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CORRELATION OF PRIMARY SCHOOL STUDENTS' MISCONCEPTIONS ABOUT CONCEPTS OF MECHANICS FROM THEIR MENTAL AGE

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Abstract:
This paper presents the results of empirical research conducted on students in the sixth grade of Primary School, misconceptions on concepts of mechanics of Physis, and their mental age. The mental age was determined by the WISC-III psychometric tool that is used to determine the Intelligence Quotient (IQ). The results of this study give a linear relationship between mental age and the number of correct answers given by a student. The meaning of this linear dependence is that the higher the mental age a student has, the more correctly he can perceive some physical phenomena related to concepts of force, weight, energy, work, etc. Also, the influence of the verbal and performance scale on the mental age of WISC-III is discussed in the results.

Keywords: mental age, misconceptions, physics, primary school

1. Introduction

Most students adopt rules and understandings of physics concepts and phenomena dictated by intuition, their senses, and common sense. This way, solid mental patterns are established and transferred to the school. The students adopt these concepts because they have been used, tested, and repeatedly confirmed in the interpretation of physical phenomena and thus become firmly established in their minds. These misconceptions are not irrational or characteristic of a few students (Osborne & Gilbert, 1979). This way, the child and the student can perceive natural phenomena, justify their existence, and predict

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their evolution. The process of prediction and, therefore, the hypothesis is inferential reasoning. It is a process where the student is called upon to synthesize information from various concepts derived from his capacity for observation, use of previous evidence he knows, and empirical experiences he has. The prediction leads to the derivation of conclusions and, essentially, the rules defined by each student for the interpretation of physical phenomena and the creation of perceptions in terms of Physics. Essentially, this process requires the mental stages of analysis and synthesis and the ability to connect new data with existing knowledge. These two components directly depend on the student's cognitive development and, consequently, his mental age. The question, therefore, arises whether there is a relationship between the student's mental age, determined by the intelligence quotient, and the correct perceptions he has of basic concepts in mechanics. We use the mechanics in this research because it is a part of physics in which students have many experiences from their daily life (Clement, 1982).

The internationally known WISC-III scale (Wechsler Intelligence Scale for Children – Third Edition) was used for the determination and evaluation of the mental age of the children in the present research, which was weighted and adapted in Greece in 1997 (Georgas et al., 1997). This test covers children aged 6 to 17 years old and consists of 12 tests. Six of these tests make up the verbal scale, and another six make up the performance scale. The child alternately faces the verbal and the performance tests.

The verbal scale consists of six verbal activities (Information, Similarities, Arithmetic, Vocabulary, Comprehension, and Number Memory). It examines the child's verbal knowledge and understanding, a knowledge that is usually acquired through children's education, mainly at school. It also examines the child's ability to use this knowledge in a new situation.

The performance scale consists of six activities (Picture Completion, Coding, Picture Sequencing, Cube Drawings, Picture Assembling, and Mazes). It examines the child's ability to understand and organize visual stimuli within a limited time. A child's performance on this scale depends to a large extent on his ability to flexibly use various strategic methods to solve a new type of problem. Each student develops these skills independently and is not the result of children's education at school.

The general intelligence quotient (IQ) results from the sum of the verbal and performance intelligence indices. According to Kaufman (1994), when the student's profile does not show significant differences between verbal and performance IQ, the general IQ can adequately describe the general mental functioning level. General intelligence is the most comprehensive, valid, and reliable indicator of a child's level of mental functioning provided by the WISC-III. A child's performance on an intelligence test has predictive value for several parameters. According to research (Neisser et al., 1996, Greek translation edited by Euclid, 1997), the intelligence quotient allows a pretty good prediction of school performance. It is considered by many to be a general assessment of the child's mental abilities. The Greek WISC-III also allows the examiner to express the child's performance in terms that indicate his mental age, which gives information on the level of cognitive development the child has achieved at any given age (Motti-Stefanidi, 1999).

In a previous pilot study, a questionnaire with eight questions related to the concepts of force and weight was given to 6th-grade children in Primary School to express their misconceptions. Their Intelligence Quotient (IQ) was correlated with the number of correct answers to the questionnaire. The result of this research was a linear relationship between IQ and the number of correct answers. In the present study, the same children were used to answer another seven questions related to engineering concepts such as work and energy (a complicated concept). However, the correlation was preferred not to IQ, but to the mental age derived from IQ, using the WISC-III psychometric tool. The reason that mental age was preferred is that we want to highlight how important it is that there are children of different mental development and, consequently, different levels of knowledge in the same class. In this paper, the results of all 15 questions are presented.

2. Research

The research population was 76 sixth-grade students from two primary schools in Ioannina. They were chosen to be sixth-grade students because they had already been taught physics concepts both in the previous grade and in the 6th grade. The purpose of this research was not to determine students' perceptions (this has been known for years from previous research) but to determine what number of questions they answer correctly, regardless of whether the question is easy, complex, or the concept has been taught. 48.1% of the population are boys, and 51.9% are girls. Students individually answered a 15-question closed-ended questionnaire to record their alternative ideas on simple engineering concepts. The questionnaire questions had been used in previous research on students of the same age (Kotsis & Kolovos, 2002; Kotsis & Vemis, 2002; Kotsis, 2011). Then each student, for about 50-80 minutes, was submitted to the Greek version, a psychometric tool of the WISC-III*, from which their IQ and mental age were calculated.

The data was processed with the statistical package SPSS 24. The student's answers to each question are presented in a table.

Table 1: Students' answers to the question:
"When does a force act on a body?"

Answer	**Students (%)**
When we push a body, it moves	50,6
When we stop a moving body	12,7
In both cases above	35,4

Only 35.4% of the students gave the correct answer, while more than half gave the well-known Aristotelian alternative idea (Lombardi, 1999), where force is incorrectly connected only with movement.

Table 2: Students' answers to the question:
"When does a soccer player exert force on a ball?"

Answer	Students (%)
The moment he kicks the ball	73,4
When the ball moves toward the net	10,1
In both cases above	10,1
In none of the above cases	5,1

The most significant percentage (73.4%) of students give the correct answer.

Table 3: Students' answers to the question:
"An insect is crushed against the windshield of a moving car because the windshield exerts a force on it. Does the insect exert a force on the glass?"

Answer	Students (%)
No, it doesn't	55,7
Yes, it does	43,0

Less than half of the students (43%) correctly answered the above question, while more than half expressed the perception that since there is no visible effect (Halloun, & Hestenes, 1985), this automatically means that the insect does not exert a force on the glass (Driver, 1984; Brown, 1989).

Table 4: Students' answers to the question:
"A table pushes down on the ground. The ground likewise pushes up the table."

Answer	Students (%)
Correct	37,8
Wrong	60,8

Only 37.8% of the students gave the correct answer, while most answered again according to the well-known alternative idea (Sjober & Lie, 1981) that since there is no movement, there is no force (Tao, & Gunstone, 1999).

Table 5: Students' answers to the question:
"The weight of a body is:"

Answer	Students (%)
Force	12,7
A characteristic property of a body	22,8
Body mass	63,3

Most students (63.3%) answer with the classic alternative idea that weight and mass are identical concepts (Mullet & Gervais, 1990). Only a tiny part of the students (12.7%) gives the correct scientific answer.

Table 6: Students' answers to the question:
"A person has weight because:"

Answer	Students (%)
The air presses him to the earth	17,7
He is drawn to the earth	35,4
None of the above	45,6

In the question about the origin of a person's weight, only 35.4% of the students give the correct scientific answer; that is, there is a reason for the weight of the earth's attraction.

Table 7: Students' answers to the question:
"When we diet, what do we lose?"

Answer	Students (%)
Weight	62,0
Mass	36,7

In this question, 2 out of 3 students answer incorrectly, unable to distinguish that the mass is first lost in the diet, which entails a corresponding weight reduction.

Table 8: Students' answers to the question:
"When you swim, your weight:"

Answer	Students (%)
It gets bigger in water	17,7
It gets smaller in water	60,8
Does not change	20,3

The students' experience leads them to a large percentage (60.8%) to answer incorrectly, that is, the weight decreases in the water. Only 20.3% correctly answer that the weight does not change.

Table 9: Students' answers to the question:
"On the moon, the gravity is much less than the earth. A bar of chocolate:"

Answer	Students (%)
It weighs less on earth than on the moon	28,95
It weighs more on earth than on the moon	63,16
It weighs the same on earth and the moon	7,89

Most students answer correctly (63.16%) to this question connecting gravity with weight.

Table 10: Students' answers to the question:
"On the moon, the gravity is much less than the earth. An apple:"

Answer	Students (%)
It has the same weight as the earth and the moon	23,68
It has the same mass as the earth and the moon	44,74
It has the same weight and mass as the earth and the moon	31,58

Similar question to the previous one, but only 44.74% of students answer correctly, while there are students who state (23.68%) the alternative idea is that the weight of the apple is the same on earth and the moon.

Table 11: Students' answers to the question:
"Friction is the force that propels a car along a horizontal road."

Answer	Students (%)
Error	31,58
Right	68,42

Most students answer this question correctly (68.42%) because of the corresponding experiential experience.

Table 12: Students' answers to the question:
"An apple is on the branch of a tree, and the other falls on the ground. Which of the two apples produces work?"

Answer	Students (%)
That which falls	47,37
The one on the tree	36,84
Both apples	15,79
Neither	0,00

A classic case of not separating the concepts is reflected in the question above (Lawson, & McDermott, 1987). 47.37% of the students give the correct answer, but also 36.84% state that the apple on the tree produces work, apparently not being able to separate work from energy.

Table 13: Students' answers to the question:
"Two runners of the same weight run 100 meters. Who spent more energy?"

Answer	Students (%)
The one who finishes first	34,21
The one who finishes second	15,79
Both consume the same energy	50,00

Another classic case of the non-separation of concepts is this question (Goldring, & Osborne, 1994). While precisely half answer correctly, there is still a percentage of students, 34.21%, who answer incorrectly, confusing the concepts of energy and power.

Table 14: Students' answers to the question:
"Two weightlifters lift the same weight. Who spends more work?"

Answer	Students (%)
The taller one	36,84
The shorter one	34,21
The same for both	29,95

Only one in three students correctly answer that the tall weightlifter spends more work.

Table 15: Students' answers to the question:
"Why do long jumpers take turns?"

Answer	Students (%)
To reduce their body weight	13,16
To reduce air resistance	18,42
To get more energy	68,42

In the above question, many students answer correctly (68.42%) since it is a question that they have acquired experiential experience.

From the application of the Greek version of the WISC-III scale, it emerged that the average IQ of the students of the present sample is 101.50 ± 17.24, corresponding to students with an average IQ. It should be noted, however, that the IQ ranges for all students ranged from 66 to 140. Each student's mental age was then calculated according to the weighted tables provided by the WISC-III.

3. Results

First, it was checked if there were no significant differences between the total mental age and the mental age obtained from the verbal and performance scales, so it can be considered that it adequately describes the general level of mental functioning of the student.

Figure 1 shows the graph of total mental age as a function of mental age, which results from the verbal scale. Figure 2 shows the graph of the total mental age as a function of the mental age obtained from the performance scale.

From figures 1 and 2, it's clear that the two scales of mental age are based on verbal and performance contributing in the same way to the total mental age. Also, it's very clear from the above figures that even though all the students are in the sixth grade in Primary School having a biological age between 12-13 years old, their mental age has ranged from 9 to 15. That means that every student has a different developmental age and a different ability to analyze and synthesize incoming information and as result is different the child's ability to answer questions from daily life. To determine how it changes this ability from the mental age the correct answers given by each student to the questionnaire were counted. The graph of the correct answers to the questionnaire was made as a function of the average mental age of the students who gave that number of answers, and the corresponding graph is shown in Figure 3. From the diagram in Figure 3, it's clear that as a student's mental age increases, he correctly answers more questions in a questionnaire.

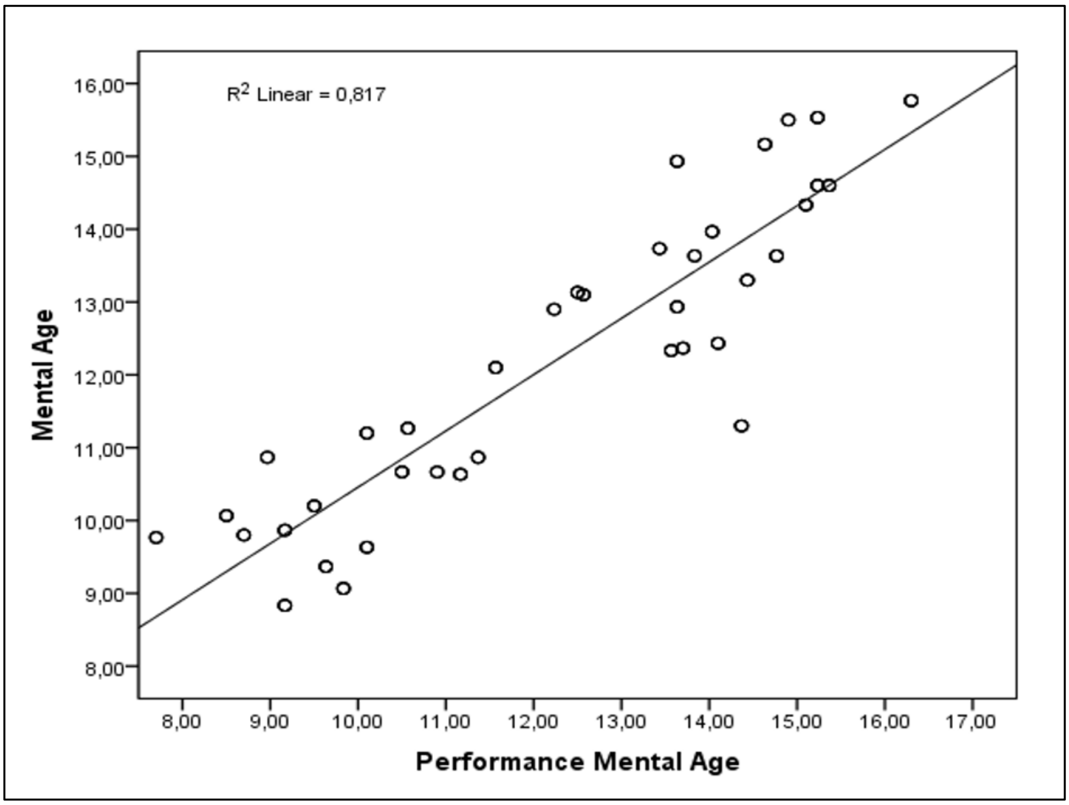

Figure 1: The graph of the total mental age as a function
of the mental age is derived from the verbal scale

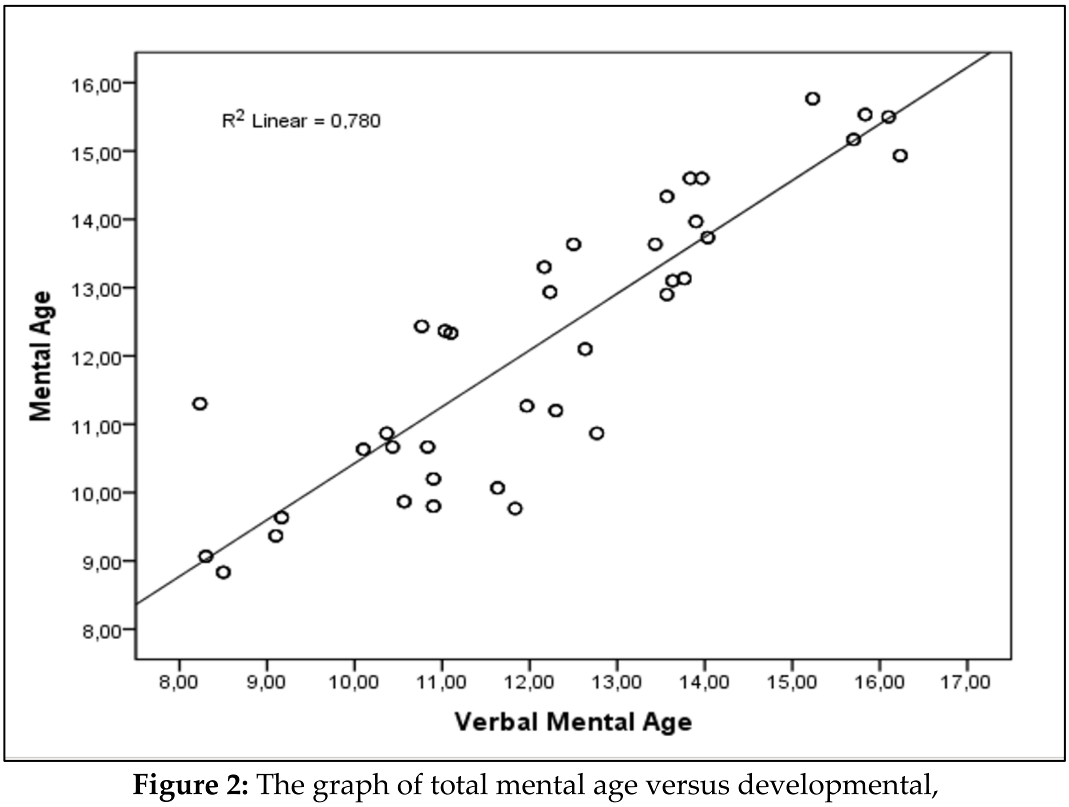

Figure 2: The graph of total mental age versus developmental,
mental age is derived from the performance scale

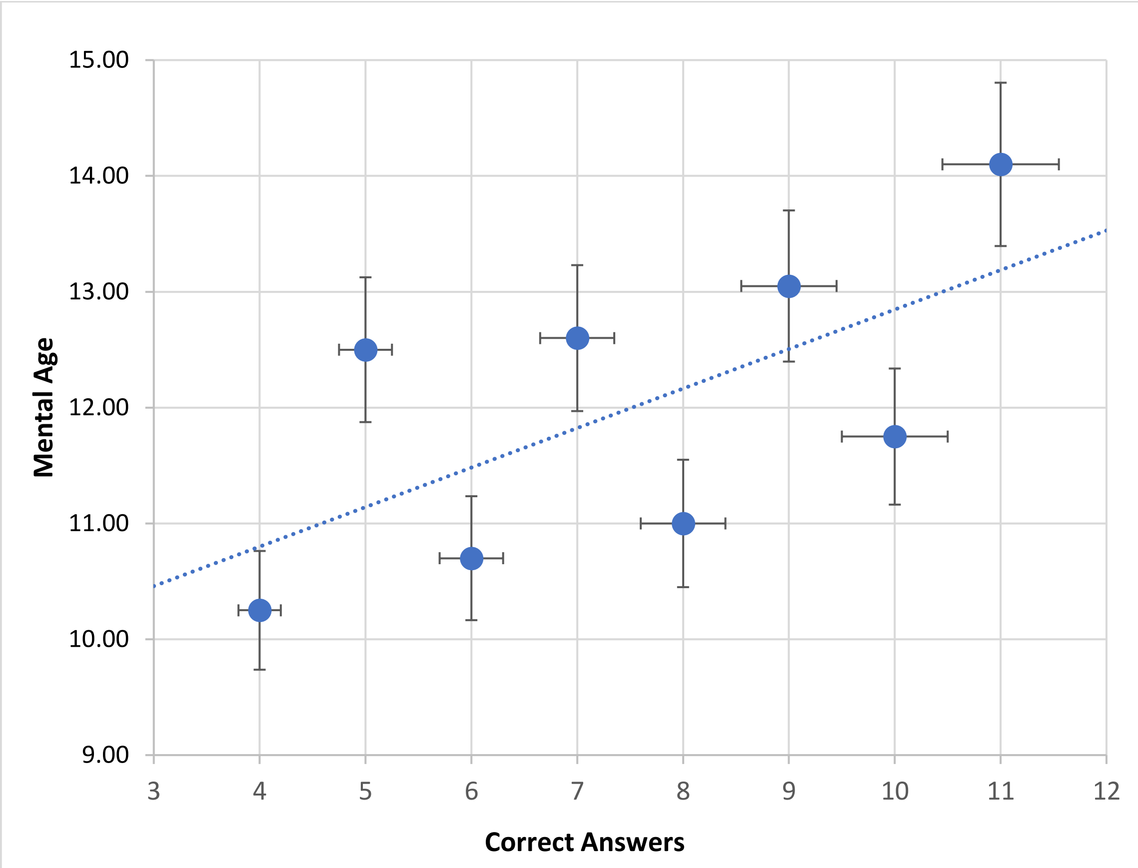

Figure 3: The average mental age of the students concerning the number of correct answers they answered in the questionnaire

It was then searched to find out whether the verbal or performance scale significantly influences mental age's relationship with the student's correct answers. The number of correct answers was plotted against both the mental age obtained from the verbal scale, that is, from the six verbal activities, which examine the child's verbal knowledge and understanding, a knowledge that is usually acquired through children's education mainly at school, as well as with the mental age resulting from the performance scale, i.e., from the six practical activities, which detect the child's ability to flexibly use various strategic methods to solve a new type of problem.

The plot of the number of correct answers of mental age from the verbal scale and the performance scale is shown in Figure 4.

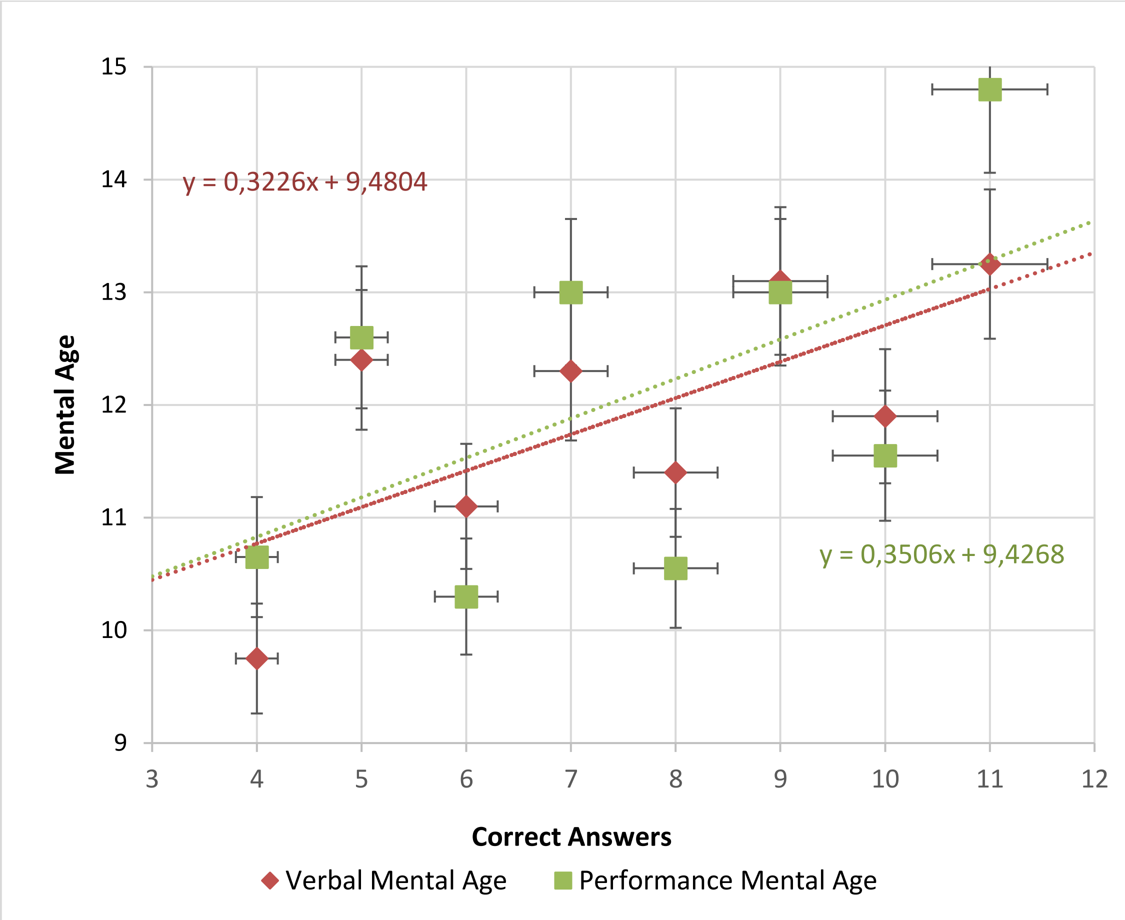

Figure 4: The mental age of the students from the Verbal and Performance scale concerning the number of correct answers, they answered in the questionnaire

From the comparison of the two linear lines, it follows that both the mental age from the verbal scale and the performance scale has almost the same relationship with the number of correct answers given by the student without showing from the present research that one scale affects more than the other.

4. Conclusions

From the present research findings, there is a relationship between the mental age of the student and the number of correct answers to questions on basic engineering concepts. This linear relationship states that the higher the mental age a student has, the more correctly he can perceive some physical phenomena related to concepts of force, weight, energy, work, etc. This conclusion cannot be generalized as a rule for all concepts of physics; however, as a finding, it is essential. It was also found that the verbal and performance scales for determining mental age contributed equally to the linear relationship identified. It is estimated that an interview would be more appropriate than a questionnaire but would be an exceptionally tedious process for the students since the application of the WISC-III alone required about one hour for each student. Further in-depth research is undoubtedly needed to capture the relationship between cognitive developmental age with the number of correct responses of students to engineering concepts.

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Conflict of Interest Statement
The authors report there are no competing interests to declare.

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