Misconceptions in Physics at Politecnico di Milano: preliminary results

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Our research aims at verifying if the background knowledge in Physics of Politecnico di Milano learners highlights the presence of some misconceptions which have already been described in scientific literature and tries to identify novel ones. To investigate these possible undergraduates' incorrect viewpoints an authentic ad hoc multiple-choice test was administered to both 619 freshmen and 370 second-year university students involved in our research. In accord with the significant bulk of data collected one can argue that misconceptions are broadly disseminated among freshmen as well as second-year university students. Moreover, to attend university for six months or one year probably contributes to the development of learners' general process of growth, but it does not appear to change their misconceptions, independently of taking or not an academic Physics course.

INTRODUCTION AND BACKGROUND

Constructivist science education research has pointed out that university learners do not start with a clean slate on the physical world (Hammer, 2000). Indeed, students who begin their academic career in a scientific programme, like engineering, science, chemistry and biology, may generally reveal some erroneous viewpoints and incorrect interpretative schemas of a broad spectrum of Physics topics (Bozzi et al., 2019; Planinic et al., 2006). These are, broadly speaking, related to intuitive thinking in sciences. Dewey (1938) states that intuitions are not "part of the theories of logical forms" (p.103). Intuition is a form of thinking that provides the learner with a sense of certainty (Fischbein, 1987): it is perceived as global (rather than analytical), coercive and self-evident. Sometimes intuitions from everyday experience contrast with mathematical knowledge and can impede learning. Andrà & Santi (2013) underline that intuitions are a way of establishing a relationship between the learning subject and the object of knowledge, they are a mode of existence of the consciousness which intertwines with perception, sensorimotor activity, emotions and scientific generalization.

Students' wrong ideas and lines of reasoning on a considerable number of physical phenomena, accumulated over the years from their previous learning and experience, were christened "misconceptions" for the first time in 1972 (Doran, 1972) in an article that illustrated a study focused on elementary school children. Thoroughly investigated, misconceptions have assumed a more and more paramount role in the didactics of Physics, being classified into five different classes or categories: preconceived notions, non-scientific beliefs, conceptual misunderstanding, vernacular misconceptions and factual misconceptions (Committee on Undergraduate Science Education, 1997). From all accounts, they are essentially defined as ideas at variance with recognised views (Fisher et al., 1983) or dissimilar from the ones generally acknowledged by scientists (Odom et al., 1995). Needless to say, not only are these alternative conceptions considered as inconsistent with physicists' accepted views, but at the same time they could represent an obstacle to the process of maturation of a correct canonical students' understanding. In fact, intuitions can start in a private, individual moment, but it is in the moment during which they are shared that they develop towards mathematical generalizations (Andrà & Santi, 2013) and may contribute to determine a learners' identity.

In this context, the Experimental Teaching Lab ST2[1] of Politecnico di Milano and another Italian institution, Università degli Studi di Trento, which provides pedagogic support, have developed a case study aimed at answering to the following research questions:

1. do university students enrolled for Engineering at Politecnico di Milano reveal any misconceptions in Physics, related to notable topics addressed in their academic basic Physics courses and studied at high school?
2. How widespread are these incorrect ideas?
3. Given the important role of social interaction in framing intuitive thinking, does attending university for some months reduce these misconceptions?

METHODOLOGY

Our research aimed at identifying and analysing some significant and widespread misconceptions shown by both first-year and second-year university students enrolled for engineering, in relation to their knowledge of Physics. These incorrect viewpoints were chosen on the basis of the following conditions:

a. to be concerned in some topics taught in the academic Physics courses of Politecnico di Milano, with specific reference to Mechanics, Thermodynamics and Electromagnetism;
b. to pertain to some issues that these undergraduates studied at high school.

The study target consisted in undergraduates enrolled for four different engineering branches, i.e. Chemical Engineering, Materials and Nanotechnology Engineering, Mathematical Engineering and Physics Engineering in the academic year 2018-2019. With regard to the purpose of our research, the students were grouped in three sections named 1, 2 and 3 respectively, taking into account the Physics course they were about to attend (Experimental Physics A+B, Experimental Physics I and Experimental Physics II) and their engineering branches, as well as their year and the term in which

[1] http://www.st2.fisi.polimi.it

they attended their Physics course. Table 1 synthesises the data collected in relation to the basic Physics courses involved in our study.

Section	Students number	Physics course	Engineering study course	Students year	Course term
1	449	Experimental Physics A+B	Chemical, Materials and Nanotechnology	1	1
2	370	Experimental Physics II	Mathematical, Physics	2	1
3	170	Experimental Physics I	Physics	1	2

Table 1: Data about the basic Physics courses involved in the research

It is appropriate to point out that the students included in section 1 (S1) were at the beginning of their academic career; consequently, they had never attended a university course and their knowledge along with understanding of Physics phenomena was related to their own previous experience and education.
Differently, even though section 3 (S3) consisted of first-year university students like S1, these freshmen were at the start of the second academic term, hence they had already taken some university courses, among which Chemistry. Notwithstanding that they had not studied Physics in a previous academic course, some issues related to Thermodynamics and Electromagnetism still had been addressed in their Chemistry classes.
The second-year university students included in section 2 (S2) were at the beginning of their second academic year; needless to say, they had already attended a good deal of university courses[2], including Chemistry and, more importantly, Experimental Physics I which was focused on Mechanics and Thermodynamics.

To investigate the possible undergraduates' misconceptions in Physics, researchers have adopted various techniques over the years, for instance interviews (Park et al., 2002), open-ended tests (Colin et al., 2002) and multiple-choice tests (Martìn-Blas et al., 2010). Since the number of overall students potentially involved in this study had been estimated to be massive when the research was planned - on balance they were 989 -, a multiple-choice test appeared to be an appropriate option to carry out our study. Consequently, the Experimental Teaching Lab ST2 of Politecnico di Milano created an authentic ad hoc multiple-choice test, identical for S1, S2 and S3, on the basis of the students' most recurrent mistakes in their Physics courses final examination, their more frequent questions during lessons or drills as well as researchers own teaching experience and the literature on misconceptions in Physics. Università degli Studi di Trento corroborated the educational and didactic suitability of how this trial was created.

This test, administered at the beginning of every university Physics course involved in our study, consisted of twelve quizzes, divided equally among Mechanics, Thermodynamics and Electromagnetism. The overall number of quizzes was set taking into account some priorities; on the one hand, the trial could not last too much, on the other hand it was essential to have an adequate number of quizzes. Every question was characterised by four possible answers: three alternatives were incorrect and focused on different misconceptions related to the issue investigated in that quiz and only one was correct.
The trial was administered to all the students through the online portal Socrative (Tretinjak, 2015) and their own electronic devices, like smartphones, tablets and laptops, aligning with the Bring Your Own Device (BYOD) strategy (Afreen, 2014).

RESULTS AND DISCUSSION

Notwithstanding the abundance of gathered data would allow to explore more thoroughly our research theme, in this context we will illustrate only some preliminary results.
Particularly, the first step of our analysis consisted in evaluating the average percentage of correct answers given by every section involved in the research as a function of each macro-area previously identified. These data are synthesised in table 2 where it is shown that misconceptions were broadly highlighted by undergraduates of all the three groups involved in our study.

Section	Right answers (%)		
	Mechanics	**Thermodynamics**	**Electromagnetism**
1	21,8 %	44,5 %	27,0 %
2	27,8 %	62,6 %	32,1 %
3	19,7 %	56,0 %	33,5 %

Table 2: Mean rate of success achieved by each section involved in the research as a function of every macro-area identified

Firstly, the worst performances were achieved by all the learners in Mechanics. This is startling owing to the fact that this branch of physics is commonly considered easier than others as is widely studied by students at high school. Moreover, it should be emphasised that the S2 undergraduates had already learnt Mechanics and Thermodynamics in their first university Physics course, attended in the previous academic year. That course had consisted of traditional lectures: the low rate of correct answers reached by the second-year students in

Mechanics and partly in Thermodynamics confirms that this type of lectures might not be so effective in terms of learning and its persistence.

Secondly, taking into account that S2 and S3 students had already attended a university Chemistry course, where they had studied some preliminary issues about Thermodynamics and Electrostatics, all the three sections attained substantially equivalent outcomes in Electromagnetism. As a consequence, although to attend university for six months (S3) or one year (S2) probably contributes to developing learners' general and integral processes of constant growth, it could be argued that this attendance does not appear to change some incorrect frames of mind that students employ to interpret the physical reality. Comparing S1 and S3 results in Mechanics seems to confirm this claim.

CONCLUSION

Our research corroborates the awareness that both Politecnico di Milano freshmen and second-year students frequently highlight some incorrect ideas and erroneous interpretative schemas on many Physics phenomena: only 35.7% of the answers in the multiple-choice test administered to the learners was correct.

It is worth to emphasise that the investigated misconceptions were related to some issues that undergraduates would have subsequently addressed in their academic career; as a result, these incorrect viewpoints could constitute a significant obstacle that may cause their failure at academic final exams, thus increasing the number of students who take longer than expected to graduate, as well as the number of dropouts (Oldfield et al., 2018). This latter phenomenon depends on both cognitive and affective aspects and our research can be regarded as an initial move to tackle this problem. Actually, highlighting some important misconceptions on classical Physics can represent a first step towards the redesign of some high school and academic Physics lectures. A learning experience attentive to these misconceptions and based on active learning may not only enhance the scientific background of the students (Bozzi et al., 2018; T. Vickrey et al., 2015), helping them to reduce their future learning difficulties, but also increase their self-efficacy and self-esteem. Indeed, this renewed didactic strategy should consider the issue of fostering students' mastery experiences, observational experiences, social persuasions and positive physiological and psychological mood states, i.e. the four main sources of creating self-efficacy according to social cognitive theory (Dinther et al., 2011).

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