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Alternative ideas about concepts of physics, a timelessly valuable tool for physics education

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ABSTRACT

Alternative ideas, defined as faulty or incomplete understandings of scientific concepts, are prevalent among students across all age groups and educational levels. In physics, misconceptions often arise from everyday experiences, intuitive reasoning, and oversimplified analogies. The persistence of misconceptions in students' understanding of physics concepts can hinder learning and compromise scientific literacy. Consequently, research on alternative ideas has emerged as a critical aspect of science education, informing teaching strategies and curriculum development. At the beginning of this research, a brief historical report is presented on how research began in the field of the didactic of physics. Then a report is presented with research that led to the identification of alternative ideas at various levels of education. Finally, modern studies on the alternative ideas on the concepts of physics and their conclusions are presented and highlight the timeless necessity of the scientific research of alternative ideas and students' perceptions of physics concepts, proving how valuable it is for physics education in the search for this topic.

Keywords: alternative ideas, misconceptions, physics education

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INTRODUCTION

It is widely accepted that students develop ideas and understandings about the concepts and principles of physics. Children begin to form various ideas about how the world works through interactions with the environment (cultural, social, and technological), social contact, and language. They use these perceptions to explain what they perceive happening around them. The idea of investigating children's perceptions of science is very old. From the beginning of the 1930s, Piaget (1951, 1960, 1970) used the interview method to investigate the child's perceptions of "physical causality", of the "world", of "motion, and speed" and presented a large number of ideas on many topics in the Sciences. In the international bibliography 1967, the term misconceptions about students are mentioned in a physics sense (Burge 1967). However, about 45 years ago, researchers Driver and Easley (1978) began systematically investigating children's ideas about science concepts and phenomena when they linked science object learning to their mental development. These perceptions bear various names, depending on the time and manner in which they were created in children. Thus, they are distinguished as perceptions-interpretations of the various phenomena children have formed by themselves at a young age, usually without the teacher's intervention. They are called preconceptions, a term proposed by Ausubel (1968) and repeated by Novak (1977). These early conceptions later, at an older age and despite the teacher's intervention, may not develop into scientific knowledge, so the term misconception was used (Helm, 1980; Hills, 1989). Other researchers reused the term in the following decade (Hammer, 1996; Rowell et al., 1990). This term in the literature was admittedly criticized due to its negative meaning. Duit (1993) characteristically notes that "this term gives the impression that students' ideas are wrong and should be eliminated". Also have been used in literature terms such as framework, alternative framework (Driver & Easley, 1978; Rowlands et al., 1999; Watts, 1983), and conceptual framework (Driver & Erickson, 1983; Engel-Clough & Driver, 1986). A combination of the above terms is often used, such as alternative conceptions (Osborne & Gilbert, 1980b). Also, of similar content to the last terms are less used terms like children's science (Gilbert et al., 1982), minitheories (Claxton, 1993), or mental models (Vosniadou, 1991, 1994). This study uses "ideas or perceptions" or "alternative ideas." The term "idea" rather than "concept" separates students' ideas from scientifically defined concepts.

These students' ideas are perceptions that are not due to their bad information but to how they perceive what is happening around them, how they observe, and how they come to conclusions. They grow in their attempt to make sense of the world in which they live. Starting from their experiences, they look for similarities and differences to observe phenomena and events to create relational structures. Many cognitive psychologists (Barlett, 1932; Rumelhart, 1975) were concerned with how cognition can interpret experience many years ago. Marshal (1995) and Rumelhart (1984) consider that knowledge is organized into complex representations that control information encoding, storage, and retrieval. This fact suggests that students explain physics phenomena using what they think they know, generalizing their personal experiences. For example, students (Halloun & Hestenes, 1985a) often associate motion with objects' tendency to stop. Perhaps, they do not understand the concept of friction (they know it as a word) or the laws of physics that describe it (they generally do not), but they feel very familiar with the fact that if you push a heavy box, it stops almost as soon as you stop pushing it. Thus, children gather evidence and build models to interpret events and make predictions. Ideas are constructed based on direct experience with the physical world and social interactions, so they are all actively constructed and inferential. That is, it was found that students do not understand the world directly but through the formation of ideas-perceptions, mental representations, and mental models. These mental representations are images of objects and events when these are absent and usually differ from the scientific point of view. Usually, these perceptions are "wrong." Thus, students gather evidence and build models to interpret events and make predictions. These mental models help students to explain some causes and represent more easily specific situations. Also, they help them answer everyday questions inside or outside of school.

Students' ideas are also created by the influence of adults' perceptions, communication, contacts, and discussions with other students, school textbooks, and teaching. Even colloquial language plays an important role in their formation, which often differs from scientific language (Kokkotas et al., 1995). For example, the expressions "turn on the light" or "turn off the light" are used in colloquial speech. It is known, however, that when the light is turned on, the electrical circuit closes, and the child, in his attempt to explain a scientific sentence, will interpret it with words that he uses in his daily life, which are different from the scientific ones (Kokkotas et al., 1999). This results in him not giving the correct interpretation that the teacher expects to hear. Often to interpret phenomena, students use terms they have heard either at school from teachers or other peers or not. This raises the question of whether students really understand the meaning of these terms and whether they use them like teachers and scientists. Dekkers and Thijs (1998) studied students' understanding of force in mechanics. They concluded that the meanings that students attribute to words differ from those of scientists and pointed out that this is a conceptual problem. Students' ideas have more general validity and some change with their development. However, there are also cases, where many students maintain the same alternative ideas (Kotsis, 2002), and one reason that justifies this maintenance is their lifestyle. For students, their ideas are sufficient since they explain natural phenomena to them, even though they often conflict with the opinions of adults. A characteristic of these ideas is that they were formed over many years before students were taught scientific concepts. Moreover, these ideas are found in students and graduates of secondary education. Of course, the percentage of those with weaknesses in understanding the concepts decreases as the "level" rises, but it is not eliminated even among physics teachers (Bernhard, 2000). Children's perceptions often differ from the scientific standard presented in school textbooks. However, these concepts are useful and logical (Kokkotas, 1989) because they are the springboard for interpreting the relevant phenomena. Students often need to learn more about the phenomena to give contradictory explanations and interpretations of the phenomena. Also, a student can have different perceptions of a phenomenon. Furthermore, this happens because using different arguments leads students to opposite predictions for equivalent situations.

ALTERNATIVE IDEAS & PHYSICS EDUCATION

Recording of students' alternative ideas (Trowbridge & McDermott, 1980) and the search for the causes that caused them occupied more than four decades for the researchers of the didactics of sciences. Result of this research is that the initial personal knowledge of the students, that is, their ideas and opinions, greatly influence learning. Students use their ideas to make sense of what they see and hear and, through them, interpret the new knowledge they acquire. The following paragraph presents a brief overview of the extensive literature on students' ideas and their conceptual change. A student can achieve conceptual change by integrating scientific knowledge with his original personal knowledge. Results of educational research show that most students still need to achieve this. The way of teaching, student's attention and interest, motivation, and positive or negative attitude toward the science course affect the learning outcome (Pintrich et al., 1993). Very often, after the teaching, students return to their original knowledge or use a mixture of scientific views and personal knowledge.

The general conclusion of the international literature, which emerged from research on the teaching of sciences, is that teachers must consider students' perceptions. Considering students' perceptions is one strategy that enables teachers to tailor instruction to their students. The result of the long-term research effort is to have categorized the alternative ideas and perceptions of the students (Driver et al., 1985) into a multitude of concepts and phenomena of the sciences. Equal attention was also given to how children think (Driver & Bell, 1986; Koumaras et al., 1994) and how they represent concepts (Osborne & Gilbert, 1979, 1980a, 1980b). Thus, the constructive teaching model was proposed for science teaching. The advantage of the constructivist model is that the teacher, knowing the students' misconceptions, uses appropriate teaching strategies to build knowledge (Driver et al., 1985) and to bring about cognitive conflict and conceptual change (Vosniadou, 1994). Therefore, the teacher must include the students' alternative ideas to achieve the conceptual change. Research results show that more than traditional, formal teacher-centered instruction is needed to achieve conceptual change (Gunstone, 1987; Hammer, 1996; Vosniadou & Ioannides, 1998). Alternative ideas can be created during teaching due to a need for more communication between students and teachers. The purpose of teacher is to convey ideas to students by translating them into words, figures, and equations, where students often attribute a meaning that is different from what teacher wanted to convey to them. This is reinforced by the fact that students combine what they hear with what they already know, making it possible to give different interpretations. Thus, students' ideas affect process of learning concepts and resist changes that teaching tries to achieve.

ALTERNATIVE IDEAS OF SECONDARY SCHOOL & UNIVERSITY STUDENTS

In the beginning, alternative ideas were studied for primary education. Still, in many cases, the ideas children use are entrenched and not eradicated by teaching at this level of education. They may persist even after reaching adulthood. The students' primary-intuitive perceptions decisively intervene in the learning process and pose obstacles and difficulties in understanding scientific concepts. This is demonstrated by the difficulties encountered in solving physics problems (Reif, 1981) in secondary education. Most students, even those considered "good," show weaknesses in handling the basic concepts of physics and developing the mechanisms of sound scientific thinking, even after years of instruction. Usually, their knowledge needs to be structured (Van Heuvelen, 1991a). Still, it is based on memorizing independent facts, procedures, and equations, which could be better organized for use or application (Van Heuvelen, 1991b). Students' passive knowledge results in serious difficulties interpreting natural phenomena and solving problems. The various problems are treated as systems of springs, inclined planes, threads, or pulleys and not as systems operating based on the principles of physics. On the other hand, many students who cannot qualitatively study simple physical phenomena can solve physics problems by manipulating complex mathematical relationships and calculations (McMillan III & Swadener, 1991). Mazur (1997) typically reports that his physics students "had memorized equations and problem-solving techniques but performed poorly on tests of conceptual understanding." The situation is similar in Greece, where the education of secondary school students is mainly focused on memorizing definitions and the standardized algebraic application of the various relations (types) in physics problems or exercises (Jimoyiannis, 1999a, 1999). Usually, students need help explaining their process or methodology to solve a problem. In most cases, they need to correctly look for combinations of formulas or equations related or not to the problem to be solved. Detailed research by many researchers in teaching physics (Halloun & Hestenes, 1985b; Pfundt & Duit, 2000; Redish & Steinberg, 1999; Trowbridge & McDermott, 1980, 1981) has shown that traditional physics teaching does not work well for a large proportion of secondary school students. Many students dislike physics, others see it as irrelevant to their personal lives or long-term goals, and others need to acquire the skills that allow them to continue to succeed in advanced science courses. Even at this age, students perceive science as incompatible (Jimoyiannis & Komis, 2003). Students' perceptions of natural phenomena even help them to interpret them while referring to various natural phenomena by alternative names, instinctive understandings, and non-scientific understandings. Even after secondary education, students' perceptions of resistance to teaching persist (Driver, 1989; Gunstone, 1987; Hung & Jonassen, 2006; McDermott & Redish, 1999; Reif, 1995; Senocak et al., 2007). Halloun and Hestenes (1985a) have shown that students can often solve complex problems without having a good understanding of physics. The secondary school student may know the information. Still, it is inert, and he cannot use it, except in very limited, almost pre-programmed situations, according to how learning and assessment are done in high school. Even though the student learns to solve many problems using equations (Saul, 1998), he still needs to understand the concepts he uses. Redish (1994) aptly observes that rapid technological changes are bringing about radical changes in science teaching and "we should focus less on what we teach and more on what our students learn".

Although since the late 1970s, learning has shifted from the classical, traditional model to a more constructivist perspective, which emphasizes the active role of learning processes (Duit & Treagust, 1998; Mason, 2003), it seems that there are still problems in learning concepts and phenomena of physics. Research over the past forty years at an international level (Brown, 1989; Clement, 1982; Viennot, 1979) conducted on secondary school students has shown that students still have serious misconceptions about physics concepts and phenomena. Indicatively, the research on the ideas, perceptions, and difficulties of pupils and students regarding the concepts of kinematics (Trowbridge & McDermott, 1980, 1981), dynamics (Clement, 1982; Enderstein & Spango, 1996; Galili & Bar, 1992; Palmer 1997), shots (Halloun & Hestenes, 1985a; Whitaker, 1983), energy (Goldring & Osborne 1994; Lawson & McDermott, 1987), momentum (Graham & Berry, 1996), electricity (Metioui et al., 1996; Shipstone et al., 1988), optics (Ambrose et al., 1999; Galili, 1996), thermodynamics (Johnstone et al., 1977; Kesidou & Duit, 1993), the structure of matter (Griffiths & Preston, 1992), and wave (Maurines, 1992). A valuable list of the international literature can be found in McDermott and Redish's (1999) paper. In the paper of Koumaras et al. (1990), there is an overview of secondary school students' perceptions of electrical circuits. Stylos et al. (2007, 2008) bring back the fact that students who graduate from high school, although they have been taught the subject of physics many times during their studies, still have a significant degree of misconceptions in concepts and phenomena of physics.

It is also known today, from documented research, that even university students show serious problems in understanding basic laws of physics and applying them to real situations (Appleton, 1995; Guisasola et al., 2002; Gustafson & Rowell, 1995; Itza-Ortiz et al., 2004; Kelly, 2000; Libarkin et al., 2005; Maloney et al., 2001; Thong & Gunstone, 2007; Yalcin et al., 2008). Research for pre-service teachers (Kotsis, 2002) and physics department students (Petrochilou et al., 2006, 2007) reach similar conclusions. Recordings of the perceptions of students of pedagogical departments in the Greek area have been made for various areas of physics, such as thermal phenomena (Karanikas, 1994), the forces of weight, friction, and air resistance (Kotsis, 2002), where the power has demonstrated them, even at this level of education. Halloun (1998) observes that "even students who choose to take physics are unable to distinguish between the various concepts as well as apply them to real-world situations". Students must often be aware that they use different concepts in different contexts. Their initial concepts are often retained long after the scientific knowledge is learned, which they forget after exams (Brass et al., 2003).

TEACHERS ALSO HAVE ALTERNATIVE IDEAS

Student perceptions have temporal validity, although some vary with student development or instructional influence (Gilbert et al., 1982). The literature has recorded that many perceptions become stable, and their power is strong, even when the student reaches adulthood. Students continue to bring alternative ideas after high school, which is a problem for prospective elementary teachers (Schoon & Boone, 1998). The teacher, as he was previously a student, is likely to transfer perceptions of the concepts, which he still needs to change in his subsequent social and educational path. Teachers carry the academic knowledge acquired during their studies and specific values, "beliefs," and perceptions about science, science teaching, the teachers themselves, and their experience of their long-term presence in the educational system (Mellado, 1998). A major cause of teachers' difficulty accepting constructivist positions on teaching and learning is primarily primary school teachers' knowledge of science content. When they have insufficient knowledge of the scientific content to be taught, they do not teach with enthusiasm and self-confidence, and they do not feel capable of implementing innovative activities (De Jong et al., 1998, Halkia, 2003). They fail to understand the difficulties that students encounter in learning specific content, they fail to assess the importance of an experimental activity and to handle it properly (McDermott, 1990).

Research results conducted to record teachers' opinions about natural phenomena/concepts show that teachers have opinions different from those scientifically accepted (Bysdikian & Psillos, 1998; Ginns & Watters, 1995; Webb, 1992). For example, research on teachers has shown that they need help understanding the concept of power, e.g., they do not consider friction and weight to be forced (Summers, 1992).

Problems in understanding the concept of light and the formation of shadow have been recorded, e.g., the shadow is treated as a hidden property of light (Cliridis, 1998). It has been found that there is complexity in teachers' perceptions of science teaching (Spyrtou et al., 2003). It is noteworthy that the alternative views of the teachers are, in many cases, similar to those of the students (Spyrtou, 1998). A representative example from the area of electricity is the case of the alternative perception, "more current enters and fewer exits from a lamp", which has been recorded in students aged 11-15 years and in department of primary education students (Koumaras, 1989) and in practicing teachers (Webb, 1992).

However, teachers much more easily than students understand the inadequacy of their knowledge of the science content, which seems to positively activate their disposition to improve knowledge (Cochran & Jones, 1998). For this reason, it is argued that teacher education programs could be more effective in teaching science content if they allowed teachers to realize their understanding of problems in the content (Kruger, 1990).

In the late decades, systematic research has been carried out on teachers' knowledge, their nature, how they are built and reconstructed, and how they affect the teaching practice. Especially in the sciences, research on student ideas has dominated the past decade and seems to drive and influence research on teachers' ideas and perceptions (Cochran & Jones, 1998). It is even argued that many corrective changes attempted in the past in education failed because the teachers' existing knowledge and beliefs were not considered (Molohidis, 2005; van Driel et al., 2001). It has often been recorded that teachers have the same perceptions as their students (Cochran & Jones, 1998; De Jong et al., 1998; Smith & Neale, 1989; Spyrtou, 2002). However, they exist somewhat and are formulated with a scientific cloak (either using terminology or through complex reasoning) (Cochran & Jones, 1998). According to Wandersee et al. (1994), this should not be surprising because the limited science programs justify the existence and sometimes the persistence of teachers in alternative conceptions during their studies. Gess-Newsome (1999) proves that the structure of teachers' subject matter knowledge is unclear and fragmented. In some cases, it has been noted that primary school teachers cannot coherently teach the subject matter. Kotsis et al. (2008) found that primary education teachers have a gradation in their understanding of the various concepts of physics they are asked to teach. Typically, teachers mix scientific and non-scientific ideas to create their worldviews and models of natural phenomena.

Alternative ideas and mixed mental models have been identified for various biology, chemistry, and physics topics. Many primary school teachers need to gain knowledge of basic scientific concepts (keys), as a result of which they show resistance to changing their perceptions. Moreover, in cases with some familiarity with the basic concepts but differ from the scientific point of view, the need for more understanding of the concepts affects their trust in science. Some of the reasons that teachers have knowledge and opinion contrary to the scientific ones are the way they have been taught (Pardhan & Bano, 2001), textbooks, intuitive and direct observations of everyday life events, the use of terms in everyday life language (energy, force, electricity) and the lack of relevant tangible and conceptual experiences to connect with abstractions to construct conceptual schemas (Novak, 1995).

Teachers use strategies and techniques to combine their knowledge of the subject, experience, or personal opinion on effective teaching methodology and institutionalized activities to achieve the goals. If, in the course of teaching, students' perceptions must change towards those accepted by science, then their negotiation with the teacher is necessary (Driver et al., 1998). However, if the teacher has alternative ideas, then it means that these will, in turn, affect the students' perceptions and the classroom climate. In contrast to the students' counterparts, the teachers' alternative perceptions are neither stated nor implied, but they are a focal point in planning activities. In the greater majority (Molohidis, 2005), the set of alternative perceptions of teachers is a genuine subset of the alternative perceptions of students. The incomplete knowledge of the teaching subject, as well as the non-identification of their views with the corresponding scientific ones (Schoon & Boone, 1998), affects various processes (organization of activities, presentation of the content, nature of the questions, understanding of the students' pre-existing ideas) during science teaching (Kallery & Psillos, 2001).

There are two reasons why the teacher needs to understand the knowledge and way of thinking about the surrounding world his students present in the classroom. First, it helps him understand what mistakes students usually make and how they misinterpret what they hear from him and what they read. He can thus creatively use these "mistakes" to design new and improved teaching. Understanding students' thinking is especially helpful in helping to answer their questions appropriately. It is very easy to misinterpret a student's question as more complex than it really is. Second, students present to the class their understandings upon which they will build their future knowledge. Since new knowledge is built only by expanding and modifying the existing mental schema, students' existing knowledge is the raw material to work with in order to help them acquire a more correct and scientific cognitive structure (Elby, 2001; Hammer, 2000). However, for the teacher to be able to manage the perceptions of his students, a necessary condition is for him to manage his own alternative perceptions successfully. However, research data to date suggests otherwise.

Many students' alternative understandings of basic concepts were observed to have arisen due to their teaching. Adeniyi (1985) found that the teacher was inadequate in dealing with these perceptions and often expressed them. It was found that the teacher did not know how to deal with his students' perceptions, resorting to the authority of the "right" answer to cover up his weaknesses. Fleury and Bentley (1991) report that only some primary school teachers have correctly understood the content of the sciences they will teach in primary school, and it is necessary to deal with their alternative perceptions.

Arons (1996) has repeatedly found, both through research and as a result of his many years of experience in teacher education and training, that teachers needed more understanding of the concepts and material they would teach. The development of concepts in the teachers' thinking was sometimes almost at the same level as the students they had to teach. He also believes that this fact is one of the most important reasons why ambitious curricula and new educational materials have failed in their implementation.

It should also be pointed out that an obstacle is not only the teacher's perceptions of the content of the concepts but also the views on the role of their students' previous perceptions (Pine et al., 2001; Spyrtou, 1995). It has even been argued that good content knowledge is essential for better teaching (Summers, 1992). The teachers, however, insist on considering themselves as the main source of the correct message that must be transmitted to the students, who are uniform receivers of this message (Spyrtou, 1995).

From the above, it follows that the students' alternative ideas, which have been formed before and outside the school, are often reinforced in the classroom by the corresponding perceptions of their teachers. The durability and extension of alternative perceptions to students and teachers is another element that makes their investigation and management an important issue for educational research.

In mechanics, Mohapatra and Bhattacharyya (1989), surveying the views of primary and secondary school teachers, sought the forces exerted on two bodies of equal mass moving, in frictionless conditions, at different constant speeds, namely, one with twice the speed of the other. Essentially, the alternative view of the existence of a force of the same direction as the movement, as its cause, is detected. According to the survey, most of teachers (75%) believed in a linear force, and more than half attribute a similar measure to it. In another research (Kruger et al., 1992), a non-separation of the concept of energy from the concept of power has been recorded among teachers as well. Elementary teachers consider energy to be a force hidden within a substance and waiting to be used. The identification or confusion of force with energy is attributed to the two strong views of teachers about the nature of energy, namely that energy has to do with life and with movement. Educators strongly associate both force and energy with movement. On the one hand, they believe that a body can move when a force is applied to it. Energy is considered to be "seen" by movement. Associating both concepts with movement makes it difficult for teachers to distinguish between them. Furthermore, the view that energy is a hidden " life force " reinforces this problem. The energetic changes of everyday life are irreversible (Solomon, 1982) by both teachers and students. The fact that students and teachers believe that energy is exhausted and not conserved once used, shows that the 2nd law of thermodynamics is intuitively more understandable than the principle of energy conservation. This is mainly due to everyday life in which all the processes that occur have a certain direction: water flows downwards to fill lakes and reservoirs, warmer bodies cool colder ones, etc.

In the area of electricity, Webb (1992), in an Australian survey of 36 3rd year teacher candidates and 21 current teachers, sought their views on the flow of electricity in a simple circuit. A prevailing view was that some percentage of the current was "lost" in the bulb, which agrees with the ideas of 302 11-year-old students in an earlier study by Osborne (1983) (whose ideas were used by Webb, 1992). Similar perceptions were recorded by Heller (1987). Heller (1987) investigated the views of high school teachers and professors on electrical circuits. Most of the 14 respondents supported a "series" model of an electrical circuit: a fixed electric current leaves the battery and reaches the lamp. The lamp uses electricity, it illuminates, and its brightness depends on the amount of electricity. The existence of a second lamp indicates the use of less current (since they both use it) and, therefore, a smaller (but equal) light output.

Other research by Stocklmayer and Treagust (1996) focuses on the images and metaphors students and teachers use when thinking about electrical phenomena. When students come into contact with electricity in their education, they need to understand the mechanistic model for current, where electrons are like balls moving through wires. Most teachers use the same model. There are several works on the concepts of electric circuits (Barbas & Psillos, 1997; Koumaras, 1989; Psillos et al., 1988). A difficulty that exists is the impossibility for both primary education teachers and future teachers (students) to think based on a model. The very common idea is that the electrical source is a constant current source.

Smith (1987), in the field of optics, recorded teachers' views and interpretations of the nature of light similar to those recorded in students (Feher & Rice, 1988; Rice & Feher, 1987). In particular, in interviews with teachers, it was found that they use a model for light. While it "illuminates" objects, it does not necessarily "reach" the sensory recording organ, the eye. Also, they did not consider that light travels from the source in all directions and therefore had difficulty in satisfactorily interpreting various phenomena, such as the creation of shadow and the creation of colors.

In the field of heat–Karanikas (1995)–recorded the use of the concept of "temperature" instead of the concept of "warmth" in students of the department of education. Thus, the view that temperature is something that is exchanged, transferred, or mixed was recorded. Heat is considered a form of energy, but it can be stored (and not transformed), i.e., it has substance properties (Kotsis et al., 2023; Stylos & Kotsis, 2023a; Stylos et al., 2021). The above is an indirect acceptance of the "thermal fluid" found mostly at young ages (Driver et al., 1985; Ravanis, 1988).

In the cognitive area of the physics of fuids (Molochidis, 2005), he observes that the students of the pedagogical departments present difficulties in distinguishing "pressure" and "pressure force," with the result that, in a large percentage, they attribute to the concept of pressure characteristics of force and recognize greater pressure in the bottom of a wide container rather than the bottom of a narrow container. Also, they maintain a rather phenomenological, rather than scientific, point of view in matters of floating bodies; a body floating in a liquid receives more buoyancy as it protrudes from the liquid. Karanikas and Karyotoglou (1996), in previous research conducted on students but also on fourth-year primary education department students and pre-service teachers, find that the majority of students and a large percentage of students are unaware of the factors on which buoyancy depends (i.e., on volume immersed body and the density of the liquid in which it is immersed) and want it to depend on the weight, the total volume of the liquid in which it is immersed, on the position of the body in relation to the surface of the liquid. Similar findings are found for young students in the research by Koumaras et al. (1997). In a project given to students in education departments and asked to compare the buoyancy experienced by a body in a liquid and the weight of the body, the students used causal reasoning, where the oriented effect requires a cause of the same orientation. So, when the body was suspended in the liquid, the students answered that the buoyancy was equal to the weight "because the body is in the middle of the liquid". When the body protruded slightly from the surface of the liquid, the university students answered that buoyancy is greater than the weight "because if it were less than or equal to the weight, the body would sink or stay in the middle of the liquid." Finally, when the body balances near the bottom (without touching it) then the students answered that the buoyancy is less than the weight "because the body sinks". The above results agree with other research (Halkia & Kalkanis, 1998) for prospective teachers, confirming that even at old ages, there are alternative perceptions of the factors on which buoyancy depends and of the floating condition (buoyancy-weight interaction). Therefore, prospective teachers maintain a rather phenomenological, rather than scientific, understanding of floating bodies: a body floating in a liquid receives more buoyancy as it protrudes from the liquid. Analogous findings were detected in later research (Gardzonika & Kotsis 2004), among active teachers. Kotsis (2002), in a survey with an open questionnaire on what causes buoyancy in liquids, found that one-third of the primary education department students consider buoyancy to be a characteristic of liquids. A smaller percentage (11%) gave answers of a teleological nature, attributing to buoyancy an anthropocentric point of view, e.g., "so that people do not drown". Although this percentage is small, it becomes important if one considers that such answers are expected from young students whom, however, teachers use such approaches to teach them (Kallery & Psillos, 2004).

Arvanitakis et al. (2009) find that students and teachers show similarities in the mental model they use to explain sound propagation. In Papageorgiou et al. (2009) that was carried out in the context of the professional upgrading program of active primary education teachers and that concerns their ideas about the particle structure of matter and their interpretations of changes in physical states, the results showed that teachers maintain perceptions of subject structure and status changes similar to those of students.

The above indicative studies point out that among teachers, there is the presence of alternative ideas in concepts of physics. Summarizing, therefore, we can formulate the claim, which derives from the last thirty years' research, that teachers often hold the same alternative ideas as their students about important scientific knowledge points they are called upon to teach.

RESULT OF RESEARCH ON ALTERNATIVE IDEAS

The research in physics teaching aims, among other things, to highlight the students' alternative ideas, analyze them, and design curricula that will yield the best possible knowledge based on them. Redish (1994) noted that "we must approach science teaching as a scientific problem, "emphasizing the importance of a systematic scientific approach to science education. Vosniadou and Ioannides (1998) emphasized the need to develop "a theory of learning that bridges science education with cognitive research", which can provide the necessary framework for science teaching.

Based on the knowledge provided by the research on the teaching of physics, appropriate teaching strategies were designed to build concepts and solve problems in physics. Many research and studies have been done in planning, organizing, and evaluating didactic interventions for teaching physics. It is possible to mention some of the work done for this purpose. Experimental teaching of physics through specially designed programs (Rosenquist & McDermot, 1987) and methodologies (Hake, 1992), teaching based on modeling techniques (Halloun, 2000; Halloun & Hestenes, 1987), hierarchical structuring of physics concepts from the overview case study program (Van Heuvelen, 1991a), use of computer-based laboratories (Sokoloff & Thorton, 1997; Thorton & Sokoloff, 1990) and the use of simulations (Jimoyiannis & Komis, 2001; Tao & Gunstone, 1999). The above efforts have been evaluated positively based on the cognitive results recorded for the students. A common feature of all the interventions mentioned is the active participation of students to build new knowledge and solve problems in physics. The field of teaching sciences was particularly studied in Greece. Several studies and research have been published in this area (Christidou, & Hatzinikita, 2006; Hatzinikita et al., 1996; Kariotogloy et al., 1990, 1993, 1994; Koliopoulos & Ravanis, 1998; Koulaidis & Ogborn, 1994; Psillos, 1999; Psillos et al., 1999; Solomonidou & Stavridou, 1993; Tselfes & Psyllos, 1998).

Nevertheless, no generally accepted theoretical framework exists after years of systematic research. There is no direct answer to the question, "what is the best way to teach physics in the classroom." There is no specific approach for all students. Both individual differences and the specific people present in a classroom must be considered. Despite the great progress that has been made in understanding physics teaching over the last four decades, there is still a long way to go to achieve an accurate view of physics teaching. All that can be done is to provide a general framework and guidelines that will likely apply to each pupil or student. Also, the decisions made by the teachers make the teaching itself particularly dependent on the specific goals that must be achieved through the teaching of this course. Traditionally, these goals have been dominated by superficial perceptions rather than a deeper analysis of the subject, i.e., choosing specific content likely to match the long-term needs of the target population rather than considering the student's ability to learn and understand. Teaching research allows us to expand the discussion on what different students can learn by taking a particular physics course. This discussion has just begun, and a specific and optimized teaching model can indeed be developed through the content of such a discussion alone. The ultimate goal of teaching is to transform good teaching from an art few possess to a science many can learn. The question that arises is since students' ideas and perceptions of concepts and phenomena in the sciences have been recorded and are known to influence learning, what is the reason for continuing research in this field, unless, of course, of those concepts that are new in education and there is no corresponding literature on them.

OTHER FINDINGS FROM RESEARCH ON ALTERNATIVE IDEAS

It is a fact that the modern teaching proposal of sciences is based on the constructive teaching model, which takes seriously the misconceptions of the students. This effort is ongoing, and many studies are carried out to propose more effective didactic suggestions for learning sciences. Although the literature has recorded students' perceptions of science concepts, there is a need to group them (Kariotoglou et al., 2004) and develop reliable questionnaires as diagnostic tools (Keramidas & Psillos, 2004). In the last decades, in the effort to implement the constructive model of science teaching, the corresponding syllabi have been proposed for all levels of education, and the corresponding textbooks have been written. There is a need, therefore, to have a way of evaluating all these new proposals to see if they help students learn scientific knowledge. In such a research question, the only constant factor is the students' perceptions so that they can be used as a criterion for the successful or unsuccessful implementation of a teaching proposal. Kotsis et al. (2004) have been conducted on primary school students. Also, it has been investigated whether the perceptions of primary school students have changed, both with the old and the new textbooks (Kotsis, 2005a). The finding of the non-conceptual change from the new school textbooks led to the conclusion that the teacher does not use experiments in his/her teaching, which is an essential parameter of the constructive model of natural science teaching (Koumaras et al., 1992). The existence of students' alternative ideas can be described, therefore, as a kind of photographic plate that captures their knowledge. If the student, regardless of who taught him, which method was used, and which textbook was used, answers, for example, that in water, the body's weight is less than out of the water, then the well-known alternative idea is recorded. It is concluded that the student does not have the correct scientific knowledge. Of course, it cannot be unequivocally answered whether the teacher, the method, or the textbook is to blame, but the conclusion can certainly be drawn that the necessary conceptual change has not been made. Once alternative ideas are common to students and we are aware of them, we can tell from their existence if there is learning and knowledge after teaching.

In many cases, students' alternative ideas are entrenched and may remain as they are into adulthood. In this field, research on university-level students highlights that students hold many misconceptions and that university teachers should take them seriously during their teaching. Research in this direction has given interesting results for more complex concepts (Rudowicz & Sung, 2003) or chapters of physics, such as that of quantum mechanics (Chandralekha, 2001), as well as proposals for their conceptual change (Kalkanis et al., 2003). Even student profiles have been studied for different admission systems to the university (Kotsis, 2004a), investigating first-year students' perceptions of physics concepts.

An important factor that shapes children's perceptions of science concepts is their sensory experiences. Therefore, the research question is created on how a student with disabilities (blind) perceives concepts for which another sighted student has a wrong perception shaped by his vision. In this field, research has been carried out (Andreou & Kotsis, 2005a) on blind students, which has shown that blind students have formed, for some simple concepts of physics, perceptions closer to the scientific standard compared to the counterparts of the sighted (Andreou & Kotsis, 2005b). In the same field, similar research (Kotsis, 2005b) finds the need to research more on learning and teaching these concepts to blind students because they are led to better understandings.

Environmental education is a great concern to modern education (Flogaiti 1993), as a result of which research is being done on students' perceptions (Boyes et al., 1999) of contemporary environmental problems. Today, research in this field is carried out both internationally (Leighton & Bisanz, 2003) and in Greece for primary (Marinopoulos & Stavridou, 2002) and secondary school students (Christidou & Grammenos, 2000). The data of this research (Marinopoulos & Stavridou, 2002a, 202b) lead to proposing the corresponding didactic proposals.

Computer use is also important in teaching sciences (Hicks & Laue, 1989). It started around the time of its mass use. Since then, it has developed into an independent branch of scientific research, with the object of study being the utilization of the computer in teaching sciences (McDermott, 1990). The international educational community (Powell & Strudler, 1993) and the Greek one (Jimoyiannis, 2002; Mikropoulos et al., 1998) prepared to include the computer in the educational process. The constructive teaching intervention with the help of the computer (Duffy & Jonassen, 1991; Mikropoulos, 2002; Scott et al., 1992) currently needs research data on the effect that the use of the computer has on students' perceptions (Solomonidou & Kolokotronis, 2001) in various science concepts. In this field today, many types of research are carried out, which concern both the macrocosm, such as engineering (Kolokotronis & Solomonidou, 2003), electricity (Barbas & Psillos, 2002), in concepts of astronomy (Bakas et al., 2005), as well as the microcosm, such as the atom, the structure of matter (Kontogeorgiou et al., 2004), the cell (Mikropoulos et al., 2003), chemical reactions (Solomonidou & Stavridou, 2001), etc. Adult education is an important area of education. This is an area, where teaching needs a different approach (Beder & Darkenwald, 1982) than that of students. Consequently, research that highlights and records the alternative ideas of adults on science issues (Fortner et al., 2000), which in several cases are different from those of minors (Leighton & Bisanz, 2003), are of interest.

An important factor that contributes to the formation of students' perceptions is the very environment in which they live. Consequently, it is necessary to investigate whether students' perceptions change over time in a world, where the environment, especially the technological one, changes quickly (e.g., the existence of mobile phones, microwave ovens, and the use of computers). Also, the use of the computer and the internet has helped the student to have easy access to information from a very young age, resulting in forming mental representations for the interpretation of the world, different from the student of the same age twenty years ago. Research in this field is expected in the coming years to be very interesting.

CONCLUSIONS

Even though the research on alternative ideas gave so many useful findings for the didactics of physics, there are still interesting findings today. For example, studies on adults' misconceptions determine scientific literacy in many science areas, such as in the environment (Gavrilakis et al., 2017; Goulgouti et al., 2019a, 2019b), the greenhouse effect, and the ozone hole (Migdanalevros & Kotsis, 2021), the vaccines (Glinavos et al., 2020), bing bang theory (Christonasis et al., 2023), radioactivity (Migdanalevros & Kotsis, 2021), bioenergy (Stylos & Kotsis, 2023b), the science (Stylos et al., 2023).

Interesting findings are given from studies on the alternative ideas on electromagnetic radiation, wi-fi, and mobile phones (Gavrilas et al., 2022a, 2022b), renewable energy sources (Gontas et al., 2021) and nuclear energy (Vavoulioti et al., 2023)

Another field studies the evolution and the progress of alternative ideas from one education grade to another (Panagou et al., 2021) or between teachers during their years of service (Kotsis & Panagou, 2023).

Interesting research is also the studies that connect the alternative ideas about mechanics concepts with the student's mental age (Kotsis & Stylos, 2023b) or student's IQ (Kotsis & Stylos, 2023a).

Recently published two studies, where, with the help of alternative ideas of force (Kotsis & Panagou, 2023a) and energy (Kotsis & Panagou, 2023b), determine the learning curve for a physics concept. The learning curve is a graphical representation of the rate at which learning occurs over time. In physics education, a learning curve will be a useful tool for understanding how students acquire knowledge and skills. The learning curve can be used to track student progress over time, identifying areas of strength and weakness and providing feedback for teachers and students. It can also be used to compare different teaching methods or curricula, assessing their effectiveness in promoting student learning. This field has much search, and the findings could be very interesting.

When the research on alternative ideas started almost 50 years ago, nobody could imagine the useful findings that came from all these studies for physics education. We argue that alternative ideas research is invaluable in refining science education and contributes to developing an increasingly scientifically literate society. Even now, the research in this field gives interesting results, proving that alternative ideas are a very useful tool for the didactics of physics.

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