IJPCE
International Journal of Physics and Chemistry Education, *9*(2), 13-16

www.ijpce.org
ISSN: 2589-8876

Contributions of "Problems Solving Strategies" in Physics Issues of ENEM

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Abstract
Brazil has some large-scale assessments, for instance, state or national exams to evaluate basic education, higher education admission process, and the national high school exam (ENEM) which is for sure the most important. We use the researches on problem-solving strategies, because they provide a number of difficulties associated with the resolution of questions of physics. As seen, know the difficulties presented by beginners in their solution strategies of a problem can suggest ways to understand what the reasons signal a wrong alternative are. The strategies analyzes results in the following inferences: a not correct use of units of measurement; the presence of symbolic forms; intuitive reasoning in solving problems; not scientific concepts and wrong images' analysis present in item. If the results returned for the schools teaches and managers can be used to promote learning, and we expected that physics teachers, use those information to improve the students' knowledge, in physic area on public schools.

Keywords
ENEM, Formative assessment, Physics issues, Problems-solving strategies, Wrong alternatives

◆Received 7 September 2016 ◆ Accepted 15 November 2016

Introduction
Brazil has some large-scale assessments, for instance, state or national exams to evaluate basic education, higher education admission process, and the national high school exam (ENEM) which is for sure the most important. ENEM is not a compulsory exam, it is used for multiples purposes, such as: (i) the only entry point for free of charge federal institutions of higher education; (ii) can provide scholarships in private institutions; (iii) gives the possibility to get a high school graduation, if the student is over 18 years old and for some reason left the educational system. Not only students that are finishing the school take the exam but also students that have already completed high school and students in the middle of high school also take the ENEM to practice. In other words, it is possible to do ENEM as many times as Brazilian students want, but it is only possible to access higher education if one has finished high school.

ENEM consists of two-days test. In total, there are 180 multiple-choice issues plus an essay. There are 45 issues for each academic discipline: math, languages (Portuguese and Spanish or Portuguese and English), natural sciences, and humanities. The first day consists of natural sciences and humanities in a 4h30min test, and the second day consists of math, languages and an essay in a 5h30min. Therefore, each day the students take 90 multiple-choice issues. We must point out that if the students keep one hour for the essay, they will have 4h30 for 90 questions, an average of 3 minutes for each question, and since the majority of the issues contains text and/or table or graphics, the lack of time for the reasoning of the problems can lead to a random guess. For the admission process, the score for each area is treated based on the Item Response Theory (IRT), which tries to minimize the effect of random guesses.

Natural Science's test includes issues of disciplines Biology, Physics and Chemistry. All issues should represent problem situations to be resolved, with only one alternative is correct. Wrong alternatives (distractors) should be reasoning hypotheses of candidates. These two assumptions about the issues present in the ENEM open space for many different forms of analysis on the knowledge of the candidate. A way to analyze the candidate mistakes is to inferring the distractors' analysis. We analyze the candidates' problem-solving strategies to identifying possible mistakes made during the resolution of the issue; as well as the possible causes of these errors. This way of analyzing allows expand our range of knowledge of candidate's physics difficulties. We expected that, it could be transformed in useful tools for physics' public teachers.

The Brazilian educational system consists of public schools (state, local, technical and military) which are free and private schools. Most students, approximately 80%, are in public schools, state schools mostly. Our sample represents these students, there are graduating in public school in the year before ENEM's test.

We use the researches on problem-solving strategies, because they provide a number of difficulties associated with the resolution of questions of physics. One of the first approaches of the researches, discusses the strategies used by novices and experts (Chi et al, 1981; Chi et al, 1982; Larkin et al, 1980; Maloney, 2011; Sabella and Redish, 2007). Novices, because they are less experienced, are more susceptible to make mistakes, especially with mathematical modeling, equations reflecting physical concepts (Larkin et al, 1980; Sherin, 2001).

One of the possible interpretations for this difficulties, is the concept of symbolic form (Sherin, 2001), which is related to the mental model that students retain the different equations, they take

https://doi.org/10.12973/ijpce/29161
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contact in basic education. Sherin suggests possible problems faced by students to "make" a formula, even knowing the concept associated with it.

Not scientific concepts also affect directly on problem solving strategies (Kou et al, 2013; Sabella and Redish, 2007). Other difficulties can be highlighted relate to the graph or images interpretation (Beichener, 1994; Hale, 2000; Kohl and Finkelstein, 2006).

Used the problem-solving strategies we can inferences how is the student's difficult in physics' problems and returned on this for the students, teacher and scholar community. For this process is necessary building a matrix of physics' difficulties, so in that point the problem-solving strategies are a big relief tool to building the matrix. After, we can produce a feedback for the scholar community. This process is essential for the development of a formative evaluation (Taras, 2010; Black, 2009). That propose was created for Maddelena Taras, say that evaluations of summative characteristics, large-scale examinations, can be used in the construction of formative evaluations (TARAS, 2010), approaching what was previously distant, from the feedback process. For this, it is necessary to understand the meanings of the specific results of each item; as well as filter the numerical values present in the large scale exams, which would allow an advance in the area of educational evaluation (Autor 1, 2015).

Based in this ideas this work should be investigate what are and what can we learn from the most common errors of high school public students in solving Enem physics issues of general mechanics domain?

Methodological Approach

As seen, know the difficulties presented by beginners in their solution strategies of a problem can suggest ways to understand what the reasons signal a wrong alternative are. These possibilities can returned to schools as a way to assist teachers and administrators in improving the teaching quality, especially publics. In work we analyze physics ENEM's issues (between the years 2009 and 2012), the chosen of this years was because in moment of investigation its only data available. These questions classified and compared independently by two physics experts as "physics issues". In the four years tests, 62 issues classified as physics; but only 13 related to general mechanics domain.

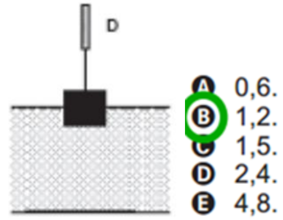
For the four years analyzed, around 20 million of candidates realized ENEM's test. Approximately 80% of candidates are from public schools. The distractor's analysis using the rate in the alternatives. This micro data can be accessed in http://portal.inep.gov.br/basica-levantamentos-microdados. Statistical analysis, to rating alternatives, was conducted using SAS 9.4 software, with 3.175.897 students.

Wrong alternatives with higher rate, could be used to identify the strategies to solve the proposed questions. All of issues where solved by the authors, carefully searching possible alternative tracks to the issues solutions. Alternative tracks, were compared with the rates item, searching to explain the students' physics knowledge used in the issues solutions. See the example in **Table 1** below.

Table 1. Example to analyze an issue.

To determine experimentally the lake water density, we used a dynamometer D graduated from 0N to 50N and a homogeneous cube with edge 10cm and mass 3kg. When the cube was attached to a dynamometer and suspended in the air, scale dynamometer shown 30N. when half cube was diving in lake the dynamometer reading was 24N.

Considering the local acceleration of gravity is 10 m/s², the lake water density (in g/cm³) is



ENEM 2011	A	B	C	D	E
ISSUE 73	14%	22%	23%	31%	10%

Resolution Process

$$W_{C\ LAKE} = W_{C\ AIR} - F_{LAKE}$$

$$F_{LAKE} = \rho_{LAKE} V_{LAKE}\, g$$

$$\rho_{LAKE} = \frac{W_{C\ AIR} - W_{C\ LAKE}}{V_{LAKE}\, g} = \frac{30 - 24}{0,5\ \times 10} = 1,2\,\frac{g}{cm^3}$$

Alternative D

$$F_{LAKE} = \rho_{LAKE} V_{LAKE}\, g = 24\ N$$

$$\rho_{LAKE} = 24\ N / V_{LAKE}\, g$$

$$\rho_{LAKE} = 2,4\ \mathrm{g/cm^3}$$

Alternative C

$$W_{C\ AIR} = \rho_C \times V_C = 30\ N$$

$$W_{C\ WATER} = \rho_C \times \frac{V_C}{2} + \rho_C \times \frac{V_C}{2} = 30\ N$$

Or

Intuitive reasoning in solving problems motivate for the image.

Results

Initially we identified 13 issues, application the strategies analyzes we found a common errors of someone issues, these wrong are exposed in the **Table 2**. The position of issues is referent of blue exam.

Table 2. The errors inferences in the Mechanics issues of ENEM (2009 – 2012).

Year	Issues	Errors Inferences
2009	17	not correct use of units of measurement; the presence of symbolic forms; intuitive reasoning in solving problems
2010	81	not scientific concepts; the presence of symbolic forms;
2011	46	wrong images' analysis present in item; not scientific concepts;
	73	wrong images' analysis present in item; immediacy mathematician;
	77	not scientific concepts; the presence of symbolic forms; immediacy mathematician; wrong images' analysis present in item
	78	wrong images' analysis present in item; not scientific concepts;
2012	47	not scientific concepts; transition of physic knowledge
	55	not scientific concepts; wrong interpretation of the problem;
	60	not scientific concepts; wrong images' analysis present in item; intuitive reasoning in solving problems
	67	not scientific concepts; wrong images' analysis present in item;
	72	intuitive reasoning in solving problems; immediacy mathematician;
	77	immediacy mathematician; not correct use of units of measurement
	78	wrong images' analysis present in item;

Like show the **Table 2**, some wrong are common in issues, the most errors inferences are a not correct use of units of measurement; the presence of symbolic forms (Sherin, 2001); intuitive reasoning in solving problems (Clement, 1994); not scientific concepts (Kou et al, 2013) and wrong images' analysis present in item (Beichner, 1994; Berg and Smith, 1994).

They reflect an important discussion of physics teaching problems, seem the literature we can relate the wrong in two big clusters, the first represent the relationship with the problems solving strategies and the wrong of mathematician formalism (**Figure 1**).

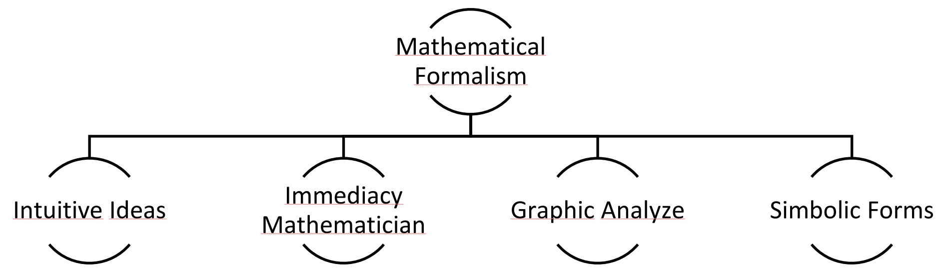


Figure 1. Cluster 1_Mathematical Formalism and your relationships with the order results of the alternatives analyzes.

As a generalization of our results, we can indicate that errors may be associated with the development and analysis of forms of representation, of physical phenomena, based on mathematical language. This difficulty with mathematical language have being corroborate by the students' choice of using intuitive reasoning in solving physical problems. This means that students choose to solve problems in an alternative way to mathematical resolutions, due to the difficulties presented with such a form of language. That result indicated one of the most problems in physics teaching in Brazil, the mathematician formalism, like the Lozada et al (2006) that formalism is a language of physics concepts, so difficulties with mathematician formalism represent a not comprehension of how the physics represents the nature.

The second cluster (**Figure 2**) represent the relationship with the problems solving strategies and the wrong of not scientific concepts, which affect virtually all forms of problem solving.

This result means that the Brazilian students use strongly non-scientific concepts in the resolution of problems and the relationship of the other wrong, that relationship represent an important result for the teaching of physics, that different errors in solving problems such as those presented in the literature are influenced by the non-scientific conceptions. In addition to indicating how students use such conceptions when solving a physics problem. An example is the influence on the intuitive reasoning that according to Clemant (1994) are conceptual logical constructions that students use to solve a problem without using mathematical formulas. Thus, now the candidate uses an intuitive idea that was formed from a not scientific conception his chances of correctness of the issue tend to decrease strongly. The other feature associated with errors originating from not scientific conceptions relates to their use to give meaning to a result or to solve a problem conceptually.

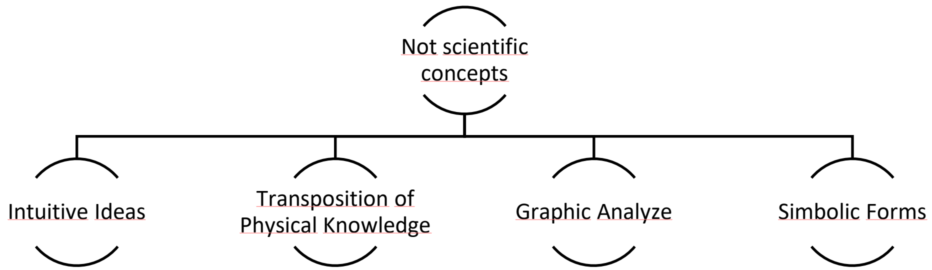


Figure 2. Cluster 2_Not Scientific Concepts and your relationships with the order results of the alternatives analyzes.

Conclusion

In this work we found a large number of errors in resolution of general mechanics physics issues, that errors were agglutinated in two cluster: mathematician formalism and not scientific concept. With the results we can construction of a reference matrix indicating which the mistakes made by students and the possible reasons that led to commit such errors. At the time that this array was returned to school and interested owed would be considered as a feedback element that essential to the development of a formative assessment (Black, 2009; Taras, 2010). If the results returned for the schools teaches and managers can be used to promote learning, and we expected that physics teachers, use those information to improve the students' knowledge, in physic area on public schools (Author 1, 2015; Author 1 and Author 2, 2016).

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