The Misconceptions in Mechanics Among Students after Completing their Secondary Level Education in Malta

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Abstract

The purpose of this study is to identify the relationship, if any, between misconceptions in mechanics and gender, repeaters/non-repeaters, grades in secondary level physics, maths and English. The study focused on all students (N = 475) admitted to the college in October 2015, intending to study physics at advanced (N = 198) or intermediate level (N = 277). In this study a multiple-choice test was used comprising of 30 questions taken from the force concept inventory (FCI) and two additional questions about distance-time and velocity-time graphs. The research analysed the first thirty questions (FCI) separately from the analysis of the last two questions for the comparison of the results with the interpretations of the FCI authors. The test was given on the second week of the academic year so that their response was not influenced by mechanics teaching. The results of the study suggest that the participants did not reach the entry level of Newtonian thinking after their secondary education whereas they showed a good understanding of distance-time and velocity-time graphs. The findings suggest that male participants have fewer misconceptions than female participants and repeating participants had a good grasp of concepts in mechanics than the non-repeating participants. The grade in secondary level physics and maths is related to a high score in the FCI while the grade in English language does not.

1. Introduction

In secondary education, students study Physics for three academic years after which they sit for a national exam at SEC level. In mechanics they study Newton's laws of motion, linear motion, energy, projectiles in vertical motion and conservation of linear momentum in collisions but not circular motion and vector addition at an angle. After this level of education, students may opt to enter a post-secondary academic institution to continue studying physics at a higher level in preparation to enter University. There are two levels of studying physics namely advanced and intermediate. The intermediate level is planned to have a weight of one-third the commitment and effort of an advanced level subject.

In 1976, Professor David Hestenes [5] was wondering why his four children were struggling to learn Physics and consequently turned to education research. He met Richard Stoner who claimed that exams are too focused on quantitative problem-solving techniques and consequently wanted to test his idea. Stoner designed new exams on qualitative arguments but emerged disappointed when the average score of the class could not get better than 40%. As a result Hestenes became curious and interested in cognitive aspects of physics and mathematics. He stumbled on the works by Robert Karplus who has been successful in implementing Piaget's research on cognitive development into science curriculum. Karplus [1] organised instructions on a learning cycle with 'exploration, invention and discovery'. This curiosity led Hestenes [2] to write a paper on Piaget and the psychological teaching of physics.

Hestenes was appointed as an advisor to a Lebanese PhD student Ibrahim Halloun in physics education. At that time Hestenes was convinced that modelling is an essential part of scientific method and started teaching introductory physics with a modelling approach. Hestenes told Halloun about his idea of learning difficulties in physics and immediately Halloun picked up the idea to work on the differences between student preconceptions about the physical world and the teaching concepts. The result of this research led to the 'Force concept inventory' project. It is a multiple-choice test which discriminates between non-scientific and scientific statements. The non-scientific statements were designed from research of popular non-scientific beliefs. For the non-science persons, the non-scientific statements appear to be more plausible than the scientific ones.

It is commonly considered that physics is a difficult subject whose possible contributing factors are abstractness of the material, logical reasoning in problem solving and the mathematical skills.

2. Objective

The purpose of this quantitative study was to identify misconceptions in mechanics. It was focused on 16-year-old students entering a post-secondary education with the intention to follow a course in

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physics. The study was intended to identify relationships, if any that exist between the misconceptions and gender, SEC level grade, repeating and non-repeating students.

3. Design

The study used quantitative statistics methods to discover the impact of students' characteristics and the misconceptions in mechanics. The tool that was used is the Force Concept Inventory (FCI) originally published in 1992 [4], and revised in 1995 by Ibrahim Halloun, Richard Hake and Eugene Mosca. The FCI consists of multiple choice questions with one Newtonian answer and four non-Newtonian options being powerful plausible answers and measures six dimensions of force concept in kinematics, the three Newton's laws of motion, sum and kinds of force.
The complete test given to the participants included two extra questions about kinematics graphs.

3.1 Research Questions

The research was meant to address the following questions.

a. Are misconceptions in mechanics related to the gender of the participants?
b. Do repeaters have fewer misconceptions in mechanics than newly-admitted participants?
c. Do high grades in SEC (ordinary level) Physics, Maths and English play a role in misconceptions in mechanics?

4. Methods

This research was a quantitative study using a multiple-choice test consisting of 30 questions from the force concept inventory with the addition of two more questions about the graphs of motion. The questions describe physical phenomena about motion of objects and the participants required choosing the best option according to their conviction. The questions were all qualitative and no mathematical calculations were involved. In this study, all the first-year participants (N = 475) of the physics department in the college took part on a voluntary basis and the test was administered by all the lecturers teaching mechanics in the second week of the academic year which was between the 6th and 9th of October 2015. The study was given as a pre-test and so early in the academic year, in order to avoid any influence by mechanics teaching in their course. In the analysis, the participants' response was divided into two parts. One part analyses questions from one to thirty, being the original FCI as designed by the authors, and the other part analyses questions thirty-one and thirty-two.
In a study with 20000 participants from 200 different high schools in the US during autumn 2000, Hestenes [3] claims that the average pre-test score is around 26% (random guessing is 20%) with some scoring above 30%.
SPSS 2.1 was used for statistics analysis. The Kolmogorov-Smirnov and Shapiro-Wilk test were used to assess the normality assumption of the percentage score distribution. The percentage score distribution was not normally distributed (p = 0) and hence non-parametric tests were used to compare means between groups. One-way Anova was used to obtain statistical descriptive values while a general test called the Kruskall-Wallis was used for the p-value because it compares two or more samples instead of the Mann-Whitney test which compares only 2 samples.

5. Results

All the results hereunder were derived for the following groups: all participants together, advanced and the intermediate level groups. The scores obtained by the groups were also divided between the first thirty questions, which is the original FCI, and the last two questions (31 and 32) about the kinematics graphs.
There were 14 (2.95%) participants who left out more than six questions among the first thirty questions (FCI) scoring a mean value of 20.00%. However there were 351 (73.89%) participants who answered all the first thirty questions completely scoring a mean value of 27.32%.
There were 3 (0.6%) participants who scored above 60% in the first thirty questions (FCI) reaching the entry threshold to Newtonian physics while no one reached the mastery threshold of 85% [3]**Error! Reference source not found.**. These participants have chosen to study physics at advanced level, two of whom are coming from a church school while the other one from a state school.

a) Are misconceptions in mechanics related to the gender of the participants?
There were 270 (56.8%) male and 205 (43.2%) female participants all together. In the intermediate level group, there were 125 (45.1%) male participants and 152 (54.9%) female participants. In the advanced level group there were 145 (73.2%) male participants and 53 (26.8%) female participants.

Table 1. Mean percentage scores for male and female participants

Q1 – 30							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	29.75	Male	22.75	Female	7.00	YES	0.000
Intermediate	27.73	Male	22.48	Female	5.25	YES	0.000
Advanced	31.49	Male	23.52	Female	7.97	YES	0.000
Q31 – 32							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	80.56	Male	80.24	Female	0.32	NO	0.573
Intermediate	80.40	Male	78.29	Female	2.11	NO	0.356
Advanced	85.85	Female	80.69	Male	5.16	NO	0.331

b) Do repeaters have fewer misconceptions in mechanics than newly-admitted participants? There were 434 (91.4%) non-repeating (NR) and 41 (8.6%) repeating (R) participants altogether. In the intermediate group there were 17 (6.1%) repeating participants and 260 (93.9%) non-repeating participants. In the advanced level group there were 24 (12.1%) repeating participants and 174 (87.9%) non-repeating participants.

Table 2. Mean percentage scores for repeating (R) and non-repeating (NR) participants

Q1 – 30							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	32.43	R	26.19	NR	6.24	YES	0.001
Intermediate	29.22	R	24.56	NR	4.66	NO	0.307
Advanced	34.72	R	28.62	NR	6.09	YES	0.004
Q31 – 32							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	84.14	R	80.07	NR	4.07	NO	0.261
Intermediate	79.62	NR	73.53	R	6.09	NO	0.546
Advanced	91.67	R	80.75	NR	10.92	NO	0.063

c) Do high grades in SEC Physics, Maths and English play a role in misconceptions in mechanics? All participants eligible to enter the college require obtaining a grade in Physics, Maths and English among other subjects at SEC level. Grades are awarded by a scale from 1 to 5, grade 1 being the highest and 5 being the lowest. The board also assigns other lower grades 6 and 7 which are not eligible grades to enter the college.

Table 3. Percentage mean score in relation to SEC Physics grades

Q1 – 30							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	32.80	Grade 1	23.72	Grade 5	9.08	YES	0.000
Intermediate	29.78	Grade 1	22.16	Grade 5	7.62	YES	0.005
Advanced	37.33	Grade 1	26.13	Grade 4	11.20	YES	0.017
Q31 – 32							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	87.39	Grade 2	67.31	Grade 5	20.08	YES	0.007
Intermediate	89.06	Grade 2	67.65	Grade 5	21.41	YES	0.002
Advanced	85.29	Grade 2	66.67	Grade 5	18.62	NO	0.827

Table 4. Percentage mean score in relation to SEC Maths grade

Q1 – 30							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	30.17	Grade 1	23.14	Grade 5	7.03	YES	0.000
Intermediate	27.00	Grade 1	22.67	Grade 5	4.33	NO	0.202
Advanced	33.33	Grade 1	24.30	Grade 5	9.03	YES	0.020
Q31 – 32							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	91.25	Grade 1	74.06	Grade 5	17.19	YES	0.001
Intermediate	95.00	Grade 1	73.33	Grade 5	21.67	YES	0.004
Advanced	87.50	Grade 1, 2	75.81	Grade 5	11.69	NO	0.436

Table 5. Percentage mean score in relation to SEC English grades

Q1 – 30							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	28.88	Grade 2	25.94	Grade 3	3.53	NO	0.222
Intermediate	28.95	Grade 1	23.84	Grade 5	5.11	marginal	0.053
Advanced	32.98	Grade 2	26.00	Grade 1	6.98	NO	0.124
Q31 – 32							
Group	Max mean %		Min mean %		Difference in %	significant	P-value (0.05)
All	87.50	Grade 2	77.40	Grade 3	10.10	NO	0.095
Intermediate	85.19	Grade 2	77.11	Grade 3	8.08	NO	0.543
Advanced	90.79	Grade 2	77.36	Grade 4	13.43	NO	0.133

6. Discussion and Conclusions

The research shows that all the participants obtained an average score of 26.73% for the first 30 questions in the survey which is within the expected result for a pre-test [3] while they obtained an average score of 80.42% for the last two questions about graphs of motion.
In the first thirty questions, being the original FCI, the results show that there are less misconceptions in male participants, being repeaters and highest grade in SEC Maths and Physics but showed no significant difference with SEC English grades. The intermediate level group showed no statistical difference in the percentage score between repeaters and newly-admitted participants and the SEC Maths grades. English language is not a barrier to understanding although this is a foreign but is the second official language of the country.
The results for the last two questions (31 and 32) in the survey about kinematics graphs show a good performance by those having a good grade in SEC Physics and Maths.

7. Acknowledgement

I would like to thank Prof. Liberato Camilleri for his advice on statistical tests performed in this study, Dr.Charles Bonello for his valuable guidance, Mr. Russell Mizzi (subject coordinator) and Mr Paul Xuereb (the principal) for the permission to carry this research at the institution, the physics staff who participated in the administration of the survey and the participants.

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