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# Analysis of electrical and electronics students' obstacles in studying physics - work in progress

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ABSTRACT: The toughest obstacle faced by the BSc-EEE students at ORT Braude College of Engineering is completing the enhanced physics courses. The average failure rate over the last five years in these courses is about 58%. In the current article, the authors examine the roots of students' difficulties in order to reduce the failure rate, without compromising the standards and level of the examinations. In-depth interviews were conducted with students shortly after they wrote their midterm examination in Enhanced Physics I. Two important findings emerged from the interviews: 1) the successful students invested a substantial degree of time in order to reinforce their theoretical knowledge. In contrast, the students who failed focused on solving exercises: 2) the successful students read every question on the examination two or three times prior to starting to answer them whereas the others did not. Additionally, all the students who passed Physics I filled in a questionnaire about their experience in studying physics. The results show that the students who invest at least 40% of their time in theory attained a grade of 75.5 on average whereas the others attained only 68.6 on average.

## INTRODUCTION

Physics courses are a crucial part of the core curriculum of electrical and electronics engineering in universities and colleges (e.g. in Israel [1][2] and abroad [3]). The students in the Electronic and Electrical Engineering Department at ORT Braude College, Karmiel, Israel, have had difficulties in Enhanced Physics I (Mechanics) and Enhanced Physics II (Electricity and Magnetism) courses since the College was founded 22 years ago. The percentage of students that fail these courses varies from 40% up to 70% or more in extreme cases.

For example, the average failing grades over the last five years in Enhanced Physics I and II is about 58%, even though the students had two opportunities to pass the final examination (i.e. achieve a grade of at least 45 out of 100) in order to pass each course. The reason for this state of affairs could be because the student population entering engineering institutions over the past two decades is more diverse in its knowledge base and cognitive capabilities than earlier cohorts [4]. Nevertheless, dissatisfaction with this situation prompted the authors of the current article to search for what is preventing students from succeeding in physics courses and to find directions to help students and lecturers reduce the number of failing students.

## THEORETICAL REVIEW

### Worldwide Difficulties in Physics Studies-related to Mathematics Skills According to Many Researchers

The opening of engineering colleges in Israel over the last two decades has resulted in a very diverse student population in terms of the latter's knowledge base and cognitive capabilities [4]. Many students are experiencing increased learning difficulties, mostly in courses that demand higher thinking abilities. Students' difficulties in studying physics have been reported in various regions of the world [5-10].

Williams et al argue that the major reasons for students finding physics uninteresting are that it is difficult for them and that they believe it is irrelevant [5]. Ogunleye, examining the reasons for students failing to solve physics problems, asked teachers and students why they find physics problems difficult to solve. Amongst the reasons most frequently mentioned were students' inability to understand the problem and their poor mathematics skills [6].

Angell et al investigated Norwegian students in Grades 12 and 13 and their teachers about their perceptions of physics studies. They found that *...general feature of physics pupils' description of their subject is that physics is regarded as difficult and with a high workload, but also interesting* [7]. They also ranked physics as highest in difficulty, workload and fast progression compared to English studies and social science [7].

Boe and Henriksen investigated Norwegian students' motivation for studying physics. They found that many students, females in particular, who take secondary physics in Grade 12 choose not to continue the subject in Grade 13 [8]. Erinosho investigated Nigerian students who were having difficulties studying physics. Students were asked to indicate whether they find physics difficult to study, what they find difficult in the subject and what specific aspects of the subject they find difficult to understand. About 58% of the students considered physics a difficult subject; among the difficulties they described were: too many calculations, problems that are not easy to solve and too much hard content to remember. Many of them said that they had difficulty in constructing the meanings of the studied content [9]. Smigiel and Sonntag reported that many French students fall into a kind of mathematical *formalism*, which prevents them from understanding the actual physics behind the question [10].

### Students Wish to Find Easy Ways to Simply Pass Physics Courses

Kim and Hannafin assert that *...in their study, students tended to search for answers that satisfied teachers' expectations rather than attempting difficult problems, posing dilemmas, or exploring alternative explanations.* This finding may explain students' difficulties in physics studies [11]. Gire and Rebello claim that students' familiarity with the examination problems plays a stronger role than complexity in their perceptions of difficulty [12].

### The Teacher's Role

Taasoobshirazi and Carr reviewed a widely recommended instructional approach called context-based physics, which involves placing physics material within a real-life context in an attempt to improve students' motivation, problem-solving abilities and achievements. They concluded that context-based physics is not necessarily better than the traditional method and that further research is needed to improve physics education [13].

Thompson el al suggested that in order to improve physics studies, future teachers should be exposed to and participate in research on student learning. With this experience, they can learn to analyse instructional materials that are based on research [14]. Yerushalmi, Eylon and Seggev reported about a workshop in which physics teachers attempted to promote transfer in problem-solving by their students. They concluded that participation in research can raise teachers' awareness of relevant characteristics of their students and lead the way toward student centred teaching [15].

Ornek et al investigated students', teaching assistants' and faculty members' beliefs about what makes physics difficult and how to overcome these difficulties. They found that students and teaching assistants have almost the same perceptions about the factors that make physics difficult; yet, the difference between students' and faculty's perceptions is so great that *...it seems students and faculty live in different worlds.* They suggested that *...the faculty members should learn how to reach their students and make physics concepts be understood by their students* [16].

## RESEARCH QUESTIONS

The research objective is to explore students' points of view regarding the following questions:

1. What can help students succeed when studying enhanced physics courses?
2. What are the factors that prevent students from being successful in enhanced physics courses?

## METHOD

After the midterm examination, 13 students were asked to participate in individual interviews. Some of these students had done well on the examination and some had failed. The purpose of the interviews was to learn from the successful students what, in their opinion, helped them to do well on the examination and try to determine what the obstacles were that hindered the students who failed, in order to track their mode of thinking. Six students agreed to be interviewed and participated in deep interviews of about 30-40 minutes each. Some insights from this information are qualitatively described in the results section.

Based on the information from these interviews, a comprehensive questionnaire was composed and a request sent to all the students who passed the Enhanced Physics I course to answer the questionnaire through Google Drive. Sixty-one students filled in the questionnaire.

### The Questionnaire

The first part of the questionnaire gathered information about grades in previous physics courses taken in high school and the number of final examinations they took in order to pass the College's Enhanced Physics I course. The second part of the questionnaire focused on study habits, e.g. number of hours dedicated to studying theory, number of hours dedicated to solving exercises, percentage of success in solving exercises, frequency of participation in study workshops. The third part was about behaviour during actual examinations, e.g. the time taken to read a question and whether the time allotted for the examination used efficiently. The last part of the questionnaire gauged students' attitudes about the mathematics background needed for the course.

The Population

Among the six students who participated in the interviews, four failed and two passed the midterm examination. The midterm examination included two questions; all the students scored significantly better on the first question than on the second one.

All 61 students who answered the questionnaire passed the Enhanced Physics I course prior to answering the questionnaire. However, the Ministry of Education's policy is to allow students two opportunities to take a final examination. This means that students can participate in one or both examination sessions, but the last examination grade is the one used in calculating students' final course grade. Only the results of the 41 students who passed the examination after taking it only once are included in the quantitative results that relate to independent study habits. Nevertheless, all 61 students' attitudes toward mathematics skills are included in this article.

Enhanced Physics I

The course is one semester (14 weeks) long. Each week, students in the course attend a three-hour lecture, two tutorials, one laboratory (two hours long) and one study workshop (one hour long). The course goals are: understanding the principles of classical mechanics, becoming proficient in the use of mathematical tools and gaining the ability for critical thinking; and acquiring the ability to model unfamiliar problems. The course covers: kinematics, Newton's laws, accelerated frames of reference, work and energy, momentum, many-particle systems, oscillations, mechanics of a rigid body and gravity.

Following the end of the semester, there is a four-week period of examinations, during which students take six to eight examinations, one for each course they took during the semester. Students usually have at least four free (no-examination) days before the physics examination. After the first examination session period, a second two-week session opens. The final grade is composed of: 20% for midterm examination, 10% for two exercise quizzes, 20% for laboratory reports and 50% for the final examination. Students must obtain at least 45% on the final examination in order to pass the course.

The Midterm Examination

The midterm examination included two questions. The first one had an acceptable difficulty level, so the students scored well; the second question, which was more challenging, is presented below.

A conservative force of the form $\vec{F}(x,y,z)=\left(-\alpha y^2+2\beta xy^3\right)\hat{x}+\left(3\beta x^2y^2-2\alpha xy\right)\hat{y}$ is acting on a small cylinder with the mass $m$ where $\alpha;\beta$ are constants and $(x,y,z)$ indicate the cylinder's position.

a. Find the potential energy $U(x,y,z)$ if you know that $U(0,0,0)=0$.

b. If you cannot solve this paragraph, use the expression below and continue from paragraph c.:

$$\frac{\alpha}{a}\left(xy^3-\frac{\beta}{\alpha}a^2x^2y^2\right).$$

The rest of the question relates to Figure 1 in which the small cylinder can move without friction in a long horizontal pipe located at $y=a>0;\ z=0$. The only forces acting on the small cylinder are $\vec{F}$ and the force activated by the pipe.

c. Write an expression for the force acting on the small cylinder,

d. The small body starts moving from $x=0$ with an initial velocity of $V_0\hat{x}$; what will be the next position $x_0$ where the cylinder has the same velocity $V_0\hat{x}$? Express $x_0$ in terms of $\alpha,\beta$ *and* $a$. What must the minimum of $V_0$ be in order to reach the point $x=x_0$?

e. What will the cylinder's velocity be when it reaches the point $x=0.5x_0$?

f. What will the cylinder's velocity be when it reaches the point $x=x_0$?

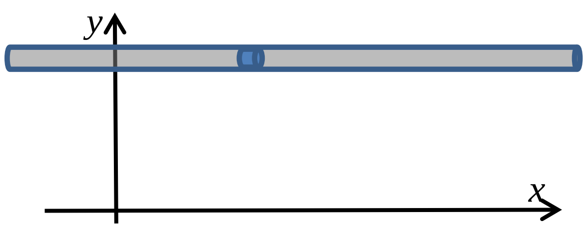


Figure 1: Figure for Question 2.

## FINDINGS

### Qualitative Results

The interviews with the students related mainly to the students' learning habits and their way of thinking during the midterm examination. Their examination notebooks were analysed by the course lecturer and a copy of the notebooks were used by the interviewers during the interview. Four main insights emerged from the interviews.

The successful students read the questions more than once, making sure they understand them, before starting to answer them, as is shown in the following quotations:

D: *I need to read the question several times to understand.*

L: *I read the question twice before answering, the first time briefly, then second time slower to see the details.*

On the other hand, when student C, who did not score well on the examination, asked about how much time he spent on reading the question, he said *...one minute*.

The successful students reported that they invested a substantial part of their self-learning time to understanding the theory before solving homework exercises, while the failed students spent their self-learning time solving problems without reviewing the theory. The citations below demonstrate this finding:

D who scored well said, *At the beginning I exercised the technique only and did not succeed in solving problems; now I spend about 70% of my time on learning theory. I read my notebook about ten times until I understood.*

In contrast, C and S said:

C: *I am afraid to waste my time when I prepare myself for the exam. I need to solve exercises. My time is too valuable to spend it on theory. We, the students, try to predict what the exam questions will be. We have no time.*

S: *Learning theory?? We can learn nothing from the notebook.*

All the students reported having difficulties in mathematics. For example, the interviewers showed student O his examination notebook and asked, *Did you understand the question?*

O answered, *I understood what to do but didn't know how to calculate the integral.*

Student H said, *I always get stuck on mathematics. When I see lot of mathematics, I get into a panic. Complicated mathematical expressions frighten me.*

The interviews revealed that some students lost their self-confidence and left the examination room before the official time ended. Other students stated that the fear of the examination blocked their rational thinking. The citations below support these assertions:

Student C left the examination room ten minutes before the end. In the interview, he explained: *I did whatever I could, I was exhausted. I lost my way in the second question and couldn't think.*

Student O several times, during the interview, repeated the sentence: *Yes, there was something like this in the homework but I didn't remember it during the exam.*

### Quantitative Results

Analysis of the quantitative data gathered through the questionnaires is presented in Tables 1 and 2. Relying on the data in Table 1, one can conclude that students who invested 40% or more of their time in reinforcing their theoretical knowledge in physics received a final course grade of 75.5 on average, while the final course grade of students who spent less than 40% of their time was 68.6 on average. A *t*-test using these results yielded a *p*-value of 0.032, indicating that the result is statistically significant. Even though 61 students answered the questionnaire, the comparison in Table 1 relates only to the 41 students who passed the final examination the first time they took it.

Table 1: Achievements of students who emphasised theory learning vs. their colleagues.

| Theory percentage | N | Average grade | SD | *p*-value |
|---|---|---|---|---|
| 0 - 39% | 27 | 68.6 | 8.7 | |
| 40 - 100% | 16 | 75.5 | 10.7 | |
| Difference | | 6.9 | | *0.032 |

The second insight revealed from the quantitative data suggests that students consider mathematics skills to be highly important to their success in physics studies. They noted the need of knowledge in solving differential equations in particular. Table 2 presents the attitudes of all 61 students that answered the questionnaire. The students also evaluated their own knowledge of mathematics. All the grades are on a scale of one to five.

Table 2: students' attitudes towards mathematical skills.

| | Mastery needed in mathematics | Mastery I reached in mathematics | Mastery needed in differential equations | Mastery I reached in differential equations |
|---|---|---|---|---|
| | 4.1 | 3.1 | 3.5 | 3.0 |
| *t*-test | *p* - value: 0.00002 | | *p* - value: 0.037 | |

The results in Table 2 suggest that mathematics skills are very important to students. The gap between the mastery needed and the mastery achieved by the students is statistically significant.

## DISCUSSION

Both the qualitative and quantitative results of the current study suggest that students indeed encountered difficulties in physics studies. The interviews revealed that successful students spent their self-studying time in strengthening their theoretical knowledge at the expense of solving exercises. This positive effect of this activity is supported by the quantitative results that show an advantage of almost seven points on average for students who spent 40% or more of their time studying theory. All the students believe that mastery in mathematics skills is crucial and that they do not have such mastery. They ranked the mastery needed 4.1 on a scale of one to five and their own knowledge as 3.1 only.

The less successful students believe that spending time on theory is a waste of time; they prefer to solve more and more exercises in the hope of having similar questions on the examination.

The less successful students stated in the interviews that they failed to cope with the mathematics part of the examination, which resulted in their ability to think clearly being blocked; some of them even reported that they got into a panic. Some of the students who failed do not use examination time efficiently; they are not thorough enough in reading the examination questions and do not use all the examination time allotted to them.

Bolstering students' mathematics skills and encouraging students to invest more of their time in reinforcing their theoretical background accompanied by further research is planned in order help students overcome their difficulties and get success in physics.

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