is emphasized that a new paradigm is required, one that takes rhetorical education seriously and that recognizes education as multidisciplinary endeavor (Hill, 2004, p. 128). Science courses are not an exception knowing that are being saturated with visual information.

Specifically, the visualized data that a student faces in a science course is very diverse, ranging from realistic drawings and photographs (e.g., a photo of a pot with boiling water) to highly abstract representations (e.g., the structure of matter or a model of an atom). Furthermore, the visual representations carry critical information about the state of our world that may have significant social and economic implications (e.g., meteorology, weather map diagrams) (Lowe, 2000, 1996; Stokes, 2002; Gordin, & Pea, 1995; Glasgow, Narayanan, & Chandrasekaran, 1995; Iding, Klemm, Crosby, & Speitel, 2002; Iding, 2000). Baca (1990) created a program in order to facilitate the development of critical viewing and thinking skills in children and identified among other parameters of visual literacy "the use of visuals for the purposes of: communication; thinking; learning; constructing meaning; creative expression; aesthetic enjoyment" (p. 65). In this paper, visual literacy is conceptualized as an ability to understand (read) and use (write) images, and to think and learn visually, that is, in terms of images (Hortin, 1983). The results of this study concern only the visual literacy skills that are connected with critical-thinking skills (Analysis, Evaluation, Inference, Deductive and Inductive Reasoning) as implemented in the TER.

On the other hand, a large portion of the educational research concerning science education is devoted to the quality of the texts provided to the students within context of the different courses (Bakken, Mastropieri, & Scruggs, 1997; Breger, 1995; Casteel & Isom, 1994; Charron & De Onis, 1993; Craig & Yore, 1996;

Drake, Hemphill, & Chappel, 1996; Graesser, Leon, & Otero, 2002; Graesser, Olde, Whitten, Lu, & Craig, 2002; Mayer, 1995; Nelson, Smith, & Dodd, 1992; Neubert & Binko, 1992; Otero, 2002; Sutton, 2000). In contemporary approaches to science education, an important aim of the educational process is considered the student capacity "to distinguish theories from observations and to assess the level of certainty described to the claims advanced" (Millar & Osborne, 1998). This skill seems to be also crucial for the in-depth comprehension of a text. A sign that a scientific text is being understood is when the reader is able to generate inferences at a deeper level of representation revealing causal relations between events, processes, and consequences. However, it is often a challenge, not only for students, but also for adult readers to generate inferences, and to ask and to answer questions concerning the causal mechanisms. There are a number of reasons why that happens, such as, lack of knowledge, insufficient training or understanding of the causal mechanisms in scientific texts etc. (Graesser et al., 2002). The lack of understanding may be among the reasons why students are so often negatively predisposed towards science courses and science education (Dunbar, 1995). Furthermore, this lack of understanding often leads students and teachers to overemphasize the memorization of terminology, which can have results only in the factual and conceptual knowledge of students (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths, & Wittrock, 2001), but has little or no effect in what it is called "deep learning" and "critical thinking" (Graesser et al., 2002).

"Interpretation" is a basic skill for critical thinking according to the Delphi Report, where is defined as "to comprehend and express the meaning or significance of a wide variety of experiences, situations, data, events, judgements, conventions, beliefs, rules, procedures or criteria" (Facione, 1990a, p. 13), but there is also an evident interconnection between visual literacy, reading comprehension, and critical-thinking skills. In response to this interconnection, the basic description of TER clearly states that "an item may require the proper analysis or interpretation or the meaning of a sentence", as well as "interpreting and reasoning with the information provided in charts and graphs, a vital part of living and working in the world today" (Facione, 2001, p. 3). Thus, TER has a series of questions engaging the participant in the interpretation and reasoning based upon the information provided in charts and graphs, as well as the information provided in textual form. These skills are considered essential for critical thinking and problem solving in everyday situations and should be fostered in science education classes.

Research Questions and Methodology

During the field-test for the standardization of the Greek TER[2], it became clear that some questions were directly relevant with science teaching approaches. It

2. The standardization research followed the California Academic Press translation policies and led to an authorized translation of the "Test of Everyday Reasoning (TER)" for the Greek population [Insight Assessment/California Academic Press LLC, 217 La Cruz Avenue, Millbrae, CA 94030, http://www.insightassessment.com/] (Facione, 2000; Malamitsa, Kasoutas, & Kokkotas, 2008).

should be noted that connecting science teaching with TER was not initially included in our research plans. Furthermore, graph/chart interpretation and reading comprehension are not the main aim of TER. Consequently, the results of this paper do not represent, or account for, the standardization results of the Greek version of TER. They simply seem to be interesting in the general context of our work in connection with the development of critical-thinking in science education courses.

Concerning the necessary skills for the interpretation and reasoning with the information provided in charts and graphs, or the analysis and interpretation of the meaning of text, it was investigated to what extent these skills are developed among (a) sixth-grade primary school students, (b) first-grade secondary school students and (c) university students (undergraduates) in Greece. For answering the respective questions, the data collected during the standardization of TER was used. The data consisted of the questionnaire survey that were collected from the respective samples. In an effort to minimize the instrumentation effect, the researchers themselves administered the questionnaire to the students. Demographic data was also collected concerning students' gender, age, institution, name, and testing date. The field-test arranged for TER included 350 teenagers and adults (primary school students, secondary school students, and university students/undergraduates) from urban, suburban, and rural areas scattered all over Greece, in an effort to represent the regional diversity of Greece. Participants' age ranged from 11 to 26 years old. A random cluster sampling technique was used, concerning primary and secondary school students, where the schools served as clusters. The undergraduate students were students from the Faculty of Primary Education of the National and Kapodistrian University of Athens. The sample consisted of almost equal numbers of males and females (47,4% Males, 52,6% Females), except the university student sample, as indicated in Table 1, since the participating Faculty of Primary Education of the National and Kapodistrian University of Athens traditionally registers more females than males.

Table 1
The Sample of the Study

	Gender	Frequency	Percent (%)
Primary School	Male	126	50,2
	Female	125	49,8
	Total	251	100,0
Secondary School	Male	34	57,6
	Female	25	42,4
	Total	59	100,0
University	Male	6	15,0
	Female	34	85,0
	Total	40	100,0
Total	Male	166	47,4
	Female	184	52,6
	Total	350	100,0

The TER Instrument

TER is a 35-item multiple choice test, designed for use with adolescents and adults of all ages. TER is used to assess an individual's or group's reasoning and critical-thinking skills, to gather program evaluation on reasoning and critical thinking skills data, and to assess educational learning outcomes. TER provides six scores from an individual's completed test: (a) an overall score which ranges from 0 to 35 and represents the number of the items answered correctly, indicating the overall ability of critical thinking, (b) three sub-scales corresponding to the following skills: (i) "Analysis," ranging from 0 to 9, (ii) "Evaluation," ranging from 0 to 11, (iii) "Inference," ranging from 0 to 15, and (c) two additional sub-scales, which follow a rather traditional conceptualization for critical thinking: (i) "Deductive Reasoning," ranging from 0 to 19 and (ii) "Inductive Reasoning," ranging from 0 to 16 (Facione, 2001, p. 11-12, 25). Each of the items of TER is assigned to only one of the three sub-scales: "Analysis", "Evaluation" or "Inference." The same items are reclassified to only one of the two other sub-scales: "Deductive Reasoning" or "Inductive Reasoning." The items of TER are multiple choice questions designed to be scored dichotomously[3] with one correct answer and three or four distractors, which represent frequently made errors, or are designed to attract the attention of those who exhibit what are known as dispositional failures in reasoning (Engel, 1999). They range from simple to more complex, and involve analysis, interpretation, and reasoning upon the information provided in charts and graphs as well as texts. TER is appropriate for persons in late childhood, adolescent, and adult populations, because the only background knowledge that is required relates to what is readily achievable through normal maturation and elementary schooling.

A selection of 20 questions from a total of 35 questions of TER was included in the analysis. The questions were grouped in different categories. The first group of questions (questions 5, 11, 12, 13, 15, 16, 22, 23, and 24) involved graph/chart interpretation skills. The second group of questions (questions 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, and 35) involved reading comprehension skills. Two composite variables were created, one for "Graph/Chart Interpretation Score," ranging from 0-9 for the first group of questions, and one for "Reading Comprehension Score," ranging from 0-11 for the second group of questions. Correctly answering TER questions also involves the use of other critical-thinking skills (analysis, evaluation, inference etc.). TER is not however designed for giving results concerning graph/chart interpretation skills and reading comprehension skills, although they are mentioned as key skills for completing it successfully (Facione, 2001).

Data Analysis and Results

The primary school students' median for "Graph/Chart Interpretation Score" was 3 showing an insufficient development of interpretation and reasoning with the information provided in charts and graphs (68,9% of primary school students answered correctly 1-3 questions from the 9 available). Similarly, the secondary

3. Missing items are considered as wrong answers.

school students' median for "Graph/Chart Interpretation Score" was also 3 (64,4% of secondary school students answered correctly to 1-3 questions), while university students' median for "Graph/Chart Interpretation Score" was 7 (67,5% of undergraduates answered correctly to 1-7 questions) indicating that they better developed this ability. Nevertheless, university students are usually selected through the national examination process for entry in university and they do not represent the general population of this age. These results are represented in Figure 1.

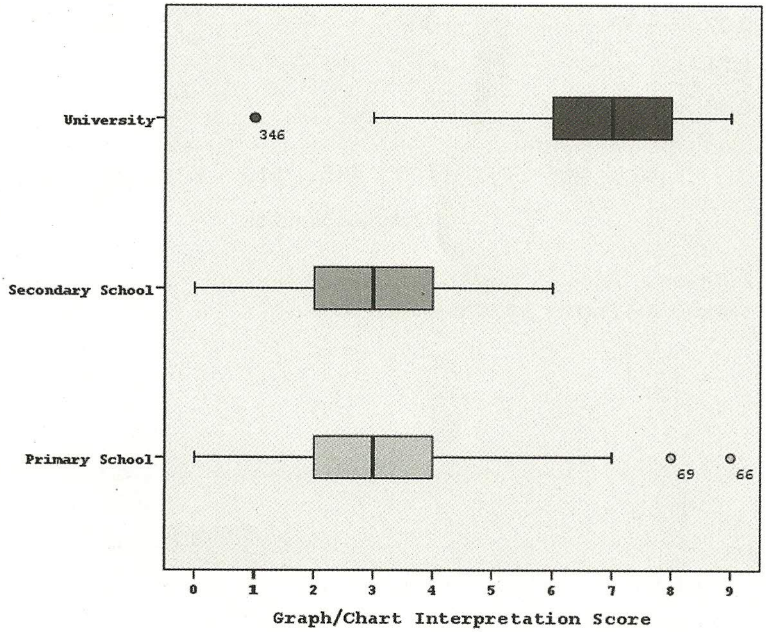

Figure 1. Box-Plot of "Graph/Chart Interpretation Score" for the Three Age Groups (Students of Primary School, Secondary School and University)

The transition from primary to secondary school also indicated a differentiation in the results with a small recess to some questions for the secondary school students, as indicated in Figure 2. It seems that secondary school students, while relatively close in age with upper primary school students, experienced the transition to secondary school as a shock (Cotterell, 1986; Hargreaves, Earl, & Ryan, 1996; Power & Cotterell, 1979; Simmons, Burgeson, Carlton-Ford, & Blyth, 1987; Kakavoulis, 1984). It may also possible that students in primary education are more engaged with visual literacy skills than in secondary education that is more theoretically oriented (Kokkotas, 2003).

In terms of reading comprehension, the primary school students' median for "Reading Comprehension Score" was 3 indicating a lack in the development in analysing and interpreting texts (57,8% of primary school students answered correctly to 1-3 questions from 11 available). Similarly, the secondary school

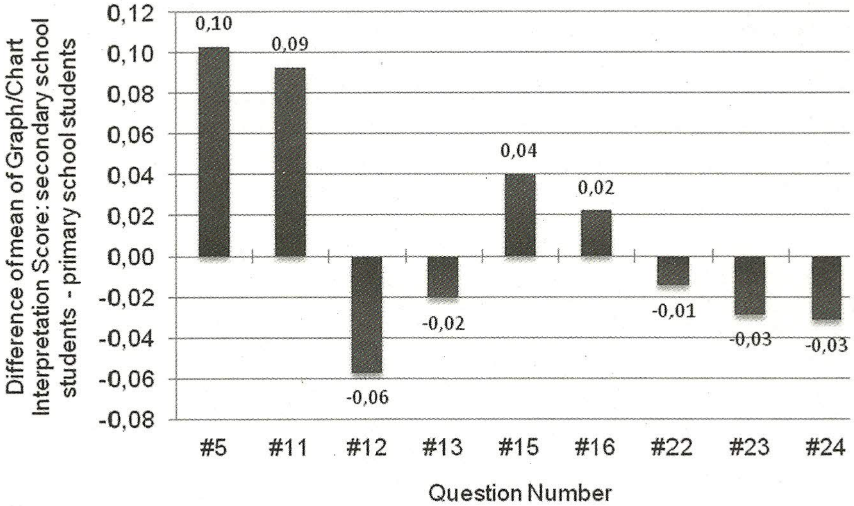

Figure 2. Difference of Mean of "Graph/Chart Interpretation Score" between Secondary School Students and Primary School Students per Item.

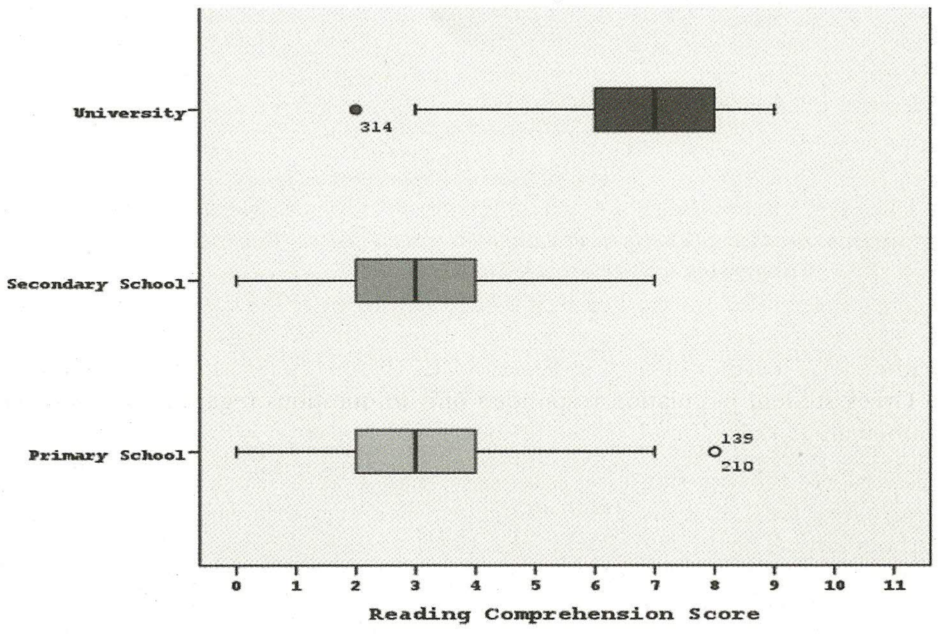

Figure 3. Box-plot of "Reading Comprehension Score" for the Three Age Groups (Students of Primary School, Secondary School and University)

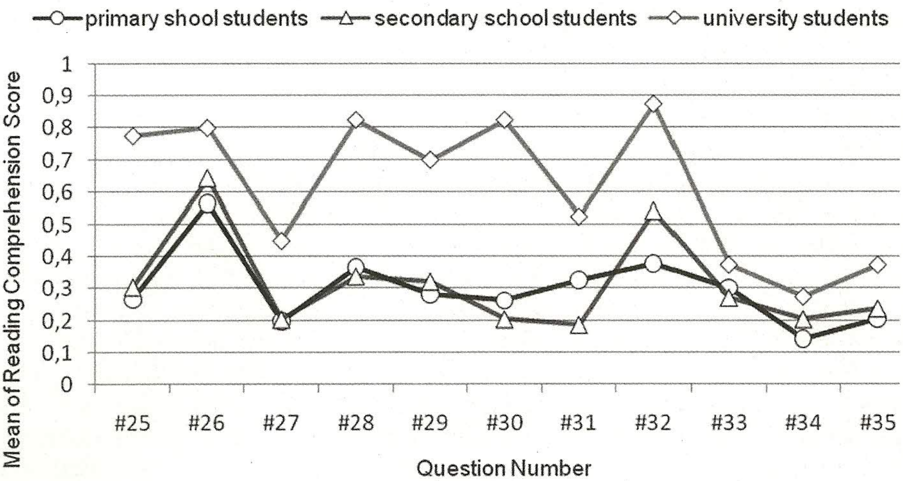

Figure 4. Mean of "Reading Comprehension Score" for the Three Age Groups (Students of Primary School, Secondary School and University) per Item.

students' median for "Reading Comprehension Score" was also 3 (54,2% of secondary school students answered correctly to 1-3 questions). Finally, the university students' median for "Reading Comprehension Score" was 7 (60% of undergraduates answered correctly to 1-7 questions). The results in terms of "Reading Comprehension" are represented in Figure 3, while Figure 4 indicates the mean of "Reading Comprehension Score" for the three age groups.

Conclusions / Discussion

The data analysis points to an inadequate development of the investigated skills (graph/chart interpretation, reading comprehension, critical thinking skills) regarding the samples of this study. This finding is in accordance with the results of the Program for International Student Assessment (PISA) 2003 (OECD, 2004, p. 91), which ranked Greece as 31st among 40 participating countries in mathematics. Furthermore, it indicated (OECD, 2004, p. 90) that more than $^1/_3$ of Greek student population responded only to questions regarding the simplest mathematical skills (Level 1), while they could not cope with more demanding questions (Level 2). These skills were investigated using questions similar to those of TER, which were analysed in the present study. Concerning reading comprehension skills, Greece was quite lower the average (OECD, 2004; 2005), although the Greek educational system is theoretically-oriented and, as such, requires the development of reading comprehension skills (Kokkotas, 2003).

In the context of this study, it was expected that the theoretically-oriented Greek educational system would be reflected in the results with improved scores regarding the reading comprehension skills. Nevertheless, the data analysis revealed low scores for "Graph/Chart Interpretation" and "Reading Comprehension" skills. This seems to indicate a strong relationship between the examined interpretation skills and critical-thinking skills. It seems that the development of visual literacy and reading comprehension skills should be cultivated in connection with critical thinking skills. More specifically "Analysis," "Evaluation," and "Inference," the critical-thinking skills measured by TER, seem to be affecting the interpretation of charts and graphs as well as texts. Further research is required before finalizing any conclusions concerning this relationship.

Thus, science and mathematics teaching in Greek schools seems to require extensive changes. The need of an improved language use in science and mathematics courses, in a way emphasizing its role as a semiotic and culturally defined tool (Vygotsky, 1978; Wertsch, 1991), is clearly demonstrated. Furthermore, the inclusion of graphs and charts during the courses should focus on understanding and interpretation, as essential components of science and mathematics education. However, this aspect of learning is very often neglected by teachers who either generally assume that pictures are self-explanatory and always function to make their subject matter easier, or they lack a better appreciation for the demand of science/mathematics graphs/charts and the knowledge of teaching strategies that can foster the development of students' visual literacy. Science teacher education should cover this topic and offer the required training and support to science teachers in Greece. Unfortunately, the resources for helping teachers to develop visual literacy are extremely limited (Lowe, 2000). Research indicates that student understanding is essentially enhanced when teachers follow constructivist learning approaches (Black & Lucas 1993; Salomon, & Perkins, 1998), because these approaches contribute to enhanced student knowledge and comprehension. Thus, teachers support meaning making, and "scaffold" new forms of students' thinking and reasoning.

The results concerning the items 15 and 16 (Facione, 2000, p. 6) are extremely important, because these items relate to "survival skills" with which every student should be equipped. These items are based on a diagram that illustrates the standard evacuation procedure for hotel clients during fire alarm. The means for these questions were low in comparison to their importance, since even 33% of university students failed to correctly answer those questions. These results are indicative of the need to seriously consider the development of students' scientific literacy (Aikenhead, 2002; Hurd, 1998; Millar & Osborne, 1998), by adopting learning strategies contributing to meaningful learning (Ausubel, 1963; Lave & Wenger, 1991; McGilly, 1994).

The use of TER (measures specific critical thinking and reasoning skills) in order to measure "graph/chart interpretation" and "reading comprehension" constitutes a limitation of the present study. Nevertheless, it was assumed that they could sufficiently be used so as to draw some useful conclusions concerning science education in Greece. The texts used for assessing the "reading comprehension score" were not initially written in Greek, and this may have affected the results, despite the careful efforts to translate the texts taking into consideration possible cultural biases. The findings of the study are considered as indicating the lack of sufficient research in Greece concerning the examined abilities, since the PISA of OECD results left the Greek educational system totally unaffected. Obviously, more research is needed for encouraging and guiding a new educational reform grounded on international standards.

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