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Research Article

Using Alternative Ideas for Determining the Learning Curve on the Concept of Force

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ABSTRACT

This study is empirical research about alternative ideas on the concept of force for five different age groups, primary school students (11), middle school students (15), high school students (17), students of the Department of Primary Education (21), and active teachers in primary education (27-50). We used the same questionnaire for all groups, which shows a relationship with the answers depending on their age. The analysis of the percentage of the correct answers concerning the age of subjects gives a sigmoid curve, which is the learning curve on the concept of force. For all the questions, there was a statistically significant correlation with age. That provides us with interesting information about the teaching of the force. In particular, our results suggest that the alternative conceptions of students and teachers, reflecting misconceptions and preconceptions, reduce with age or equivalently with the education level. Our study can be used in science teaching classrooms, on the design of curricula, and teachers' professional development.

Keywords: alternative ideas, force, learning curve, sigmoid learning curve, teaching physics

INTRODUCTION

It is well known that students and adults develop ideas and perceptions about the concepts and phenomena of physics (Kerr et al., 2006). These alternative ideas are used to explain what is happening around them. For over thirty years, research has shown that a person's ideas and opinions greatly influence his learning from physics at all levels of education (Guisasola et al., 2002; Itza-Ortiz et al., 2003; Kelly, 2001; Libarkin et al., 2005; Maloney et al., 2001; Thong & Gunstone, 2007; Yalcin et al., 2008). University students have serious problems understanding the fundamental laws of physics and applying them to real situations. Similar conclusions exist for students of the Department of Physics. Research on teachers shows that they have different views from the scientifically accepted ones (Ginns & Watters, 1995; Summers, 1992; Webb, 1992). Even high school teachers have misconceptions about physics (Bayraktar, 2009; Taber & Tan, 2010).

It is noteworthy that the alternative views of teachers are, in many cases, similar to those of students (De Jong et al., 2002; Smith & Neale, 1989). The vast majority of teachers 'alternative perceptions are an open subset of students' alternative perceptions. Insufficient knowledge of the subject matter, as well as the non-identification of their views with the corresponding scientific ones (Schoon & Boone, 1998), influences various processes (organization of activities, presentation of content, nature of questions, understanding of students' pre-existing ideas) during the teaching of physics sciences.

Alongside one of the main characteristics of each research group is the age of the respondents. It is certainly not the only variable because there is a repetition of the teaching of the concept in the various levels of education the mental development (Rapp, 2005), the experiential experience (Wallace & Brooks, 2014), the way of teaching the concept method (Sperandeo-Mineo et al., 2006), the teacher who teaches it, and other factors, which in the present research cannot be isolated in order to make their analysis. What is certain is that the respondents were of different ages when they were asked to answer the questionnaire. It is interesting to look for a function relationship between the correct answers to each question depending on the age of the respondents. There will undoubtedly be a mathematical relation, which will describe the relation for each question, but the aim is to be the same for all six questions.

LITERATURE REVIEW

A key point for effective teaching of students is students' ideas about concepts and natural phenomena. The finding that students come to school with specific ideas about the phenomena of the natural world, which usually deviate from the scientific ones, was an alarm to the international scientific community (Ferreira et al., 2017; Kurnaz & Arslan, 2011; Villarino, 2018). Thus, new teaching strategies and curricula were developed, which had as a starting point, reference, and evaluation these ideas.

Alternative ideas are cognitive constructs that are structured in the minds of students as they attempt to interpret natural phenomena, interacting with the natural world and their social environment. They are not arbitrary constructions but they are integrated into conceptual structures that provide a logical and consistent understanding of the world on their part, and they are different from scientific concepts, as they are descriptive formulations of the phenomena of the natural world which students attempt to interpret concerning their personal experiences (Duit & Treagust, 2004).

Researchers have interpreted the evidence for the nature of students' conceptions in two distinct ways. Some researchers viewed students' conceptions as being theory-like, in that they are stable, coherent, persistent, and found helpful in a wide range of tasks (Blown & Bryce, 2007; Vosniadou, 2019). Others characterized students' conceptions as unstable, fragmented, transient, and context-bound (Clough & Wood-Robinson, 1985; Tytler, 2007). Therefore, students' simultaneous use of multiple alternative conceptions sometimes coexists with scientific conceptions. Diverse and inconsistent explanations of scientific phenomena were often prompted by context and created in situ by operating various conceptual elements (Taber, 2008). A limited number of studies have explored the consistency of students' conceptions concerning physical, chemical, and biological phenomena among different age groups (Alonzo & Steedle, 2009; Chu et al., 2012; Nieminen et al., 2017; Palmer, 1993; Tytler, 2007). Findings from studies have shown that few students used scientifically correct concepts in physics tasks. Contrary to many students that used alternative perceptions in different ways in response to their assigned tasks. (Alonzo & Steedle, 2009; Chu et al., 2012; Palmer, 1993; Tytler, 2007).

Alternative conceptions (AC) or alternative ideas (AI), as these ideas are generally referred to, become a primary element in students' learning process (Driver & Easley, 1978). In particular, it has been pointed out that AC turns out to be remarkably more persistent and diverse than one would naively expect, eventually affecting students' critical thinking (Taber, 2008). Furthermore, students may also hold various views on scientific subjects, which are often inconsistent with well-established theories (Abell, 2000). The AC is being formed through mechanisms of empirical understanding. They are usually developed through daily life experiences in the children's attempts to make sense of the world they live in. Hence, in some cases, they are so deeply rooted that they cannot be abandoned or even slightly affected by the educational process (Driver, 1989). To this end, teachers and other education professionals must know their students' various AC characteristics to prepare suitable teaching interventions. In this way, they can recant or critically confront these crucial aspects of children's considerations (Panagou et al., 2022).

In conclusion, as the reader, can discern there is an enormous range of literature that explores students' alternative ideas (Liu & Fang, 2016; Turker, 2005; Wells et al., 2020), as well as teachers' misunderstandings about the concept of force (Bayraktar, 2019; Narjaikaew, 2013; Topalsan & Bayram, 2019). In addition, many studies have used one of the most popular and most analyzed tools known as the force concept inventory (FCI), which deals with the concept of force and Newton's laws, to investigate this concept of physics (Blandin & Poutot, 2015; Crogman et al., 2018; Fazio & Battaglia, 2018).

In the Greek educational reality plainly and there are similar researches that study the concept of force and the alternative ideas of students and teachers, yet our research goes one step further, investigating the concept of the force and the possible misunderstandings that students and teachers may have, in relation to their age in order to create the sigmoidal curve of learning.

SELECTING FORCE DOMAIN

In the context of our research, we focus on classical mechanics to detect students' and teachers' alternative ideas and if they change according to their age. It would be impractical to provide a questionnaire covering all areas of physics, and for this reason, the concept of force was chosen. The concept of force is the most fundamental concept yet the most misunderstood in physics. The students across different age levels (primary, middle, high, and university) have a wide variety of vague and undifferentiated ideas about the force incompatible with Newtonian mechanics (Ahmad et al., 2017; Yürük, 2007).

Force, as we say, is a fundamental concept in Newtonian mechanics that teachers are expected and should understand well. Nonetheless, even when teachers are familiar with Newton's laws of motion and gravitation, they hold several misconceptions about force (Narjaikaew, 2013; Shome, 2017). For this reason, we deemed it necessary to investigate if and since there is a similar problem in the Greek educational system for the age groups of our research in the concept of force.

As is widely known from the international literature, the learning curve correlates an individual performance on a task and the number of efforts or time required to complete the task. This curve can be represented as a direct analogy to a graph. The learning curve theory proposes that a learner's efficiency in a task improves over time as much as the learner performs the task (Morrison, 2008). The learning curve model requires that one variable be tracked over time, repeatable, and measurable. The model is the most commonly cited learning curve known as the "S-curve" model (Leibowitz et al., 2010).

Our research measures the respondents' performance on the concept of force according to their age to determine at what age students should ideally teach force concepts based on a sigmoid curve.

PURPOSE OF THE STUDY

In the Greek educational reality context, this study intended to examine how the progression and consistency of students' and teachers' understanding of physics concepts in everyday contexts changed across years. The main objective of this paper is to highlight the possible alternative ideas of students and teachers regarding the concept of force, which will contribute to the broader research carried out in the field of didactics of science, on the design of curricula, and the professional development of teachers in primary and secondary education in Greece.

This research was prepared to investigate the following fundamental questions:

1. How consistent are students and teachers in their scientific and non-scientific (alternative) understandings of force concept across the different age groups?
2. Is there a statistically significant difference in students' and teachers' performance for their answers depending on their age?

METHODOLOGY

The present study investigates whether "there is a relationship in the chain, of perceptions in the concept of force for primary school students, middle school students, high school students, student candidates of the department of primary education, and primary school teachers." Considering the purpose of this study is not to detect new alternative ideas but to see if and how much they change depending on age, a multiple-choice questionnaire was used for research purposes.

The questionnaire addressed all research age groups and included simple conceptual understanding questions that can be answered even by primary school students. All candidates were provided a multiple-choice questionnaire, which included questions about the concept of force. The same questionnaire was used for data collection for all candidates. Statistical analysis based on their answers has been performed with the use of the χ^2-test (Wagner, 2019) and the help of the IBM SPSS Statistics 25 computer software (Field, 2013). The methodology adopted for this study was quantitative in nature. Survey data were collected at a single time from students and teachers without any intervention or changing the learning environment.

Such a questionnaire was developed and used in previous surveys of primary school students (Kotsis, 2005; Kotsis et al., 2002; Panagou et al., 2022). Questions from the same questionnaire were used to survey high school students (Kotsis, 2005; Panagou et al., 2022) and newcomers to the pedagogical department (Stylos et al., 2008).

Subsequently, it is interesting to look for the existence of a function relationship between the correct answers to each question depending on the age of the respondents. The solution to such problems was sought in Curve Fitting Software from experimental data. In the case of the present study, what was used to provide an answer was LAB Fit Curve Fitting Software V. 7.2.48 (Da Silva & Da Silva, 2010). This software searches for and finds the best curves, which describe a series of experimental data, among about 500 mathematical functions, which it ranks in order based on the least-squares method.

PARTICIPANTS AND RESEARCH CONTEXT

The prefecture of Ioannina was used for the selection of the sample for all research groups. Our sample's total number of students and teachers is n=1032, chosen from several public education facilities in Ioannina. The sample distribution is shown in **Figure 1**. The choice of schools has been made using random sampling to avoid research bias.

The survey groups correspond to five specific education classes: The primary school students were in the 5th grade, the middle school students in the 3rd grade, and the high school students in the 2nd grade. The students of the primary education department used were at the end of the third year, having been taught a compulsory course in the first year of mechanics.

The specific number of students and teachers in each group is given in **Figure 1**. Our investigation is based on a comparison of the answers received from the five groups. The survey was carried out in May-June (2020) in Primary Schools, September-October (2020) in middle and high schools, and for students of the primary education department in February (2021).

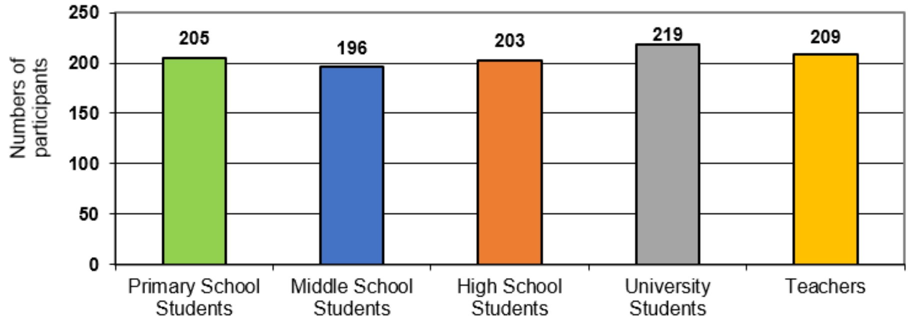

Figure 1. The distribution of the research population

DATA COLLECTION–INSTRUMENT

In the background of the investigation of students' alternative ideas, multiple-choice questionnaires tend to be a popular choice. Standard multiple-choice questions require students to choose 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 that all research groups can answer.

It should be noted that the questionnaire was given to a group of students and teachers of primary and secondary education to comment and check the clarity of the questions. The primary school teachers agreed that it is within the capabilities of the final grades of primary school, while the secondary school teachers characterized it as easy (Kotsis, 2011).

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

The data were collected using the revised closed type of multiple-choice questionnaire of 6 items about the force concept. All questions are similar to examples from school textbooks. The questionnaire did not include graphic or pictorial representations to avoid any unwanted misinterpretations. Students could easily read the scripts given on the objects without using or knowing scientific terms.

RESULTS

For research question (1), the questionnaire responses were processed using the statistical package SPSS V.25 (Landau & Everitt, 2004). To investigate whether the answers to the survey questions depend on age, we used the χ^2-test as a statistical control criterion. From the statistical analysis of the data, one can easily see a statistically significant difference in the respondents' age.

We want to elucidate at this point that the age of the respondents was chosen as an independent indicator as a function of the concept of force, in order to study the sigmoid curve and to extract the results that we will analyze. The percentages of the correct answers of the respondents will be studied, as the index increases and the sigmoid curve will be formed as a function of age and correct answers. There was a statistically significant relationship between the age and the percentage of correct responses in all six questions.

From the sample, there were some students who repeated a class with the result that they were older than the specified years studied by our research. At this point, we want to clarify that the students who repeated a class in our sample were not more than five. As a consequence, they were removed from our sample since such a small sample was judged not to yield a significant finding. If the sample was larger, it would be included in our research and it would be interesting to study the answers given by these respondents.

Question 1 has to do with the definition of the concept of force. At age 11 (primary school), we see divided answers: they do not know the definition of force, although the primary school teaches it. We observe almost the exact percentages of correct answers (both) that range close to 70-80% in the following age groups-detailed results based on age groups in **Table 1**.

Table 1. (Q1) What is the effect of force acting on a body?

	(A) Deformation	(B) Change of kinetic state	(C) Both
Primary school	26%	37.7%	36.3%
Middle school	1%	38.8%	60.2%
High school	-	29.1%	70.9%
University students	2.7%	18.7%	78.5%
Teachers	2.9%	24.4%	72.7%

The next question (Qn2) is whether the concept of the direction of a force is understood. From the answers, it is found that in the ages of 11 (primary school), only 39.1% of the sample gives the correct answer (same line and opposite direction). In the ages of 15 and 17, we see 58.9% and 62.1%, respectively. At the age of 21, the percentage increases to 68.5%, and finally, it is noteworthy that the teachers answer correctly only 50.5%. The force vector concept turns out to be difficult since four out of 10 cannot understand it scientifically correctly in all age groups (**Table 2**).

Table 2. (Q2) In a high-five with a friend, what is the direction of forces engaged by both boys' hands on the other's hands?

	(A) Same line and same direction	(B) Same line and opposite direction	(C) Different line and different direction
Primary school	40.6%	39.1%	20.3%
Middle school	3.2%	58.9%	37.9%
High school	3%	62.1%	35%
University students	6.4%	68.5%	25.1%
Teachers	1.4%	50.5%	48.1%

Question 3 deals with whether force is related to the apparent effect of its reaction. The correct answer (in both cases) is attributed only by 46.1% at the age of 11. At the age of 15 rises to 75.4%. At the ages of 17 and 21, we have 94.1% and 93.6% respectively and finally the age group of teachers at 92.3% (**Table 3**).

Table 3. (Q3) When is a force exerted?

	(A) When pushing a bike	(B) When pushing against a wall	(C) In both cases
Primary school	28.9%	25%	46.1%
Middle school	20.5%	4.1%	75.4%
High school	3%	3%	94.1%
University students	5.5%	0.9%	93.6%
Teachers	7.2%	0.5%	92.3%

The next question (Qn4) detects whether the force is related to the results of its action in motion. Most in the age group of 11 possibly associate the action of a body only with movement; that is why we have low percentages in the correct answers, 27.6% (in both cases). At the age of 15, it reaches 80.9%, and at 17 years of age, 91.1%. At 21 years, the percentage reached 90.9% and in the age groups of teachers 93.7% (**Table 4**).

Table 4. (Q4) When is a force acting on a body?

	(A) When we start moving a body	(B) When we stop a moving body	(C) In both cases
Primary school	61.1%	11.3%	27.6%
Middle school	17%	2.1%	80.9%
High school	5.9%	3%	91.1%
University students	8.2%	0.9%	90.9%
Teachers	3.9%	2.4%	93.7%

Question 5 detects the well-known alternative idea that students have about the concept of force called the Aristotelian perception, that is, force is associated with the movement of a body. The correct answer is given by 44.9% in the age group of 11. At 15 years, it becomes 54.6%, and at 17, it does not change significantly, reaching 52.7%. In the 21 and age groups of teachers, the percentages go up 68% and 62.5%, respectively (**Table 5**).

Table 5. (Q5) When does a football player exert a force on a ball?

	(A) When the player shoots the ball	(B) When the player moves towards the nets without the ball	(C) In both cases	(D) In no case
Primary school	44.9%	0.5%	54.6%	-
Middle school	53.7%	2.1%	42.1%	2.1%
High school	52.7%	-	47.3%	-
University students	68%	3.7%	27.4%	0.9%
Teachers	62%	2.5%	34.5%	1%

The last question (question 6) is in the same spirit as the previous one except that there are no alternatives (in both cases) and (in no case). The answers show that most age groups give the correct answer (When the stone its ready to leaves the hand). In 11 years, we have 84.3%, 15 92.8%, and 17 97%. At 21 86.3% and in the age groups of teachers, we observe 97.6% (**Table 6**).

Table 6. (Q6) A child throws a stone. When does the child exert a force on the stone?

	(A) When the stone its ready to leaves the hand	(B) When it's in the air
Primary school	84.3%	15.7%
Middle school	92.8%	7.2%
High school	97%	3%
University students	86.3%	13.7%
Teachers	97.6%	2.4%

From **Table 7**, there is an alternation of the statistical difference and the random variations between the different levels of education answers. The above concludes that the correct scientific answer or alternative idea to a physics concept has to do with the level of education and what it entails (age, experiential experience, and repetition of teaching the concept). It is of particular interest to investigate whether such a relationship exists and what information its possible existence may provide.

Table 7. Statistical analysis of the results using the χ2 criterion for pairs of groups for the levels of education

Question	Primary school Middle school	Middle school High school	High school University students	University students Teacher
1	S.D.	S.D.	S.D.	R.V.
2	S.D.	R.V.	S.D.	S.D.
3	S.D.	S.D.	R.V.	R.V.
4	S.D.	S.D.	R.V.	R.V.
5	S.D.	S.D.	S.D.	R.V.
6	S.D.	R.V.	S.D.	S.D.

Note. S.D.: Statistical difference & R.V.: Random variation

For research question (2), the percentage of correct answers in each research group was isolated from the research data. The graphs were made according to the age of the respondents from each level of education. It is easy to calculate an age for all levels of education (except teachers) since students belong to the same class. The teachers had stated their ages. With this definition of variables, the survey data (correct answers by age) take the form of **Table 8** for the six questions.

Table 8. The percentage of correct answers per question and per age

Age	Qn.1	Qn.2	Qn. 3	Qn. 4	Qn. 5	Qn. 6
11.0	36.3	39.1	46.1	27.6	44.9	84.3
15.0	60.2	58.9	75.4	80.9	53.8	92.8
17.0	70.9	62.1	94.1	91.1	52.7	97.0
21.0	78.5	68.5	93.6	90.9	68.0	86.3
27.0	60.0	40.0	90.6	90.0	65.1	97.6
32.0	70.5	41.9	94.5	87.5	62.1	95.3
39.0	71.2	64.2	92.5	95.5	62.1	97.6
45.0	72.7	51.7	93.1	93.7	61.0	94.7
50.0	83.3	58.8	85.1	85.7	63.4	93.7

As one can easily discern from Table 8, it is observed that in the age groups 11 to 17, and in the six questions that have to do with the concept of force we have a statistical difference, which clearly indicates that age and what it contains (experiential experience, educational level, gender and socioeconomic status not studied in this research) play a role in students' correct answers.

On the other hand, in the age groups 21, 27, 32, 39, 45, and 50 respectively, there is a variation of the correct answers of the future and active teachers, not to such an extent as the students, notwithstanding this does not mean that it negates that even in these age groups there is a statistically significant difference.

From all the graphs that emerged for the six questions, it is evident that the percentage of the correct answer depending on the respondents' age can be described by a mathematical function (straight, exaggerated). However, it is interesting to require that the curves of all questions be characterized by a single mathematical function, which may also provide an empirical rule for how the scientific conception of a concept of physics changes with age through the levels of education.

The use of LAB Fit Curve Fitting Software V. 7.2.48 for all the data from all the questions in the questionnaire gave those two mathematical functions that can describe those (Leibowitz et al., 2010). The mathematical functions that resulted from the software and satisfied all the data for all six questions are the second-order exaggeration: Y=A/X2+B, and the sigmoid curve (logistic function) of the form: Y=A/(1+exp(-(xB)/C)), where X is the age and Y is the percentage of correct answers to each question.

However, the second-order exaggeration curve gives that the percentage of correct answers gets negative values for age and below (about seven years), a fact with no logical significance. So, the only proper mathematical function that describes all the data for all six questions is the sigmoid curve. In a recent paper, a mathematical approach has been presented that the learning curve in the attempt to acquire knowledge of something takes the form of a sigmoidal curve if a person has some interest in this object (Leibowitz et al., 2010). The findings of the present study are in line with the above work. In all levels of education, the concept of force is taught, with the result that as a person ages, the more and more often deals with this concept.

The constant C, was calculated for almost all questions at a value close to 2, which simplifies the original function in the form: Y=A/(1+exp(-(x-B)/2)). The constant A is essentially the maximum percentage of correct answers to a question, which can exist as the level of education increases and age. If the constant A has a significant value (the maximum that can be reached is the value 100), then it means that most respondents' perception of a physics concept is scientifically correct. If constant A has a small value, then it means that there is no correct scientific conception of a concept, but there are still alternative solid ideas.

The constant B has units in years and essentially expresses the function's derivative as a maximum. It is the point where the slope of the sigmoid curve changes and where the correct answers begin to increase significantly. The value of constant B is for the value of Y=A/2. The higher the value of constant B, the older age, the more correct answers appear. The application of the function, which describes the research data for questions 1 and 4, is shown in **Figure 2** and **Figure 3**. The Y-axis is the percentage (%) of the correct answers to the question, and the axis-X (X-axis) is that of age.

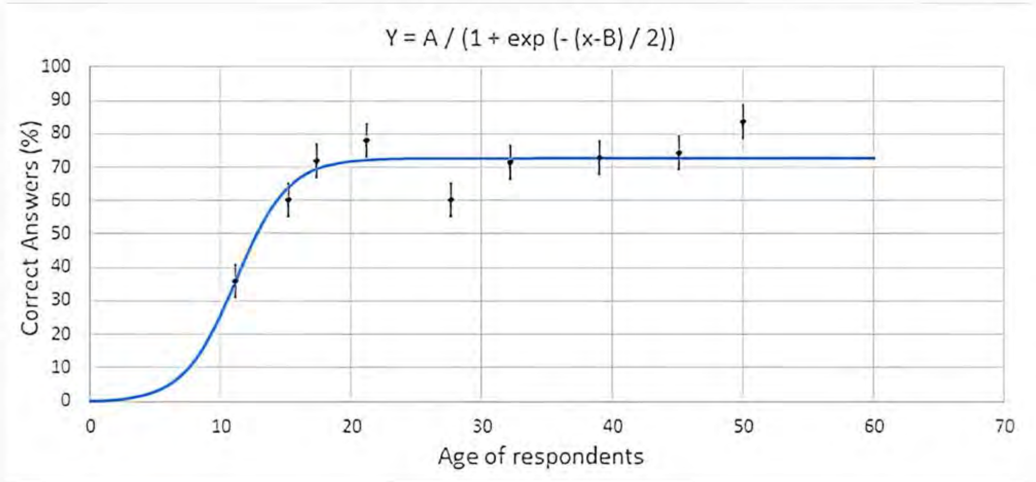

Figure 2. The research data for question 1 and the curve that describes them

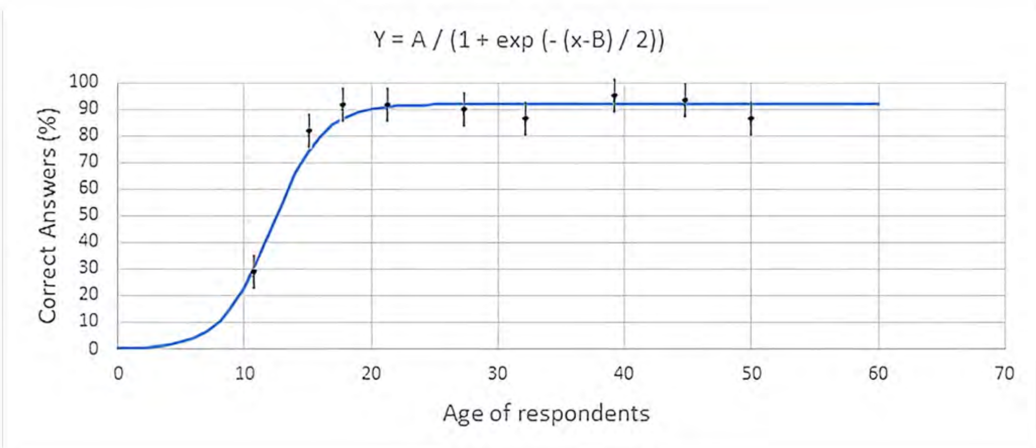

Figure 3. The research data for question 4 and the curve that describes them

The constants A and B, their errors σA and σB respectively, and the correlation coefficient R2, as calculated by the software, are presented in **Table 9**.

Table 9. The constants A and B of the sigmoidal curve describing the research data for each question

Question	Concept	A	±σA	B	±σB	Correlation factor (R^2)
1	Force (effect)	72.5	2.4	11.1	0.7	0.94
2	Force direction	56.0	3.6	9.0	1.9	0.78
3	Force-motion	92.0	1.6	11.1	0.3	0.98
4	Force-motion	91.9	1.8	12.2	0.4	0.98
5	Effect of force	61.7	1.6	9.3	0.7	0.96
6	Effect of force	94.7	1.3	7.0	0.7	0.99

DISCUSSION

The current study provides evidence for the progression and consistency of students' conceptions about concepts in classical mechanics across distinct age groups. There are not a lot of longitudinal studies in the Greek education system that record students' understanding of such concepts from primary (11) to high school (17) and even university students (21) or for primary school teachers (27-50), in an interpretative manner.

From the data in table 9 above, it appears that there are questions where the value of constant A indicates that they can reach a large percentage of correct answers after all age groups. Such questions are 3, 4, and 6, which could be characterized as easy to obtain scientifically-accurate understanding. On the other hand, there are questions where the value of constant A indicates that they cannot reach a large percentage of correct answers after all the age groups. The constant B, which expresses years, suggests that there are questions where the respondent begins to answer correctly at a young age. Such questions are 2 and 5, which could be described as challenging to obtain scientifically correct understanding.

In the case of the concept of force, the conclusion is that it can begin to be taught possibly better at the age of 9.95 years. That's why it is the average of the constants of parameter B, as shown in **Table 9** above. What will be taught about force or what is needed before it is conducted depends on the values of parameter A since we know today the existing way of teaching. For example, in question 2, which is related to the concept of direction, A's value is low, which indicates that this feature of force is difficult to understand in the way it is taught today. In contrast to questions 3 and 4, which relate to the relationship of force to the motion of bodies, A's value is close to 92, which means that this property of force is easy to understand in the way it is taught today.

CONCLUSIONS

As our analysis shows, there is a correlation between AC and all age groups of students and teachers regarding the concept of force. Each person has created their own mental model and alternative ideas to explain the natural phenomena they observe and are related to concepts of physics. Research has shown that there are alternative ideas for the concept of force in all age groups. The large or small reduction in the percentage of alternative ideas depends on characteristics related to the concept of force, and the age of the respondents. Other factors mentioned above (gender, experiential experiences, socioeconomic status, religion, etc.), which are not analyzed in our research, may play a role in the correct answers and it would be interesting to study in future research together with other studies in this field.

The sigmoidal curve, which describes the increase in the correct answers concerning age, makes it possible to attribute whether the concept is difficult or not, depending on its ceiling value. Also, the result is obtained, at what age, the correct answers start to be given by the students, which means when the concept can start to be taught. This curve is the learning curve for the specific concept of physics.

Admittedly, the result of the research needs further investigation and even at the ages of 7 to 15 years to become stronger. Other factors that were not studied in this research and related to the provided education such as teaching methods, quality of education, technology infrastructure, or factors related to the students such as social environment and religious background need to be examined further. In conjunction with other studies on this subject, the results presented here are anticipated to help teachers develop more effective educational methods, construct analytical programs, and design improved curricula programs.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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