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Research Article

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Self-concept of Greek primary school teachers and their conceptions of force and weight among their years of service

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ABSTRACT

This paper describes an empirical study (n=352) into Greek in-service primary school teachers' conceptions of concepts of force and weight. A closed multiple-choice questionnaire is given to primary school teachers as a tool to explore conceptions, which has been used in previous research. The study population consisted of teachers at primary schools who work in the Greek education directorate. The research data is related to the teachers' years of service, from where it is studied whether their teaching experience changes/reduces the alternative conceptions. The research data investigated whether the teachers' teaching experience alters or reduces alternative conceptions based on their years of service. Years of service correlate statistically significantly with most questions. In particular, our results indicate that the alternative conceptions of teachers, reflecting misconceptions and preconceptions, reduce as the years of professional experience increase. Our study can be employed in science teaching, the design of Curricula, and teachers' professional development.

Keywords: alternative conceptions, force, weight, teachers professional development

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INTRODUCTION

Primary education, as we know, is a critical stage for students' academic life because it is the main base for the following steps of education (Pangrazi & Beighle, 2019). These are essentially the mental shapes that each person forms for concepts or phenomena of the physical sciences and highlight the depth with which he perceives and understands them. The recording of students' alternative ideas and the search for the factors that have caused them to have occupied the researchers of science teaching for decades (Duit & Treagust, 2003).

The research results indicate that students' initial personal knowledge, ideas, and opinions greatly influence learning. Students employ their ideas to understand what they see and hear and interpret the new knowledge they acquire (Ferreira et al., 2017, 2019; Kurnaz & Saglam-Arslan, 2011, 2014; Villarino, 2018).

The outcome of many years of research effort is to have categorized alternative ideas and perceptions of students in various concepts and phenomena of the physical sciences (Driver, 1989). Researchers also paid appropriate attention to how students think (Abell, 2000) and represent concepts (Taber, 2009).

Hence, the constructivist model of teaching and learning science was proposed. The advantage of the constructivist model is that the teacher, knowing the students' misconceptions, uses the appropriate teaching strategies to build scientific knowledge (Dysthe, 2002; Matthews, 2002; Taber, 2002) and bring about cognitive conflict and conceptual change (Treagust & Duit, 2008; Vosniadou & Skopeliti, 2014).

Thus, the teacher must include the students' alternative ideas in their teaching to achieve conceptual change. Nevertheless, what if teachers carry alternative ideas with them like their students?

In recent years, research has shown that adults have alternative ideas (Kotsis, 2011; Kotsis & Panagou, 2022; Panagou et al., 2022), even if they have completed all levels of education. These alternative ideas are related to the so-called scientific literacy, based on the exploratory method, the modern way of teaching the physical sciences. In both the constructive and exploratory methods, alternative ideas or perceptions of individuals play an essential role. Students still bring alternative ideas after graduating from high school, and these ideas are a challenge for those about to become primary school teachers (Schoon & Boone, 1998).

Since the educator has been a student, their perceptions of physical concepts probably did not change even as he or progressed through his social and educational life. Teachers carry the academic knowledge they received during their studies and specific values, "beliefs," and perceptions about science, science teaching, the teachers themselves, and generally their experience from their long-term presence in the education system (Mellado, 1998).

Nevertheless, teachers much more quickly than students understand their lack of knowledge of the content of science, which seems to positively activate their willingness to improve knowledge (Murphy & Smith, 2012).

Systematic research has been done on teachers' knowledge, nature, built and rebuilt, and how they affect teaching practice. Especially in physical sciences, research on students' ideas, which dominated the last decade, seems to lead, and influence research on teachers' ideas and perceptions (Zhang et al., 2015). It is even argued that many corrective changes attempted in the past have failed because teachers' existing knowledge and beliefs have not been considered (Van Driel et al., 2002).

Hence, this study investigates the possible alternative perceptions of in-service primary education teachers in Greek schools regarding the concepts of force and weight. Further analysis is conducted to determine if these conceptions change with the length of service of each teacher.

REVIEW OF LITERATURE

The evidence from different educational systems worldwide shows that the quality of teachers and teaching is critical in determining student achievement (Kunter et al., 2013). Teachers in the world's best education systems are chosen from among the best graduates and trained rigorously and effectively, emphasizing classroom practice (Ramnarain & Schuster, 2014). They then ensure that teachers receive adequate professional development throughout their careers, with opportunities to observe and work with other teachers and appropriate leadership positions (Department for Education of London, 2010).

Most primary teachers believe proper knowledge exists and can be transmitted to another person through explanations and demonstrations of scientific principles (Rogers et al., 2007). Teaching science in the elementary classroom often emphasizes rote learning and content coverage (Tobin, 1990).

Many reports showed that primary school science teachers lack content preparation (especially in physical sciences) (Appleton, 2003). Furthermore, there is a lack of facilities and equipment, a lack of confidence in teachers teaching science, and an unawareness of students' misconceptions about scientific concepts (Abell & Roth, 1992; Appleton, 2003; Davis & Petish, 2017). These issues would cause students difficulty in learning science. Andersson and Bach (2005) believed that learning at school could be improved by integrating research-generated knowledge and the experience of teachers.

Even if they teach physical science, primary school teachers have alternative ideas/conceptions, often the same as their students (Kokkotas et al., 1995). It is a finding reflected in the Greek educational system and several other countries (Bayraktar, 2009; Gabunilas, 2017; Smith & Neale, 1989). These perceptions exist to a lesser extent and are formulated scientifically, using terminology or complex reasoning (Botha & Reddy, 2011). According to Wandersee et al. (1994), the above should not be surprising because the limited physical science programs justify teachers' existence and persistence in alternative concepts during their studies.

Prior studies conducted with teachers have shown that they have substantial problems understanding the concept of force, e.g., they do not consider friction and weight are forces (Summers, 1992). Preece (2006) explored the views of primary and secondary school teachers, looking for forces exerted on two bodies of equal mass that move, in the absence of friction, at different constant speeds. Essentially, the alternative view of the existence of force in the same direction of motion is detected as its cause. According to the survey, the majority (75%) of teachers believed in a force that acts collinearly, and more than half attribute a similar measure to it.

Further research has shown that a non-separation of energy with the concept of force has been recorded in teachers (Summers & Kruger, 1992). Primary school teachers believe energy is 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 on the nature of energy, namely that energy is related to life and movement. Teachers strongly associate both force and energy with movement. On the one hand, they believe that a body can move when force is exerted on it. On the other hand, energy is treated to be "shown" by movement. Associating both concepts with movement makes it difficult for teachers to distinguish them.

Research has also been carried out on teachers' alternative conceptions of the concept of weight. In a previous study on future teachers, Panagou et al. (2022) found that most students ignore the factors which determine buoyancy (i.e., the volume of a submerged body and density of the liquid in which it sinks). The weight, volume of fluid sinks, and the body's position on the liquid's surface determine the sinking rate.

Nevertheless, if the teacher has alternative ideas, they influence the students' perceptions and the classroom climate. Unlike pupils, alternative teachers' perceptions are not stated or spoken of but are a focal point in planning activities. In the immense majority (Kallery & Psillos, 2001), all alternative perceptions of teachers are an open subset of alternative perceptions of students. The lack of 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 content, nature of questions, understanding of student's pre-existing ideas) in the teaching of physical sciences (Hatzikraniotis et al., 2010).

Physics is complicated for Greek students, who may be similar to many other countries (Narjaikaew, 2013; Soankwan et al., 2007). Students express in the classroom their perceptions, on which they will build their future knowledge. Since new knowledge is constructed only by broadening and modifying the existing mental shape, students' existing knowledge is the raw material to help them achieve a more correct and scientific cognitive structure (Elby, 2001).

Consequently, for the teacher to manage his students' perceptions, a necessary condition is to manage his alternative perceptions successfully. Fleury and Bentley (1991) say that few schoolteachers have correctly understood the content of the physical sciences they will teach at primary school and suggest that it is necessary to deal with their alternative concept. It should also be mentioned that the teacher's perceptions of the content of the concepts are an obstacle and their views on the role of their pupils' earlier perceptions (Pine et al., 2001). However, teachers insist on considering themselves as the primary source of the correct message to be conveyed to the pupils, who are uniform receivers of this message.

In light of this, the teacher may have alternative perceptions of physics concepts when he finishes his studies and enters the teaching profession. Our main objective is to determine if those perceptions are maintained while he teaches. After taking up his service and depending

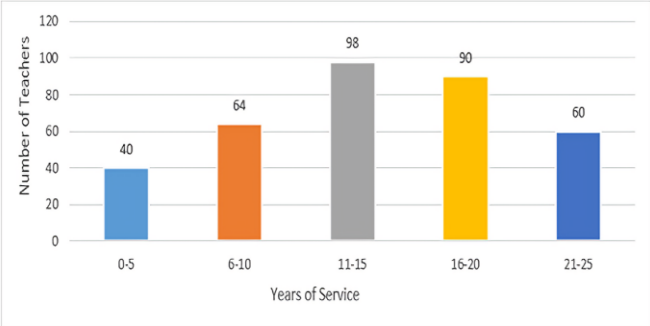

Figure 1. Number of teachers participating in our research and across years of service (Source: Authors)

on their effort, each teacher tries to eliminate their alternative ideas in concepts or phenomena of physical sciences. It is, therefore, worth exploring whether teachers' ideas are being eliminated as their years of service increase.

Purpose of the Study

In the context of the educational reality of Greece, this study aimed to examine the conceptions of primary education teachers in force and weight concept and if they evolve/changed according to the years of service. The research described in this paper taps into the expertise of (participating) primary teachers by analyzing the insights and thinking that emerged as they attempted to answer some physical science questions about force and weight.

Subsequently, we tried to notice if an alternative perception occurs and which mechanics concepts it focuses on (force and weight). Many studies have investigated how science education can influence students' alternative conceptions of science. However, there has been less research exploring teacher knowledge in science content. Therefore, this study explores Greek primary school teachers' understanding of force and weight and their possible alternative conceptions.

Specifically, this paper seeks to identify alternative perceptions of mechanics concepts among teachers, which will serve as a basis for further research on the design of curricula and professional development of teachers in primary education in Greece in the field of didactics of Physics. This research was prepared to investigate the following fundamental questions:

1. **RQ1.** Is there a statistically significant difference in teachers' understanding of the concepts of mechanics based on years of service?
2. **RQ2.** How consistent are teachers in their scientific and non-scientific (alternative) understandings of physical concepts across the different years of service?
3. **RQ3.** Is a teacher's experience significant in weight and force concepts?

METHODOLOGY

The principals of the schools and teachers were primarily informed about the research topics and aims. Data were collected during May and June (2018) using the same questionnaire.

This article investigates primary school teachers' perceptions of physical sciences and, more specifically, the concept of force and weight. According to their years of service, candidates chosen from the schools are split into five groups. These include 0-5 years of service, 6-10, 11-15, 16-20, and 21-25 (**Figure1**).

All candidates were provided with a closed-form multiple-choice questionnaire, including two primary physical concepts: force and weight. Statistical analysis based on their answers has been performed using the χ^2-test (Wagner, 2019) and the help of the IBM Statistics 25 computer software (Field, 2013). This cross-sectional study (Zhou et al., 2015) involved teachers from five different years of service groups (0-5, 6-10, 11-15, 16-20, and 21-25). The methodology adopted for this study was quantitative in nature.

Participants and Research Context

As aforementioned, our study targets teachers at primary education schools. We conducted empirical research among 352 primary school teachers from 17 schools in four prefectures of the country. More specifically, 112 teachers and from the Prefecture of Heraklion, 110 Prefecture of Ioannina, 46 Prefecture of Preveza, and 84 Prefecture of Etoloakarnania participated in the research.

The selection of schools and teachers has been made using random sampling to avoid research bias. The distribution of teachers across their years of service is shown in **Figure 1**.

Data Collection-Instrument

In the context of the investigation conceptions, multiple-choice questionnaires tend to be a popular choice. Standard multiple-choice questions require choosing the best answer to a given question from a given set of alternatives. Questionnaires are flexible, practical, objective, easy to use, and less influenced by a person's tendency to react in a specific way (Brancato et al., 2004).

It was considered appropriate to use a multiple-choice questionnaire for research purposes. The questionnaire questions are simple conceptual understanding questions.

Initially, the questionnaire contained 28 questions since it also addressed the pedagogical department's undergraduate students (Kotsis, 2005). However, because the present study specializes only in concepts of force and weight, some questions regarding other concepts such as energy, action/reaction, and work have been removed.

After the changes were made to the changing and differing educational policies, the differing aims, and the needs of education, the questionnaire was formulated based on current data (school textbook, curriculum) in nine questions.

It should be noted that the questionnaire was given to a group of primary and secondary education teachers to comment and check the clarity of the questions. Primary and secondary school teachers described it as adequate (Kotsis, 2011, p. 40).

The questionnaire has been used again in studies conducted in Greek and Cyprus schools (Kotsis, 2005; Kotsis et al., 2002; Panagou et al., 2022). Each question is based on a scenario from familiar everyday environments followed by statements that include the scientific explanation and alternatives.

Consequently, the data was collected using the revised closed type of multiple-choice questionnaire of 9 items. All questions are similar to examples from school textbooks, and the questionnaire did not include graphic or pictorial representations to avoid unwanted misinterpretations. Participants answered the questionnaires during their break (20 minutes). Before administering the test, the participants

Table 1. Independent sample t-test for equality of means in concept of force across years of service

Years of service	t	df	Sig. (2-tailed)	MD	SED	95% CI of the difference	
						Lower	Upper
Question 1	1.231	326	0.219	0.128	0.104	-0.077	0.334
Question 2	-1.119	336	0.264	-0.196	0.175	-0.540	0.148
Question 3	2.443	332	0.015	0.471	0.193	0.092	0.851
Question 4	1.927	326	0.055	0.197	0.102	-0.004	0.398
Question 5	1.040	324	0.299	0.133	0.127	-0.118	0.383

Note. MD: mean difference; SED: Standard error difference; & CI: Confidence interval

Table 2. Independent sample t-test for equality of means in concept of weight across years of service

Years of service	t	df	Sig. (2-tailed)	MD	SED	95% CI of the difference	
						Lower	Upper
Question 6	1.655	336	0.099	0.193	0.116	-0.036	0.422
Question 7	-1.071	332	0.285	-0.105	0.098	-0.298	0.088
Question 8	-1.988	328	0.048	-0.271	0.137	-0.540	-0.003
Question 9	-0.300	332	0.764	-0.064	0.213	-0.484	0.356

Note. MD: mean difference; SED: Standard error difference; & CI: Confidence interval

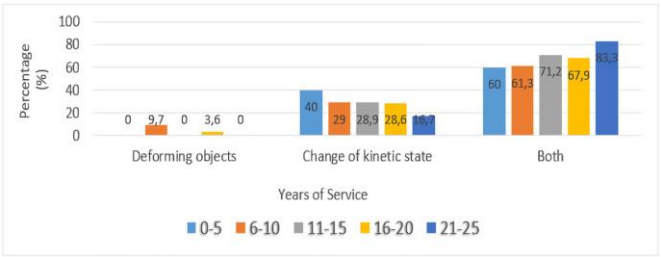

Figure 2. Teachers' answers, in this research, to the question "force is the cause" in relation to their years of service (Source: Authors)

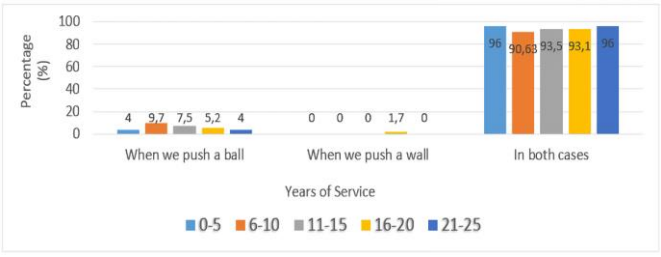

Figure 3. Teachers' answers, in this research, to the question "when do we exert a force" in relation to their years of service (Source: Authors)

were informed that their answers to the questionnaire would be used for research purposes.

Data Analysis

The questionnaire was tested with 352 teachers, and the reliability of the (Cronbach's alpha coefficient) was 0.7. According to Nunnally and Bernstein (1994), a Cronbach's alpha reliability coefficient greater than 0.7 indicates high reliability, while values in the range of 0.5-0.7 indicate moderate reliability and are acceptable in cognitive nature studies. Among the data from the nine-item questionnaire, items with 2 or 3 (a, b, and c) alternatives each were initially coded in SPSS by identifying the selected choice. For example, choice A was coded as '1', and choice B was coded as '2', and so on. If a teacher did not respond, it was coded as '0'. Then, the data were re-coded in SPSS, assigning '1' and '0' for each correct and incorrect response, respectively. Furthermore, simple statistical procedures were used to assess the significance of differences between years of service within the sample (independent samples t-test). Independent t-tests (**Table 1** and **Table 2**) were conducted at the 0.05 level of significance for all data.

For research question **RQ1**, using the re-coded data, the percentage of each group of teachers' scientific responses to each item was calculated. Also, all teachers' total standard questionnaire scores (nine items were included) were calculated.

RESULTS

The questionnaire responses' processing has been performed using the statistical package SPSS V.25 (Landau & Everitt, 2004). To investigate whether the answers to the survey questions depend on years of service, we used the χ^2-test as a statistical control criterion. The data were processed with the statistical program SPSS 25.0. Teachers' answers are presented in the form of diagrams for each question separately.

From the statistical analysis of the data, one can easily see a statistically significant difference in the response's years of service (**Table** and **Table 2**).

At this point, it is important to clarify that the respondents' years of service were considered an independent indicator regarding the concept of force and weight.

In question (1), teachers were asked to answer the question "force is the cause." Their answers are presented in (**Figure 2**). Teachers with 0-5 years of service give the correct answer, "both," at a rate of 60%, and as the years of service increase, they give an increasing percentage of the correct answer resulting in teachers with 21-25 years of service to give the correct answer at a rate of about 83%. It is observed that teachers with the fewest years of service (0-5) answer question 1 incorrectly at a rate of 40%, and as the years of service increase this percentage decreases and reaches 16.7% (21-25).

In question (2), teachers answer the question "when do we exert a force," where the answers have a visible effect and an invisible one (**Figure 3**). Regardless of the years of service, the teachers answer correctly in a substantial percentage (over 90%), giving the correct answer that force is exercised "in both cases."

In question (3), teachers are asked to answer, "when a force acts," starts moving a body or stops moving. Teachers' answers are presented in **Figure 4**. This question seems to increase the correct answer

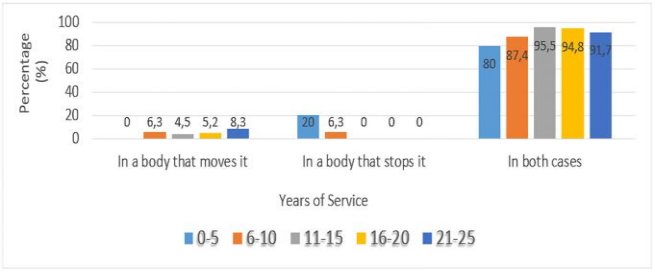

Figure 4. Teachers' answers, in this research, to the question "When a force acts" in relation to their years of service (Source: Authors)

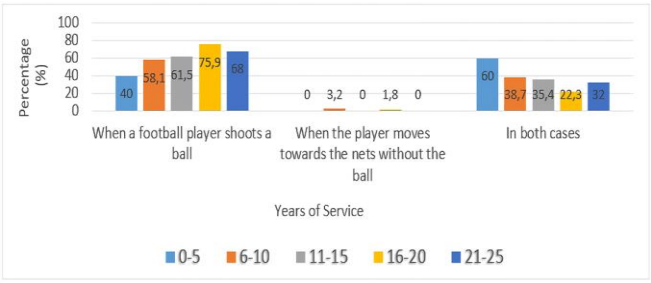

Figure 5. Teachers' answers, in this research, to the question "When a force is exerted" in relation to their years of service (Source: Authors)

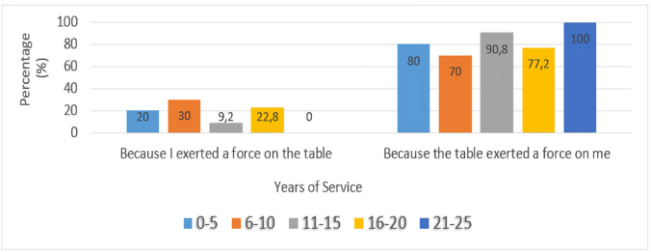

Figure 6. Teachers' answers, in this research, to the question "I slap my hand hard on the table. Why does my hand hurt?" in relation to their years of service (Source: Authors)

percentage (in both cases) like the years of service increase. In the category years of service (0-5), the correct answer is 80%, which in the category of (21-25) becomes about 92%.

The next question (4) tries to determine whether teachers have the Aristotelian conception of force. Teachers are asked to answer, "when a force is exerted." The possible answer was "when the player shoots a ball," "when the player moves toward the net without the ball," or "in both cases." The teachers' answers are presented in **Figure 5**. It is clear that this question also seems to increase the percentage of the correct answer as the years of service increase ("when a football player shoots the ball"). Specifically, in the category 0-5 years of service, the teachers give the correct answer only in a percentage of 40%. In the category 6-10 years of service, the percentage becomes about 58%, in the category 11-15 it increases to 61.5% and finally in the category 21-25 years of service it becomes 68%.

Finally, in the last question (5) about the concept of force, teachers answer an experiential question. "Why does their hand hurt when they hit a table with force?" Essentially, they are asked to determine the cause and effect of a body interaction. Their answers are presented in **Figure 6**. In this case, the correct answer percentage increases "because the table exerted a force on me" as the years of service of teachers increase.

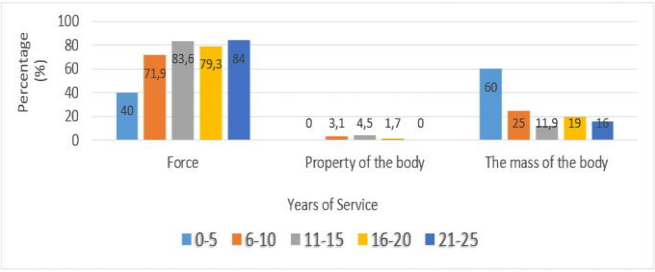

Figure 7. Teachers' answers, in this research, to the question "The weight is" in relation to their years of service (Source: Authors)

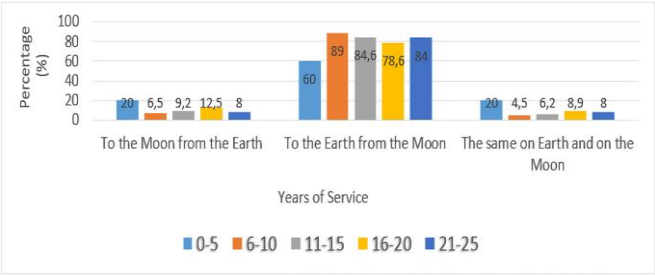

Figure 8. Teachers' answers, in this research, to the question "A chocolate has more weight" in relation to their years of service (Source: Authors)

However, there are statistical variations for the increase in this question. Notably, in this question, there is a large percentage in all the service groups of teachers, since we see a percentage of over 70%, and in the group with the most years of service (21-25) reaches even 100% of the correct answer.

In the following question (6), to detect the well-known alternative idea, the impossibility of separating the weight from the mass, the teachers were asked to answer, "the weight is …" Their answers are presented in **Figure 7**. As their years of service increase, teachers give them an increasing percentage of the correct answer: "force" Specifically, in the category (0-5) years of service, the teachers give the correct answer only a percentage of 40%. For category (6-10), the correct answer is about 72%, in category (11-15), by 84%, and finally, in category (21-25), it is given by 84%. Here is observed in the group with the years of previous service 0-5 a difficulty in separating the concepts, since we see a large percentage of 60% in the incorrect answer.

In question (7), teachers answer when a chocolate weights more, on Earth or the Moon? Specifically, they answer the question "a chocolate has more weight." Teachers' answers are presented in **Figure 8**. At the beginning of their service, teachers give the correct answer in a percentage of only 60%. They answer "to the Earth from the Moon" chocolate has more weight. As the years of service increase, the percentage of correct answers in the category (21-25) years of service also increases, reaching 84%.

In the following question (8), teachers are asked to answer a question with a similar theme to the previous one, i.e., to answer if "an apple has the equal weight or mass in the Earth and the Moon." The answers of the teachers are presented in **Figure 9**. In the category 0-5 years of service, the teachers give the correct answer (equal mass) to 80%. This becomes about 93% in the other categories, and in the category, 21-25 years of service becomes 100%.

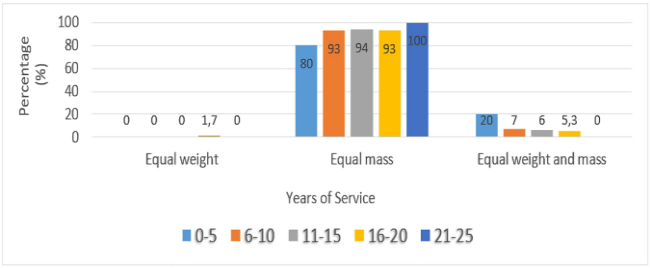

Figure 9. Teachers' answers, in this research, to the question "Does an apple have equal weight or mass on the Earth and the Moon?" in relation to their years of service (Source: Authors)

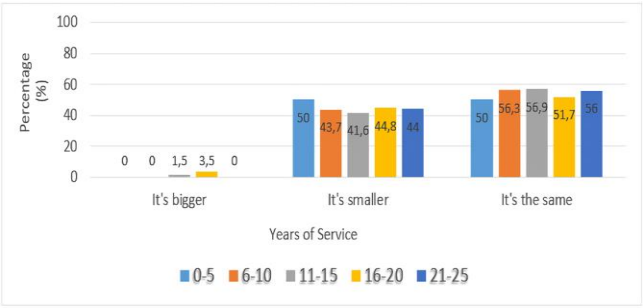

Figure 10. Teachers' answers, in this research, to the question "The weight of a body in water" in relation to their years of service (Source: Authors)

The last question (9) tries to determine whether teachers can recognize that the weight of a body does not change if the body is in water. An experiential experience that people have when they enter the sea or a river. Teachers are asked to answer the question "the weight of a body in water." The answers of the teachers are presented in **Figure 10**.

It is clear that this question shows only about half of the teachers, in all categories of years of service, give the correct answer, i.e., "It is the same." There is almost no increase in the correct answers as the years of service goes by. We notice that this is a solid and timeless alternative idea for teachers.

DISCUSSION

The current study results provide evidence for the consistency of teachers' conceptions of concepts of force and weight across different years of service. The research data show that the more years of service a teacher has, the higher the percentage of correct answers to questions related to the concept of force and accordingly expresses fewer alternative conceptions.

Figure 11 summarizes the dependence of the rate of correct answers for each question regarding the concept of force depending on the teacher's years of service. The x-axis of service years is expressed in units of five years.

It is evident that for all five questions concerning the concept of force, there is a linear dependence of these two variables, indicating that the teacher has more correct answers and fewer alternative conceptions of the concept of force as years of service increase. This result does not

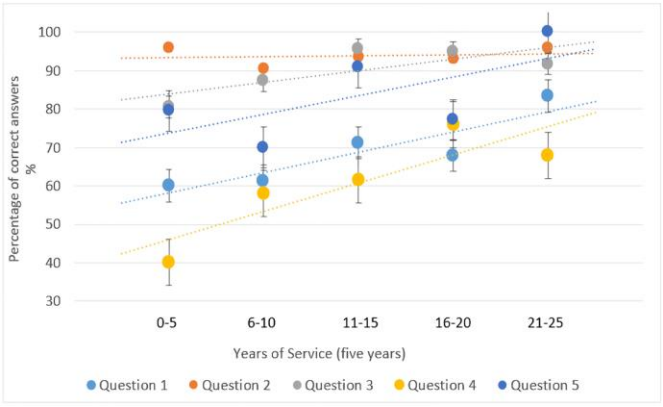

Figure 11. Percentage of teachers' correct answers in force concept across years of service (Source: Authors)

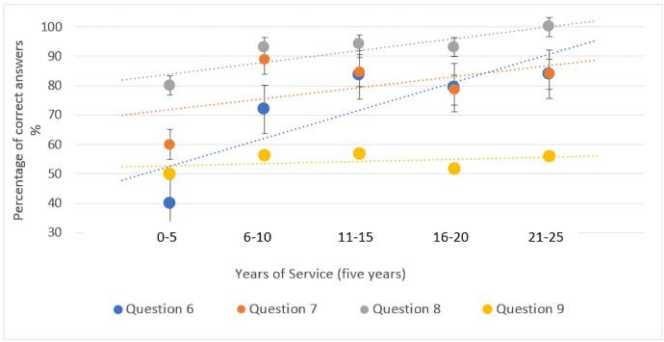

Figure 12. Percentage of teachers' correct answers in weight concept across years of service (Source: Authors)

mean that the final percentage for correct answers is close to 100% for all questions. Instead, there is, for all, a linear increase.

Figure 12 summarizes the dependence for the percentage of correct answers for each question related to the concept of weight as a function of teachers' years of service. Obviously, for all four questions on the concept of weight, there is also a linear dependence of these two variables, which suggests that for more years of service, the teacher has more correct answers and fewer alternative ideas for concept of weight.

CONCLUSIONS

Generally, from the data studied in the present study, we observe that teachers of all categories with years of service are scientifically literate in the concept of force; in the questions explored after, we observed a large percentage of 75% correct answers. Furthermore, there was a slight difficulty in questions 1 and 4 in the category 0-5 years of service, but as the years of service increase, so do the percentages of correct answers from teachers.

Simultaneously, in the concept of weight from the data studied in this research, we observe that teachers in all categories with years of service are scientifically literate in the concept of weight, in the questions studied, after watching a percentage of 60% correct answers. However, significant interest arose in question 9, which has to do with the concept of buoyancy and, more specifically, with the principle of Archimedes. One in two teachers answers correctly to all categories with years of service. This finding may need to be further studied because if one observes the international literature on the concept of

buoyancy, students of all levels of education face the same difficulty. The linear increase exists for all nine questions. Indeed, further investigation is needed with a more significant number of teachers for safer conclusions. The findings of the present work could be argued that, at least for physics, they prove the well-known saying "I grow old while learning." Teachers who have low scientific literacy levels cannot grow scientifically literate people or apply the curriculum effectively. When we consider the data obtained from this study, university-level curricula should increase the teacher candidates' scientific literacy level.

The same research data also highlight another conclusion: an experienced teacher is more suitable to teach these concepts in the upper grades of primary school. Therefore, the teacher with more years of service is preferable to undertake terms of natural sciences in the 5th and the 6th grade of primary school. Understandably, the conclusion refers to teachers from the existing Greek educational system. Indeed, further research is needed in these fields and other concepts of natural science so that this conclusion is considered safe.

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