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An Empirical Study on the Evolution of Students' Perceptions in Basic Concepts of Physics of Primary and Secondary Education in Cyprus

Dimitris Panagou
University of Ioannina

Konstantinos T. Kotsis
University of Ioannina

Georgios Stylos
University of Ioannina

ABSTRACT

In recent years, more and more systematic research has been conducted in science fields, focusing on identifying alternative ideas that the students have for essential concepts and principles of physics. This has resulted in the production of essential and valuable international bibliographic information in various science fields, including mechanics. In the present paper, we focus on physics, particularly in classical mechanics, including key concepts such as weight, energy, force, action/reaction, and work. A multiple-choice questionnaire was given to senior students of primary school, middle school, and Cyprus's high school. We analyzed the percentage of correct and incorrect responses of the three survey groups to determine whether the responses were related to the group's age or representative of statistical fluctuations. For most questions, there was a statistically significant correlation with age, as opposed to gender, which does not appear to play a role in students' correct answers. In particular, our results suggest that the alternative conceptions of students, reflecting misconceptions and preconceptions, reduce with age or equivalently with the education level. Nevertheless, there are also many questions for which such a correlation cannot be established. Our study can be used in science teaching, on the design of curricula, and teachers' professional development.

Keywords: alternative ideas, physics sciences, mechanics, curriculum, professional development of teachers

Introduction

The constructivist learning approach advocates that learning materializes when new knowledge is associated with existing knowledge (Dysthe, 2002; Matthews, 2002; Taber, 2002). Research in the field of science education in the past years suggest that students enter the educational process while holding their ideas and conceptions on scientific principles. Such ideas reflect preexisting views and primary perceptions of physical phenomena and typically create obstacles in the learning process (Duit, 2004).

In the pertinent literature, one encounters many studies regarding students' alternative ideas on concepts such as force, motion, heat, temperature, power, and energy (Arslan & Kurnaz, 2009; Kurnaz & Arslan, 2011). Further studies worldwide have also reported and confirmed students' conflicting ideas on force, Newton laws, energy, weight, etc. (Ferreira et al., 2017; Kurnaz & Arslan, 2011; Villarino, 2018).

According to Taber (2014), prior knowledge of what learners already know and understand is a major determinant of what students will learn from their science classes. An abundance of research suggests that very frequently, students may hold ideas about science topics that are different and indeed often inconsistent with canonical scientific principles and theories (Abell, 2000). Bountiful studies have described students' ideas related to science subjects in diversified ways, including misconceptions, intuitive theories, and alternative conceptual frameworks. However, there are no widely agreed meanings for these different terms. These perceptions, which are found today under the term "alternative ideas," are an intrinsic part of the learning process, affecting it deeply. Researchers also accent that students' ideas vary in different dimensions that affect how vital students' thinking is to learning scientific ideas (Taber, 2009). As a result of this, research shows that students can often preserve different physics science ideas that are often incompatible with the correct scientific principles and theories (Abell, 2000). Since students' alternative conceptions are used as a starting point for advanced learning, recent studies have focused on students' alternative ideas (Calik & Kurnaz, 2008).

As stated in the bibliographic review carried out in the theoretical context of the present work, it appears that, in recent years, several kinds of research have been carried out on the exploration of students' alternative ideas in science. However, as the review shows, the literature mainly concerns the foreign educational community. Therefore, in the context of the Cypriot educational community, we do not find an appropriate response to this issue. This is where the interest in this research derives. This work investigates and highlights the possible alternative ideas of students in mechanics concepts, which will contribute to the broader research carried out in teaching, on the design of curricula, and the professional development of teachers in primary and secondary education in Cyprus.

Theoretical Background

"Conceptual understanding" invokes the construction of well-connected and hierarchically organized conceptual structures instead of incomplete and roughly connected knowledge pieces (Delgado et al., 2010). Notwithstanding, research has shown that developing scientific conceptual understanding is somewhat tricky due to the resilience of the alternative conceptions ingrained in larger conceptual frameworks (Skopeliti & Vosniadou, 2014; Treagust & Duit, 2008).

Alternative Conceptions (AC), as these ideas are commonly attributed to nowadays, turn out to be a primary ingredient in students' learning process (Driver & Easley, 1978). In particular, it has been pointed out that AC turn out to be remarkably more persistent and diverse than one would naively expect, eventually affecting students' critical thinking (Taber, 2009). Furthermore, students may also hold various views on scientific subjects, which are often inconsistent with the well-established theories that they are being taught (Abell, 2000). Thus, AC are being formed through mechanisms of empirical understanding. AC are usually developed through daily life experiences in the child's attempt to make sense of the world in which it lives. Hence, in some cases, AC 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 professionals in education must know beforehand 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.

A large-scale factor in the implementation of the constructive model of teaching Physics Sciences is the educator. Ideally, educators must possess both a sufficient scientific background and the pedagogical abilities to impart their knowledge to their students. However, in many studies, it has been pointed out that primary school teachers often hold misconceptions in basic scientific principles similar to those of students. Recent research has extended this observation to secondary school teachers within Turkey in Bayraktar (2009) and international Taber (2008). It is reasonable to expect that the misconceptions of teachers are imprinted in the AC of students. The more these concepts deviate from the established scientific principles, the harder it becomes for students to alter and abandon their AC. Therefore, by studying the presence or absence of AC at different primary and secondary education levels, we can picture the teachers' educational backgrounds. Doubtless, as is usually the case in this research field, such an interpretation should be regarded with caution. Other variables can affect AC's relation with age, including the students' growing mental ability, new mathematical and logical tools at various education stages, cumulative experience, etc.

This study aims not to detect new forms of AC but instead investigate how much they change across the education levels. The survey for this study was an appropriate choice, due to the utilization of a multiple-choice questionnaire format with all questions focused on Classical Mechanics concepts. Classical Mechanics is an area of Physics with a prominent position among all others since it deals with phenomena one meets in daily life. Related concepts such as weight, force, and mass are widely used outside the classroom and in various activities. Additionally, these concepts are used directly or indirectly in almost all other physics areas, such as optics, thermodynamics, electromagnetism, etc. For instance, without the laws of motion, there can be no proper explanation for the kinetic theory of gases or the electromagnetic theory (Carson & Rowlands, 2005).

In the relevant literature, many multiple-choice questionnaires have been developed for investigating AC in Classical Mechanics (Huey-Por et al., 2007; Nieminen et al., 2010). Nevertheless, most of them are addressed to Middle and High School students and become unsuitable for our purpose here. To include Primary School students in the study, our questionnaire needs to involve only basic concepts with which all three groups are familiar. The questionnaire, which has been developed (Kotsis et al., 2002) for Primary School, has also been used (partially) in secondary education (Kotsis & Anagnostopoulos, 2006) and even with undergraduate university students (Stylos et al., 2008). After removing complex concepts targeted at bigger classes, the questionnaire was designed to address all our research groups based on the current curriculum and school textbooks.

Factors Affecting Students' Conceptions of Science

Students' misconceptions on several scientific concepts, including physics, might result from their misunderstanding of basic affairs. This may portray a shortage of skills embodied in scientific literacy, usually affected by several socio-demographic, cognitive, and motivational factors. These factors can be organized by student level, gender, etc. (Organization for Economic Co-operation Development, OECD, 2016). In the individual's socio-demographic level, gender is an alternative factor influencing students' achievement in science (Acar & Tuncdogan, 2018; Martin et al., 2016; OECD, 2016). In many scientific disciplines, males perform better than females in achievement tests (Miyake et al., 2010). The Programme for International Student Assessment survey also indicates that boys tend to demonstrate better performances than girls (OECD, 2016). Other factors that are not investigated in this research are classified in the cognitive domain, affecting students' achievements in their secondary-school specialization and past academic performance (De Clercq et al., 2012). In the affective domain, individuals' motivation towards scientific issues (OECD, 2016; Sun et al., 2012) like their interest (Hidi & Renninger, 2010) and confidence towards the subject (Kang & Im, 2019; Tsai et al., 2017), is positively correlated to science performance (OECD, 2016).

Students' Alternative Conceptions

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; Kalman, 2019). Others characterized students' conceptions as unstable, fragmented, transient, and context-bound (Tytler, 2007; Wood-Robinson & Clough, 2010). Therefore, students' simultaneous use of multiple alternative conceptions sometimes even coexist with scientific ones, as evidenced in their explanations of the same phenomenon. Such diverse and inconsistent explanations were often prompted by context and created in situ by operating various conceptual elements (Taber, 2008; Wood-Robinson & Clough, 2010). 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; Palmer, 1993; Pozo & López-Íñiguez, 2014; Nieminen et al., 2017; Treagust & Chu, 2014; Tytler, 2007). Findings from some studies indicated that few students utilized scientific conceptions across tasks with equivalent content. Numerous students inconsistently utilized different AC in response to different tasks (Alonzo & Steedle, 2009; Palmer, 1993; Treagust & Chu, 2014; Tytler, 2007).

Notwithstanding, teachers must acknowledge and comprehend their students' misconceptions to apply teaching techniques for their transformation (Slater et al., 2018). Nonetheless, it has been found that this is not happening, and students graduate from school and university with their former perceptions (Chu et al., 2012).

Selecting Physics Domain

In the context of our research, we focus on the field of Classical Mechanics to detect students' alternative ideas. It would be impossible to provide a questionnaire covering all areas of Physics. However, our specific choice is also motivated by the fact that

> "mechanics" is a physics field with a prominent place among its other fields, such as light, sound, heat, electricity, etc. That is true because these areas are defined by mechanics in the sense that, without the laws of motion, for example, there would be no kinetic theory of gases or there would be no electromagnetic theory. (Carson & Rowlands, 2005, p. 476)

The field of mechanics also declares that the ideas of weight, force, and mass comprise the foremost basic physics ideas and primarily concern physics general knowledge (Seker & Welsh, 2006). Also, Galili (1995) characteristically states that: "physics is thought as a particularly fertile ground" for students' perceptions (p. 371). An enormous structure that nowadays we tend to decision physics consists of many sectors. The importance of Mechanics is more significant than any single one in all these areas. It defines the "rules of the game," defines most physics tools, and presents nature's foremost universal laws. It introduces the basic strategies of physics that apply to all other areas. That is why mechanics continually guide each physics curriculum.

Purpose of the Study

In the context of the Cypriot educational reality, this study intended to examine how the progression and consistency of students' understanding of physics concepts in everyday contexts changed across grade levels. Subsequently, we tried to notice if a conceptual change takes place from tier to tier (educational) and which concepts of mechanics it focuses on. The main objective of this paper is to highlight the possible alternative ideas of students to the concepts of Mechanics, 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 Cyprus. This research was prepared to investigate the following fundamental questions:

1) How consistent are students in their scientific and non-scientific (alternative) understandings of physical concepts across the different grade levels?
2) Is there a statistically significant difference in students' understanding across the concepts of Mechanics or based on their level of education?
3) Is there a statistically significant difference in students' understanding of the concepts of Mechanics based on gender?

The statistical criterion χ^2 test was applied through the SPSS program (Table 3) to achieve the first objective. That enables us to determine whether the answers given to the survey questions for each primary and secondary education class are independent of each other. For the second goal, the questions have been first grouped according to the relevant general concepts (i.e., Force, Action/Reaction, Weight, Energy, Work) (see Table 4). Besides, the average degree of correct answers has been calculated in each category (see Table 7). In the end, the average grades were compared both between classes, using the paired samples t-test, and between training levels, using the one-way ANOVA (see Table 6). In the case of multiple comparisons, the Bonferroni correction has been used. A t-test has been performed to achieve the third goal, associating the final score of correct answers with gender to determine if gender plays any role in the percentage of correct answers (see Figure 2).

Methodology

Initially, a Detailed Research Plan was submitted to the Ministry of Education and Culture of Cyprus (Directorate of Primary and Secondary Education). After approval and securing the required license, the investigation proceeded. Students, parents, teachers, and principals were primarily informed about the research aims and participated voluntarily. The research was conducted in May – June (2019) in primary schools and September – October (2019) in middle and high schools. The same questionnaire was used for data collection in all classes.

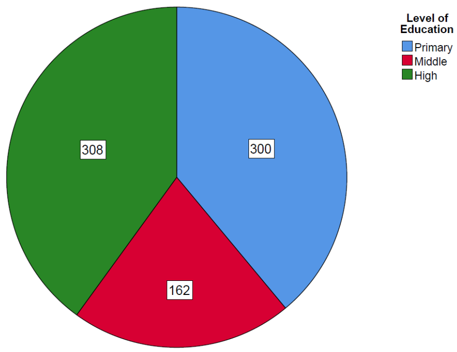
In this article, we investigate the AC of students related to Physics. Our survey sample consists of students attending primary and secondary education classes in Cyprus. According to their age/education level, candidates chosen from schools in five different cities were split into three groups. These included seniors in primary school (age 11), in middle school (age 14), and in high-school (age 17), following the standard 12-grade educational system of the country. All candidates were provided with a multiple-choice questionnaire of closed-form. It includes basic physical concepts such as weight, energy, force, action-reaction, and work. Statistical analysis based on their answers was performed with the use of the χ^2-test (Wagner, 2019) and with the help of the IBM SPSS Statistics 25 computer software (Field, 2013).This was a cross-sectional study (Zhou et al., 2015) involving students from three grade levels (primary school (6^{th} grade), middle school (3^{rd} grade), and high school (3^{rd} grade)) (Olsen & Diane, 2004). The methodology adopted for this study was quantitative in nature. Survey data were collected at a single time from students of three grade levels without any intervention or change to the learning environment.

Participants and Research Context

As aforementioned, our study targets populations in primary, middle, and high school. The total number of students in our sample is N=770 chosen from several public education facilities in five Cyprus cities: Limassol, Larnaca, Nicosia, Paphos, and Famagusta. The choice of schools was made using random sampling to avoid research bias. Students from each grade level were almost evenly distributed by gender. The survey groups corresponded to three specific education classes: the 6^{th} grade of Primary School (age 11), the 3^{rd} grade of Middle School (age 14), and the 3^{rd} grade of High School (age 17). The specific number of students in each group is given in Figure 1. Our analysis is based on a comparison of the answers received from the three groups. The survey was carried out in May-June (2019) in Primary Schools and September-October (2019) in Middle and High Schools.

Figure 1

Number of Students Participating in Each of the Three Survey Groups of the Study and Their Corresponding Education Level



Data Collection – Instrument

In the context 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 can be answered by primary, middle school, and high school students.

Initially, the questionnaire contained 28 questions since it was also addressed to the pedagogical department's undergraduate students (Kotsis, 2005). However, because the present study also specializes in primary school students, some questions that contained complex concepts were removed to make the questionnaire more accessible. After the changes were made on the changing and differing educational policies, the differing aims, and needs of education, the questionnaire was formulated based on current data (school textbook, curriculum) into 20 questions. 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 the questionnaire was within the capabilities of the final grades of primary school, while the secondary school teachers characterized it as easy (Kotsis, 2011, p. 40).

The questionnaire has been used in past in studies conducted in Greek schools (Kotsis, 2005). Each question is based on a scenario from familiar everyday environments followed by statements that include the scientific explanation and one or more alternatives (see Table 1). The data was collected using the revised closed type of multiple-choice questionnaire of 20 items mentioned previously. All questions were 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. The questionnaire was tested with 770 students, and the reliability of the Cronbach alpha coefficient was 0.7. According to Nunnally & Bernstein (1994), a Cronbach 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. Besides, the names of the five conceptual groups were modified in the current study, using analysis of variance (ANOVA), with Conceptual Group 1 being titled

Table 1

Questionnaire Based on a Scenario from Common Everyday Environments

Questions	Available answers			
	A	B	C	D
Q1. "What is the effect of force acting on a body"	*"Deformation"*	*"Change of kinetic state"*	*"Both"*	-
Q2. "In a high-five with a friend, what is the direction of the forces engaged by both boys' hands on the other's hands?"	*"Same direction"*	*"Opposite direction"*	*"Different direction"*	-
Q3." When is a force exerted?"	*"When pushing a bike"*	*"When pushing against a wall"*	*"In both cases"*	-
Q4. ''When is a force acting on a body?''	*'When we start moving a body''*	*'When we stop a moving body''*	*'In both cases''*	-
Q5. ''When does a football player exert a force on a ball?''	*'When the player shoots''*	*''When the player moves towards the nets''*	*''In both cases''*	*''In no case''*
Q6. ''A child throws a stone. When does the child exert a force on the stone? ''	*'' When it leaves the hand''*	*'When it's in the air''*	-	-
Q7. '' I stumble upon a stone that I move. The stone:''	*''Wields force on me, too''*	*'Doesn't wield force on me''*	-	-
Q8. ''I hit my hand on a table and my hand hurts, because: ''	*'I exerted force on the table''*	*'The table exerted force on me''*	-	-
Q9. ''When we swim, we push the water backwards with a force and this pushes us forward' with a force''	*''Correct''*	*''Incorrect''*	-	-
Q10. '' When we walk, we push the ground:''	*''Forward''*	*"Backward"*	-	-

Questions	Available answers			
	A	B	C	D
Q11. "When can we drive a car more safely on an icy road? When it is: "	*"Empty"*	*"Loaded"*	-	-
Q12. " A small car and a heavy truck wait in front of a red light. After the green light turns, they develop the same speed. Which one will start faster?"	*"The small car will start faster"*	*"The heavy truck will start faster"*	-	-
Q13. "The weight of the body is: "	*" A force"*	*"A property"*	*"Mass"*	-
Q14. "Gravity on the moon is smaller than gravity on earth. The weight of a chocolate is: "	*"Smaller on Earth than on the moon"*	*''Bigger on Earth than on the moon"*	*''The same on Earth and on the moon"*	-
Q15. " When you are at sea and lift a stone inside water, the weight of the stone is:"	*"Bigger in the water"*	*"Smaller in the water"*	*"The same"*	-
Q16. " An apple is hanging on the branch of an apple tree and another is falling to the ground. Which of the two produces work? "	*"The falling apple"*	*"The hanging apple"*	*''Both apples"*	*"Neither of them"*
Q17. " You go up to the second floor of your house, once empty, once loaded with stuff. When do you spend more work?"	*"When you're empty"*	*''When you're loaded"*	*''The same"*	-
Q18. "Two athletes with the same weight and height run for 100 meters. Who consumes more energy?"	*''The one who finishes first"*	*''The one who finishes second"*	*''They consume the same energy"*	-
Q19. "When does a truck have more energy?"	*"When it moves"*	*''When it's stationary"*	*''It always has the same"*	-
Q20. "Two weightlifters lift the same weight. Who spends more energy?"	*''The one who's taller"*	*"The one who's shorter"*	*''The same both"*	-

"Weight," Group 2 "Energy," Group 3 "Work," Group 4 "Force," and Group 5 as "Action-Reaction" (see Table 4). Since the questions concerned five different physics fields, it was chosen to group them in this way. The participants responded to the questionnaire items within one class period (40 min). Before administering the test, the volunteer participants were informed that their responses to the questionnaire would not affect their course grades but would be used for research purposes to evaluate their understanding of physics (mechanics).

Data Analysis

Among the data from the 20-item questionnaire, items with 2, 3, or 4 (a, b, c, d) 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 student 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.

For research question RQ (1), using the re-coded data, the percentage of each group of students' scientific responses to each item was calculated (Table 3). The patterns of change in understanding each physics (mechanics) concept (e.g., force, energy, weight, Etc.) were compared across grade levels (Table 4). Also, all students' total standard questionnaire scores (20 items were included) were calculated.

Results

The questionnaire responses' processing was performed using the statistical package SPSS V.25 (Landau & Everitt, 2004). To investigate whether the answers to the survey questions depend on education, we used the χ^2-test as a statistical control criterion. Table 2 summarizes the results of the χ^2 test mentioned previously for each question separately.

Table 2

Comparisons of the Chi-square Test on the Correctness of the Responses Depending on the Education Level

Question	χ^2	*Df*	*P*		Pairwise
1	36.642	2	<0.001	Statistical difference	1<2<3
2	23.108	2	<0.001	Statistical difference	1<2=3
3	73.126	2	<0.001	Statistical difference	1<2<3
4	18.753	2	<0.001	Statistical difference	1=2<3
5	5.891	2	0.053	Random Variation	-
6	5.818	2	0.055	Random Variation	-
7	12.223	2	0.002	Statistical Difference	1<2<3
8	50.149	2	<0.001	Statistical difference	1<2<3
9	3.440	2	0.179	Random Variation	-
10	6.981	2	0.03	Statistical difference	1=2<3
11	7.816	2	0.02	Statistical difference	1=2<3
12	6.038	2	0.049	Statistical difference	1=2=3
13	40.820	2	<0.001	Statistical difference	1<2=3
14	1.762	2	0.414	Random Variation	-
15	5.556	2	0.062	Random Variation	-
16	5.854	2	0.054	Random Variation	-
17	2.929	2	0.231	Random Variation	-
18	32.700	2	<0.001	Statistical difference	1=2<3
19	4.513	2	0.105	Random Variation	-
20	4.527	2	0.104	Random Variation	-

Table 3 shows the percentages of students who provided scientifically correct responses to each questionnaire group at each grade level. From the statistical analysis of the data carried out, one can see a statistically significant difference in the respondents' level of education.

RQ (1) How consistent are students in their scientific and non-scientific (alternative) understandings of physics (mechanics) concepts across the different grade levels?

Table 3

Percentage of Students' Correct Answers Across Groups

Questions	*% Of Scientific Responses*		
	Group 1[a] (N =300)	Group 2[b] (N=162)	Group 3[c] (N=308)
Q1. "What is the effect of force acting on a body"	40.2	52.5	64.8
Q2. "In a high-five with a friend what is the direction of forces engaged by boys' hands on the other's hands?"	50.5	64.8	69.1
Q3." When is a force exerted?"	48.7	79	78.2
Q4. "When is a force acting on a body?"	45.5	48.1	62.2
Q5. "When does a football player exert a force on a ball?"	60.4	71.3	61.4
Q6. "A child throws a stone. When does the child exert a force on the stone?	87.5	93.8	91.9
Q7. "I stumble upon a stone that I move. The stone:'	66.7	82	72.6
Q8. "I hit my hand on a table and my hand hurts, because:"	40.1	74.1	56.4
Q9. "When we swim, we push the water backwards with a force and this pushes us forward' with a force"	88.9	90.7	85.3
Q10. "When we walk, we push the ground:"	78	77.2	85.3
Q11. "When can we drive a car more safely on icy road? When it is:"	71.8	68.5	79.3
Q12. "A small car and a heavy truck wait in front of a red light. After the green light turns, they develop the same speed. Which one will start faster?"	84.5	85.8	90.9
Q13. "The weight of the body is:"	30	49.4	55.1
Q14. "Gravity on moon is smaller than gravity on earth. The weight of a chocolate is:"	61.3	64.8	66.4
Q15. "When you are at sea and lift a stone inside water, the weight of the stone is:"	16.9	24.8	23.5
Q16. "An apple is hanging on the branch of an apple tree and another is falling to the ground. Which of the two produces work?"	58.8	62.1	51.5
Q17. "You go up to the second floor of your house once empty once loaded with stuff. When do you spend more work?"	82.5	76.1	81.6
Q18. "Two athletes with the same weight and height run for 100 meters. Who consumes more energy?"	37.7	44	60.5
Q19. "When does a truck have more energy?"	72.1	72.3	79
Q20. "Two weightlifters lift the same weight. Who spends more energy?"	30.7	23.9	33.4

Note. [a] Primary school (11), [b]Middle school (14), [c]High school (17)

From Table 2, it is observed that there is a statistically significant relationship between the level of education and the percentage of correct responses in eleven (11) questions out of twenty (20). This result indicates that the answers' correctness depends on the education level in most of the questions. Many variables can affect this phenomenon, such as mental development (Rapp, 2005), teaching method (Sperandeo-Mineo et al., 2006), experiential experience (Wallace & Brooks, 2014), and other factors that cannot be isolated in the present research (Hazari et al., 2010).

Nevertheless, it is interesting to investigate in detail by class pairs if and to what extent there is a statistically significant difference in the answers to each question's questions separately. Specifically, we collect groups from education classes, i.e., for the groups of primary-middle (pair1), middle-high (pair2), and primary-high (pair3) education.

To avoid listing multiple pages with shapes and relevance tables, we quote only a table that summarizes the values of χ^2, degrees of freedom (df), and the level of statistical significance (p). In the list of "pairwise," we distinguish per education pair, which pair is superior, depending on the students' percentage of correct responses (see Table 2).

As previously mentioned, the names of the five conceptual groups were modified in the current study, using analysis of variance (ANOVA), with Conceptual Group 1 being titled "Weight," Group 2 "Energy," Group 3 "Work," Group 4 "Force," and Group 5 as "Action-Reaction" (see Table 4). The percentages of scientific concepts that include five different physics concepts at different education levels can be seen in Table 4.

Table 4

Percentages of Students Who Consistently Provided Scientific or Nonscientific Responses Across Concepts

Concept Group	**Item**	**% Of Scientific Responses**		
		Group 1[a] (N=300)	Group 2[b] (N=162)	Group 3[c] (N=308)
Force	Q1, Q2, Q3, Q4, Q5, Q6, Q12	59.9	70.8	74.1
Weight	Q13, Q14, Q15	36.1	46.3	48.6
Work	Q16, Q17	70.8	69.8	66.7
Energy	Q18, Q19, Q20	46.9	46.8	57.9
Action/Reaction	Q7, Q8, Q9, Q10	68.5	81.4	75

Note. [a] Primary school (11), [b]Middle school (14), [c]High school (17)

Table 5 presents each question's meanings for the statistical or random variation of each education level's difference to overview all the research questions. The audit was performed by using the χ^2 criterion here as well. In Table 5, we give only the final aggregated results. The table displays, for each pair of education groups, only the information for each question's relevant physical concept and the statistical conclusion, namely whether the result reflects a Statistical Difference (SD) or a Random Variation (RV). In Table 5, one may notice several interesting patterns from the responses to the questionnaire. In questions 1,5,7,and 8, one observes a Statistical Difference for pairs of groups (1-2, 2-3), while in questions 9,12,14,17, and 19, one observes random variation instead. In questions 4,10,11,16,18, and 20, there is a random variation for "primary school-middle school" which changes into a statistical difference for "middle school-high school". Of course, such a pattern is also expected. It suggests that students remove slowly and gradually their AC for some physical phenomena through education (Gilbert et al., 2002). It also indicates that the educational system works effectively in this respect. However, we note that for questions 2,3,6,13, and 15, the reverse pattern is observed for groups (1-2, 2-3), suggesting no further improvement in the students' perception of those concepts in later education stages. In pair 1-3, the results are at expected levels, i.e., 11 out of 20 questions, the high school students did better than those of the primary school, of which they are mainly related to the concept of force and action-reaction, probably because the concepts are taught in middle and high school.

Table 5

Statistical Analysis of the Results Using the χ^2 Criterion for Pairs of Groups for the Levels of Education.

Question Concept	[1]Primary school [2]Middle school	[2]Middle school [3]High school	[1]Primary school [3]High school
Q1. Force	SD	SD	SD
Q2. Direction of Force	SD	RV	SD
Q3. Force - Motion	SD	RV	SD
Q4. Force - Motion	RV	SD	SD
Q5. Impact - Force	SD	SD	RV
Q6. Impact - Force	SD	RV	RV
Q7. Action / Reaction	SD	SD	RV
Q8. Action / Reaction	SD	SD	SD
Q9. Action / Reaction (Water)	RV	RV	RV
Q10. Action / Reaction (Ground)	RV	SD	SD
Q11. Friction	RV	SD	SD
Q12. Force - Mass	RV	RV	SD
Q13. Weight - Mass	SD	RV	SD
Q14. Weight - Gravity Field	RV	RV	RV
Q15. Weight - Levitation	SD	RV	SD
Q16. Work	RV	SD	RV
Q17. Work	RV	RV	RV
Q18. Energy	RV	SD	SD
Q19. Energy - Kinetic	RV	RV	RV
Q20. Energy	RV	SD	RV

Note. The Statistical Difference (SD) or Random Variation (RV) is displayed with a brief description of the relevant physical concept attributed to each question.

RQ (2) Is there a statistically significant difference in students' understanding across the concepts of Mechanics or based on their level of education?

Initially, having separated the questions based on concepts (Force, Action/Reaction, Weight, Energy, Work), the average score of the correct answers in each category was calculated separately. The mean scores were then compared between the categories using the paired samples t-test instead of correlation analysis (see Table 6). As is known, correlation analysis is used when the aim is to examine whether there is a correlation between two phenomena (Soh et al., 2010). For example, correlation analysis would be used if our objective was to examine whether students with a high score on "Weight" have a high or low score on "Force". However, that is not our objective. We want to examine whether the score on "Weight" differs or not from the score on "Force". Considering that the same students responded to these questions, a paired-samples t-test is an appropriate test in this research point (Ross & Willson, 2017). Afterward, a one-way ANOVA (see Table 7) analyzed the education levels (Yockey, 2007). In cases of multiple comparisons for the between training levels comparisons, a Bonferroni correction was used. The following tables list the results from the analyses.

Table 6

Comparisons Between the Scores of the Different Pairs of Concepts

	Paired Sample Test **Paired Differences**							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower.	Upper	t	df	Sig. (2-tailed)
Pair 1. Force / Action-Reaction	-0.05827	0.26460	0.00955	-0.03951	-0.03951	-6.099	766	0.000
Pair 2. Force / Weight	0.24627	0.30677	0.01108	0.22453	0.26802	22.233	766	0.000
Pair 3. Force / Work	-0.00995	0.36635	0.01322	-0.03590	0.01600	-0.753	767	0.452
Pair 4. Force / Energy	0.16464	0.31364	0.01135	0.14235	0.18693	14.500	762	0.000
Pair 5. Action - Reaction / Weight	0.30566	0.32588	0.01178	0.28253	0.32879	25.943	764	0.000
Pair 6. Action - Reaction / Work	0.04896	0.39596	0.01431	0.02087	0.07704	3.422	765	0.001
Pair 7. Action - Reaction / Energy	0.22544	0.35616	0.01292	0.20008	0.25080	17.450	759	0.000
Pair 8. Weight / Work	-0.25544	0.43946	0.01588	-0.28661	-0.22427	-16.087	765	0.000
Pair 9. Weight / Energy	-0.08004	0.38451	0.01395	-0.10742	-0.05266	-5.739	759	0.000
Pair 10. Work / Energy	0.17738	0.40357	0.01462	0.14868	0.20608	12.133	761	0.000

Table 7

Impact of the Education Level in the Score of Each Category of Physics Concepts

Question Concept	Group 1 Primary School (11)	Group 2 Middle School (14)	Group 3 High School (17)			
	M (SD)	M (SD)	M (SD)	F	p	Post-Hoc
Weight	0.35(0.26)	0.46(0.31)	0.48(0.30)	15.043	<0.001	2<1
Energy	0.47(0.27)	0.46(0.24)	0.57(0.26)	15.590	<0.001	3<2
Work	0.70(0.33)	0.68(0.33)	0.66(0.31)	1.172	.310	-
Force	0.59 (0.23)	0.70 (0.21)	0.74 (0.22)	34.168	<0.001	2<1
Action/Reaction	0.68 (0.25)	0.80 (0.23)	0.74 (0.26)	13.338	<0.001	1<3<2

RQ (3) Is there a statistically significant difference in students' understanding of the concepts of Mechanics based on gender?

A total score (score_total) of the correct answers was created depending on the gender of the respondents. From the total sample (*N* = 770), 375 students were boys and 395 girls. A t-test was performed with the final score of the correct answers per gender to determine if gender plays a role in the percentage of correct answers. Looking at the Mean Difference (see Figure 2), we notice that boys' average grade is 0.58 lower than girls, which practically shows us that there is no difference between students' sexes. This result contrasts with several studies (Kahle, 2004; Murphy & Elizabeth, 2006; Sjoberg & Imsen, 1998; Soerensen, 1991) that want boys to perform better in physics. This is not confirmed here.

Figure 2

Total Score of Correct Answers Depending to Gender

Independent Samples Test										
		Levene's Test Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig.(2-tailed)	Mean Difference	Std.Error Difference	Lower	Upper
score_total	Equal variances assumed	1.113	.292	-2.365	768	.018	-.57826	.24450	-1.05822	-.09830
	Equal variances not assumed			-2.367	767.755	.018	-.57826	.24428	-1.05780	-.09873

Discussion

The current study results provide evidence for the progression and consistency of students' conceptions about concepts in classical mechanics across distinct educational levels. There are no longitudinal studies in the Cyprus education system that record students' understanding of such concepts from primary to high school in an interpretative manner.

As our analysis shows, there is a correlation between AC and the age/education-level of the students concerning physical concepts. In eleven (11) out of twenty (20) questions, the results suggest that the AC reduces with students' age, as one would expect. Nevertheless, for the other nine (9) questions, such a correlation cannot be established with sufficient statistical significance.

This conclusion suggests that age/education, although a primary factor driving AC's suppression, is not solely responsible for their presence. As for the percentages of correct answers based on the concepts of physics, the results range in logical and expected contexts, i.e., primary school students in the lowest percentages of correct answers and high school students in the highest, except for the answers of the concept "work", mentioned previously. Also, it became clear that the "student gender" factor does not play a role in whether they will answer the questions of physics correctly or incorrectly.

Other factors related to the provided education such as teaching methods, quality of education, technology infrastructure, or related to the students like social environment and religious background, possibly particularly significant, need to be examined further. Together with other studies in this subject, the results presented here are expected to help teachers develop more effective educational methods, construct analytical programs, and design curriculum.

Conclusions

In conclusion, it should be emphasized that students rely primarily on their perceptions, which are sometimes intuitive and sometimes empirical. However, their education's scientific knowledge often results in contradictions and confusion between pre-existing and new knowledge. The research showed that there are alternative ideas of students in different concepts of physics in all classes. In most cases, there is a change in these ideas over time, and that this phenomenon may show some reduction. However, it does not cease to exist even at the highest education levels, which means that more emphasis should be placed on this issue.

The teacher's teaching approach should consider that children's alternative ideas cannot be ignored because teaching will not be linked to learning. It is a point that must be paid special attention by all actors in the education system so that from Primary School, the student begins to acquire scientific knowledge. Further research is needed that will include more detail and more variables that can affect the phenomenon and describe more accurately the root of the problem. Ideally, it will be possible to implement a teaching system where teachers will know the appropriate age that students should be ready to teach the relevant concepts of physics. The research conclusion deserves a special observation where the proper processing by various educational institutions (e.g., Universities, Pedagogical Institute, Ministry of Education and Culture) can be led to a qualitative improvement of students' learning performance in the course of Physics Science.

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Dimitris Panagou (dimitrispanagou@yahoo.com) Is a primary school teacher. He graduated from the Democritus University of Thrace in 2015 and completed his master's degree at the University of Ioannina with an emphasis on physics sciences in education in 2021. In the same year, he started his Ph.D. at the Pedalogical department of primary education of the university of Ioannina with an emphasis on didactics of physics.

Konstantinos T. Kotsis (kkotsis@uoi.gr) received a B.Sc. degree in the Physics Department from the Aristotle University of Thessaloniki, Greece in 1980 and his Ph.D. degree from the University of Ioannina, Greece in 1986. In 1987, he joined the Department of Physics, University of Ioannina, Greece. In 2000, he joined the Department of Primary Education, University of Ioannina, Greece. He is now a Professor at the Primary Education Department, University of Ioannina, Greece, and Dean of the School of Education, University of Ioannina, Greece. He presently teaches the graduate elective course on Didactics of Science in Primary Education and Department of Physics, University of Ioannina. His primary research interests focus on Didactics of Physics, Science Education, Teacher Training, Pedagogy and Education.

Georgios Stylos (gstylos@uoi.gr) teaches physics as Laboratory Teaching Staff of Science Education in the Department of Primary Education at the University of Ioannina, Greece.

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