INNOVATION IN PHYSICS EDUCATION IN BELGIUM

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In the last thirty years education innovations in science, and in physics in particular, have changed significantly. The context and causes of these changes include the democrationisation of education, the flexibility of the job market, the development of new education techniques, the new objectives and role of physics in several education programs. According to several recent studies (Beyond 2000, Rose, Euroscene, ARAS), the majority of young people do not view physics, and especially its teaching, very positively. They consider physics to be an incoherent compilation of concepts, ideas facts, and mathematical equations. In their minds, above all, only a good memory is required to master the subject.

All this led to reforms. Education is now less centred on the teacher, more attention is paid to the learning process but, in addition to acquiring knowledge, the development of “competences” now has an important role. The goal is to actively involve the student in the education process. Gradually “instructivism” has shifted towards constructivism with an increased emphasis on the research skills in the learning process. The student is expected to process the course matter more thoroughly and to build on his knowledge. As a consequence, physics should be regarded as a science, which questions nature and seeks to understand reality by designing models.

More than in the past, one takes the characteristics of the specific target group into account, including learning styles and student perceptions of physics. The education landscape and learning facilities are also taken more into consideration.

At several Belgian universities interesting initiatives were taken to make physics teaching more effective and appealing to an ever wider public. Some of the groups involved are working within the framework of international projects, such as for instance “Enhancing Teaching – Learning Environments in Undergraduate Courses” (ETL project) [1].

This article does not try to convey an overall picture of all the initiatives taken in Belgium, but wants to present the main trends in education innovation using some examples. When enhancing teaching, the actions can be classified according to their objectives:

- The detection (diagnosis and awareness) of the target group’s characteristics to better adapt the means of education to their needs.
- The remediation of a frequent recurrent bottleneck in the learning process or the stimulation of some aspects of physics education by adjusting existing or implementing new education forms.
- The global and coherent reform of a teaching and learning strategy. This article will treat these three types of actions successively.
Finally, a few examples of newly developed teaching tools dedicated to high school education will be presented.

**Characterization of the Target Group**

Within physics education this characterization can be directed at the cognitive as well as the meta-cognitive aspects, hence at the insight, the reasoning process, as well as at the learning style.

Misconceptions build an essential restraint for a reliable insight into a phenomenon or a concept. They are a priori interpretations that go against a general accepted physics theory. In every country, research has shown the universal character of misconceptions. They are lingering and extremely hard to correct by conventional education methods.

This aspect is of interest to several Belgian groups, more particularly to the Centre for Research and Innovation in Physics Education (CRIPE) [2] of the Universiteit Gent (UG). This centre confirmed results obtained in other countries. Unlike many teachers, the members of the CRIPE-group have long been convinced that ideas which students bring to class are of utmost importance in the learning process.

Within this framework the renowned “Force Concept Inventory” (FCI) test played a decisive role in the 1980s. Its main objective is to determine whether or not the student is a Newtonian thinker. The test is now being used worldwide as a pre and post test to evaluate among other things new instruction models. The CRIPE gave it to more than 1500 students starting the bachelor program.

CRIPE has also adapted a similar test “magnetism concept inventory” for Flemish students learning magnetism. By comparing two different education strategies, they confirmed with this test that as far as insight is concerned interactive education and stimulating teaching methods score much better.

The “Laboratoire de Didactique de la Physique” [3] of the PAMO unit in the Physics Department of the Université Catholique de Louvain (UCL) studies the learning process of secondary school and freshmen. To measure the efficiency of new pedagogic initiatives, they questioned freshmen and searched for indicators that measure their difficulties in learning physics in order to take appropriate steps to remedy the situation.

The group did not develop a test that evaluated acquired knowledge, but rather one that looked at the capacity of cross disciplinary competences such as the ability to read and interpret a graph, or translate a question in prose into an equation or graph. For several years, this test was presented to hundreds of students and detailed analyses as a function of different parameters (gender, age, total amount of hours of mathematics in the secondary school, …) were carried out.

A part of this test was adopted by the Mohican-project of the CIUF [4] (Conseil Interuniversitaire de la Communauté française de Belgique) study group that aims to determine the success rate of first year undergraduate students as a function of their initial abilities.

It also provided the basis for the interactive handbook “Let’s math” designed for senior high school students and which helps them to learn what their strong and weak points are to prepare them for higher education.

Some groups also take an interest in the learning styles of students, within the analysis of the target group’s characteristics, in order to develop instruction forms that might improve their strategy to study physics.

Since the beginning of the 1990s, this has been systematically the case in the “Zelfstudiecentrum B” [5] (ZSCB) for the Freshman year in the Science Department at the Vrije Universiteit Brussel (VUB).
In the “Instituut voor Onderwijs en Informatie Wetenschappen” [6] of the Universiteit Antwerpen (UA) one has also dealt with this problematic to improve study guidance.

**Education Forms for Remedial Teaching or Study Enhancement**

Among the initiatives taken to stimulate education in physics, one finds mainly actions that promote the active processing of the subject material, the conceptualisation and the dismantling of misconceptions, the development of new experiments and the application of information technology to motivate insight.

In a traditional lecture students largely listen passively and without much intellectual commitment. In order to encourage them to think and reason, various research programs in many countries were initiated to develop alternative teaching methods, i.e., to stimulate the student’s active participation by interaction. Often modern information technology is used to this effect.

At the UG, and under impulse of the CRIPE, two such teaching approaches were used, namely “Peer Instruction” (PI) and “Just in Time Teaching” (JITT) [7].

In PI one stimulates the processing of material, preferably in collective activities, with conceptual assignments and carefully formulated questions. The effectiveness of this kind of instruction was investigated in the case of a course on magnetism, and its positive impact was confirmed.

In JITT, classes or laboratory classes are preceded by the offer, via the net, of such conceptual assignments. The lecturer adjusts his instructions based on the analysis of the answers (taking problem areas into account). There is a powerful learning environment with continuous feedback in which effort and evaluation are essential. The JITT is in full development.

The “Laboratoire de didactique de la physique” (UCL) undertook – by itself or with external help– several initiatives at the secondary and university levels to improve the learning of physics and to help students develop scientific thinking.

Based on the conclusion that spontaneous conceptions leading to misconceptions are an important obstacle in the learning process, the education laboratory of the UCL developed a socio-constructivist experimental methodology for high school students. In this approach, the pupil acquires knowledge by asking questions that are related to problems in everyday life. The acquired knowledge becomes meaningful through an active process of integration of new information with initial knowledge. The analysis of assignments given to students showed that this method has its limitations, but nevertheless accounts for an apparent increased interest in physics education.

In the 1990s, in the “ZSCB (Wetenschappen)” of the VUB, small task specific interactive groups were formed. These paid more attention to the learning process than to the learning product, and emphasized conceptualisation and identification of misconceptions. Research showed that this method improves in-depth understanding, student interest and self motivation. For a few years, this group has designed physics “work assignments.” These are complementary homework problems assigned to small groups of (mostly two) students. Usually after a few weeks, the students make a short group oral presentation. Typically, the core of the problem consists in targeting misconceptions in physics, or elaborating modelling approach to otherwise more or less standard problems, or analysing physics applications in other fields such as biology, geography … Crucial is the assessment technique utilized, enhancing feedback during the process of “solving” the problems.

Since the 1980s, Information Technology (IT) has been of great value in teaching physics. A real innovating impact has however only been noticeable for the past few years. An interesting aspect is the development of “Physics Applets” or “Physlets”, simulations in which the student can change the parameters on a simple yet realistic level. The application of Physlets has experienced a strong growth. Physlets can be applied to the course level with...
only a minimum of information. The use of IT does not provide by itself any guarantee of better education, but offers very interesting perspectives for education innovation. Within CRIPE (UG) the development of Physlets is an important activity. Recent advances, particularly in computer technology and software, has brought a number of more advanced techniques and methods of signal analysis within the financial reach of most departmental teaching budgets. This offers the opportunity to set up (better) demonstrations to introduce more difficult concepts as well as more up to date topics and laboratory techniques.

At the Universiteit Hasselt (UHasselt), there is a specific research group “Practica en demo’s natuurkunde” [8] which develop laboratory experiments and class demonstrations to teach physics. The group’s research activity is focused on developing this type of applications. Among them: a study of viscous flow (air flow) through tubes and a laboratory experiment for students in medicine aimed at a better understanding of the mechanics of respiration and blood circulation.

The “Unité didactique de la physique” (Facultés Universitaires de Notre Dame de la Paix - FUNDP) has emphasized the development of new experiments. To facilitate the study of physics, this unit developed on the internet [9] interactive simulations for several freshman year experiments (eg., alternating current, X-rays, waves, conservative forces,…). At the department of physics of the University of Antwerp a new concept for the teaching of experimental skills has been developed. Instead of being asked to follow descriptive menu’s when performing a particular experiment, the students are trained to develop their experiments on their own. Based on general information about available equipment and a general assignment the students design their own experiment based on their own interests. It takes more time than in the classic approach, but the students have a much better understanding of the experimental process as well as the underlying physics.

The group of the “Academische Lerarenopleiding Natuurkunde” [10] (Katholieke Universiteit Leuven - KULeuven) plays an important role in the training of secondary school teachers. In addition to various initiatives in designing handbooks, in physics information technology, and in continuing education it has several didactic and pedagogic projects. As an example of these, a course was developed to encourage students to apply on an active basis the newly acquired physics material in particular for mechanics. The study of mechanics forms a large part of the curriculum during the last year of high school. Although experiments and exercises are carried out by the teachers to help students understand “kinematics” and “dynamics” and to help them gain a deeper insight in the subjects “work and energy”, many students need additional practicing before they really understand these concepts. Simulations in physics can enhance inquiry learning and stimulate discovery learning by visualising abstract physical concepts, exploring the physical world, testing hypotheses, and investigating “what-if” scenarios. They can help develop inquiry skills and physics knowledge by allowing the user to vary physical parameters and to measure their effects. Using this approach, the teacher hopes to develop skills that are both specific (e.g., describe the movement of an object in terms of position, speed and acceleration) and general (e.g., acquiring and processing of information).

The education package developed by the KULeuven consists of an “Interactive Physics” (IP) [11] software program. This is an open program in which complicated simulations within the area of mechanics can be developed. Since Interactive Physics is widely used, many examples and simulations are now available. However, they had to be adapted as the purpose was to provide an independent learning course; worksheets were included with every simulation. Seven different topics in mechanics are covered and each topic has four part demonstrations with short simulations, exercises with closed and well specified assignments, open labs and extra material.
Coherent New Education Strategy

At some universities, the thinking has been in terms of a global education strategy to be introduced gradually.

Compared to many other universities, the UHasselt has a non-traditional and global approach to education that covers all disciplines, including physics. Evaluations and exams are spread across the whole year and active and student orientated education aspects play a central role. The academic year is divided into time periods with exams at the end of each. Thus there is no lengthy accumulation of subject matter and, therefore, the hope that students will learn early to work regularly. One of the most important objectives of the education system is to teach the student to study independently and to deal actively with the subject matter. In addition to attending classes, there are self study periods and group assignments. During the work sessions the results of these assignments are discussed and the teaching is modified accordingly. Additional and realistic problems are then solved by the entire student group. One expects that with this approach the student will develop as fast as possible an efficient study method.

When discussing new global education strategies, the group of the “Département des Sciences, Philosophies et Sociétés” [12] (FUNDP) should certainly be mentioned. In one of their research projects they clearly emphasize the social role of education in scientific and technical secondary school education. This work has had a clear impact on education reforms at the high school as well as the university levels.

The Didactics of Sciences and Learning and Guidance Centre co-department (DIWE-ZSCB) at the Faculty of Sciences of the VUB has historically set as his mission the active engagement of students in deep learning. Over the last two decades projects and guidance programs have been worked out to complement the regular university first-year curricula in the sciences. They are designed to help students who want and need assistance to become better skilled learners.

In recent years much work is devoted nation-wide to move university education to a more competency-oriented endeavor.

In physics education much effort has been devoted to giving new life to the physics course for non-physics majors. For example, by enriching its content with modern examples of how and where physics is applied in our daily lives, and in other scientific fields. Physics problem solving sessions were improved with more generic problems involving tactics and strategies, illustrating that solving physics problems is more than just a plug-and-chunk game. Conceptual development, along with cognitive and metacognitive development, were the main themes in complementary guidance sessions called interactive working groups.

In the course of time it became clear, based on a quite extensive search of the physics and general education literature, that much of the efforts were parts of an overarching goal. Concept development, abstraction, meta-cognition, purposeful problem solving etc. are all important and interconnected aspects of a scheme, that of modeling the physical world using mathematics.

For D. Hestenes one of the most important goals of physics education must be “to engage students in understanding the physical world by constructing and using scientific models to describe, to explain, to predict, to design and to control physical phenomena”. Straightforward as it may sound, what Hestenes prescribes nevertheless requires a major overhaul of physics education.

Nevertheless, it is the intention of the DIWE-ZSCB department to further implement model based curricula as modelling can be considered as a practical vehicle to achieve competency based education through the physical sciences.
Secondary School Education and the Support from Universities

Some years ago, the ultimate objectives of science education at the secondary school level were thoroughly discussed and revised. In the Flemish Community [13] and for physics, more importance was given to develop an enquiring mind. Links between science and society are emphasized and attention is paid to attitudes towards science. In this reform, the physics course material did not undergo major changes.

In 1997, in the French speaking community [14], the final objectives, competences and attitudes with regard to physics education were determined by decree. Secondary school students with a general scientific education will hopefully behave according to scientific ethic. They are expected to have general scientific skills, such as the ability to apply models, to carry through a research, to communicate, to use the tools of mathematics and information technology, etc. As an ultimate goal, knowledge and the proper skill to apply it play an equally important role.

The development of new teaching material is required to achieve these objectives. Almost all universities in Flanders, Wallony and Brussels are willing to help teachers and respond to their scientific needs, whether general or specific. The UCL wants to provide resources to secondary school teachers. Within the project “Science Infuse” on the “e-media sciences” site, they can easily access and quickly prepare required educational topics. With these resources they want to integrate the phenomena of everyday life into physics education [15].

At the ULB, the "Laboratoire de Didactique des Sciences Physiques" [16] dedicates an important part of its activities to the training of teachers and the teaching of physics in primary and high schools. In its “Experimentarium,” secondary school students can carry out physics experiments. In one of their projects, this group developed scientific software specifically designed for youth and in which interactivity, meaningful images and games take a central position.

Scientists of the Université de Liège communicate through “Physique On Line” [17] with pupils and teachers, in order to help them and to debate problems in physics education. At the Université de Mons-Hainaut, the “Centre de Didactique des Sciences” [18] (CDS) groups all scientists who wish to work on the public image of the sciences. For example, they attempt to alter the negative perception of physics on the part of young people.

Pupils in elementary school regularly visit and discover, by means of experimental challenges, concepts like electricity, pressure, .. . From the experience gained in these sessions, pedagogic files for teachers were prepared. The center organises each year an interactive exhibit with several experiments that illustrate in some way the physics taught in secondary school. At this time when experiments in school are being reduced to a minimum, teachers naturally use this resource more extensively.

In the French speaking community, SciTe brings CDS, Science Infuse, Réjouï sciences, Atout sciences .... together. These are groups from different universities that strive to improve the image of sciences. In this way, in times when the interest in science studies is waning, all forces are united.

In the Flemish community, university support for secondary education is significant as well. We have already referred to the UG (CRIPE) and the KULeuven (Academische Lerarenopleiding Natuurkunde). Other universities also support physics secondary school teachers. The “Interdepartementeel Departement voor Lerarenopleiding” [19] at the VUB started a project to advise teachers about research competences in science. At the UA three projects “Brugproject”, “Fysica is cool” and “Project Edison” were launched to support high school physics teachers and to arouse interest in physics with high school pupils [20]. As an example: in the project “Fysica is cool” a self-contained kit for teachers was developed, with physics demonstrations, multimedia support material and teacher training courses.
Conclusion
In Belgium, major interesting initiatives are taken to improve physics education. In most instances innovation is rarely a university priority. In comparison with neighboring countries or the United States, much less thought has been given in Belgium to these problems. Whether we can conclude that the physics education in these other countries is better is another question.

References
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