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Promoting active learning in physics courses for the agro-food degrees[1]

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Promoting active learning in physics courses for the agro-food degrees[1]

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Abstract. Teaching/learning physics in the bio area require a revision of contents, approaches, methods. In the last years at the University of Udine, an experimentation was carried out in the physics course for the agro-food degrees. The main choices will be discussed, highlighting the basic role of active learning proposals and continuous assessment

1. Introduction

Research in physics education highlighted the importance of promoting active learning also at university level [1-3]. Several groups have been studying how to "reinvent" physics for courses for students of the bio and natural sciences sectors [4-6]. One of the main knot is to involve students in addressing issues that they feel distant and little related to the respective field of study [7-8]. This involves further problems in the case of those courses of study in which the role of technological applications is strong, such as those for future agricultural, food production, environment and nature technicians. In these thematic areas, physical concepts are applied at different levels, almost always in an uncritical and dogmatic way. On the other hand, knowledge in physics courses is often constructed away from application contexts, assuming that the students then create the link between concepts and applications.

For an effective approach to physics it is necessary to carry out a profound process of reviewing the issues addressed, the angles of attack used, and the contexts in which to address the different issues with the aim of making physics an effective and useful work-tool and not a set of knowledge that remains confused, vague or inactive.

In the last three years at the University of Udine, an educational innovation project was designed for teaching/learning physics in the four degree courses: Agronomy; Oenology; Science of nature and environment, Science and technology of food. The project was tested in the basic Physics courses involving cohorts of 400-500 students per year. Approaches followed and learning outcomes concerning specific topics have been presented in previous works [9-12].

The present work discuss the strategic choices made and the educational tools activated, aiming to improve the level of involvement of students both on the web and in the presence. Some main results will be discussed to document the formative success of the courses and the role of the educational environment activated.

2. Context for the research

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In the last three years at the University of Udine, an innovative educational approach was designed to contextualize Physics in the undergraduate degrees of Agronomy; of Oenology; of Science of Nature and Environment and Science and Technology of food. It was tested in the two basic Physics courses, Course A and Course B each of them of 6 cts – 60 h, involving cohorts of more than 400 first year students of the four degrees from 2015/16 as shown in Table 1.

Table 1. Cohorts of students involved in the Food-Agricultural degrees of the University of Udine, in three academic years of the experimentation: 2015/16-16/17-17/18. A pre-experiment was carried out in the academic year 2014/15. The last column show the number of students actively attending the courses of physics in 2017/18 (analogous percentage in the previous academic years)

Degree	14/15	15/16	16/17	17/18	FIS (17/18)
AGR-AGRicultural Science	76	94	71	91	71 (78%)
VOE-Viticulture & OEnology	159	142	156	103	79 (77%)
SEN-Science for Environment & Nature	94	82	80	78	60 (77%)
Physics Course A AGR+FOE-SEN	329	318	307	272	210 (77%)
Physics Course B FST - Food Science & Technology	151	185	164	166	74%
TOTAL (Course A + Course B)	480	503	471	438	342

Each of the two course included: 40 hours of lectures, interactive lectures demonstration [3] and exercises/problems/questions (~8 h per each topic), usually each hour was divided in 45 minutes of explanation, 5 minutes of examples/experiments, 10 minutes of exercises; 10 hours of clicker sessions, exercises, paper pencil questionnaires, problems (~2 h per each topic); 10 hours of experiments in groups (each groups: nominally 50 persons, really 30-40) divided in four section of lab experiments. To support the students' formation, an e-learning environment was implemented, requiring the following compulsory tasks (Equivalent to 30-40 hours of personal activity): a contribution per each of 5 topics forum (Mechanic, Fluids, Thermodynamic, Optics & Waves, Electricity and Magnetism); 10 on-line questionnaires; Reports on lab activity.

3. Research design of the Physics courses

Designing the courses, the focus was on raising the quality, rather than adopting simplifying approaches, which are ineffective both in terms of understanding the concepts and the ability to apply them [4, 13]. The approach to physics looks at contents and contexts taken from the specific area of study of the students in increasingly invasive and punctual way. It was decided to analyze problematic contexts typical of the study courses involved in order to draw new angles of attack on the different topics dealt with [11], as exemplified in the next section.

Specific classroom activities were proposed to achieve an active involvement of the students, with a high level commitment, also with the high numbers of students involved in the experimentation [4, 2, 13]. Paper and pencil and clickers questionnaires was inserted inside the lesson to activate reflection of crucial conceptual knots and after lectures for reinforcement and self-evaluation of students. Demonstrative experiments using web cam and real time graph experiments was carried out in form of interactive lecture demonstrations using tutorials [1,3], and was reinforced offering learning objects on the web prepared as interactive questionnaires.

We aimed to build a functional understanding [13] of the physical concepts that gave to students the tools: to appropriate of the methodologies with which physics builds its laws and validates them experimentally; to reach an understanding of the physical concepts that allow students to face the main conceptual knots often on which are connected the main learning problems; to know how to use physical concepts to interpret qualitatively but consistently phenomena of daily life and of their respective fields of study; to know how to apply concepts and physical laws to the resolution of simple both qualitative and quantitative problem solving [14-15].

4. Examples of contextualized approaches to contents

To introduce the Physics contents, the approach adopted considers first of all some problematic contexts, which are specific to the areas of study. Students identify concepts and physical laws necessary to understand contents involved in these contexts of their own interest. The physical concepts are then systematized and deepened focusing on the conceptual nodes on the one hand and providing on the other hand operational skills in the application of the physical laws to the explanation of the everyday life phenomena and to the resolution of simple quantitative problems.

In the case of Mechanic, the approach to kinematic considers the 2D and 3D motions of water flow in a real river and in a duct, the motion of a drone mapping a natural area or a cultivated field, the problem of a cheetah catching a gazelle. The physical quantities as position, velocity, and acceleration are constructed analyzing these problematic contexts, reversing the usual abstract approach adopted in physics lesson and enriching the discussion with context aspects. For instance, in the third case, the specific capacities of the two animals (maximum speed, acceleration, maximum distance at maximum speed [16]) enrich the classical meeting problem, because the success of the catch depend on these capacities. To emphasize the Galilean principle of the motions independence, the paradigmatic parabolic motion are treated in specific cases as that of the flow of an irrigator and of the seed catapult of cardamine parviflora [17]. The possibility to decompose each motion in two or three independent motions occurring in two or three independent directions motivates the study of motion in one direction using on-line sensors. The analysis of real time graphs for the motion of a student walking in front of a sensor or the motion of a car on a table activates the connection between the phenomenon observed and realized and the formal (graphical and algebraic) representation of the physical quantities describing that phenomenon. To pass from the kinematical description of motion to its framing and interpretation in the dynamic perspective, different examples are considered to recognize the role of friction in real motions, to characterize the translational state of motion of a body with the knowledge of the position and velocity of a point of the body and to introduce the first principle of dynamics. This principle stress the fact that to change the state of motion means to produce an acceleration of the body, that means the body must interact with other bodies/systems. The concept of force emerges as the formal descriptor of interaction and is framed in the third principle, extensively contextualized and exemplified as the mechanical interaction between and in living systems or other interesting situations as the collision of a mosquitos and a windscreen, the interaction between parts of a fluid systems. Different forces are introduced and measured statically and dynamically with sensors and then connected to the measured acceleration of bodies, to account the reasonability of the second law of dynamics. Applications exemplify how the construct physical model based on the second principle of dynamic following a strategic pattern, to solve the problem: not solving trick, formula application…but application of general procedure also in simple problems as well in complex phenomena using numerical solution. In this frame for instance many problems and applications are treated concerning the role of friction in the agricultural sciences and food production. The basic of conservation principles are introduced as base of the science research, base for analysis of specific context (the elastic collision of a mosquitos and a rain drop [18]) and to create a web of connections between the different parts of the course (with the dynamic of fluid, the concept of energy in thermodynamic, the dynamic of a magnetic momentum in an external field).

The concept of interaction offers the more direct link to the second example considered here, that is the contextualization of the electric and magnetic phenomenology. As emerged in a first analysis [12], the starting point is the panorama of the different scales size important for the bio area: nuclear/atomic, molecular size; cells size; human/living size, planetary/astronomical size. The main effort is putted to show that physics unify the treatment of phenomena at different scale sizes. For instance the concepts of d.d.p. and of equivalent circuit was exemplified in the case of the polarization of a cell membrane or in the case of the atmosphere electric field and in the lightning bolt phenomenon. The concept of the circuit as a system was connected to the systemic nature of livings, the current in an electric circuits are presented as a paradigmatic model for other circuits, as the blood circulation in human, the fluid flow in a pipe. The review of the magneto-reception in animals [19] are the context to introduce the concepts of magnetism in materials; magnetization; magnetic momentum, electromagnetic induction. These few hints just want to give an idea of the types of situations that are faced and the level of detail with which the different concepts are treated, not being possible here for reasons of space to enter into further details.

5. The e-learning platform

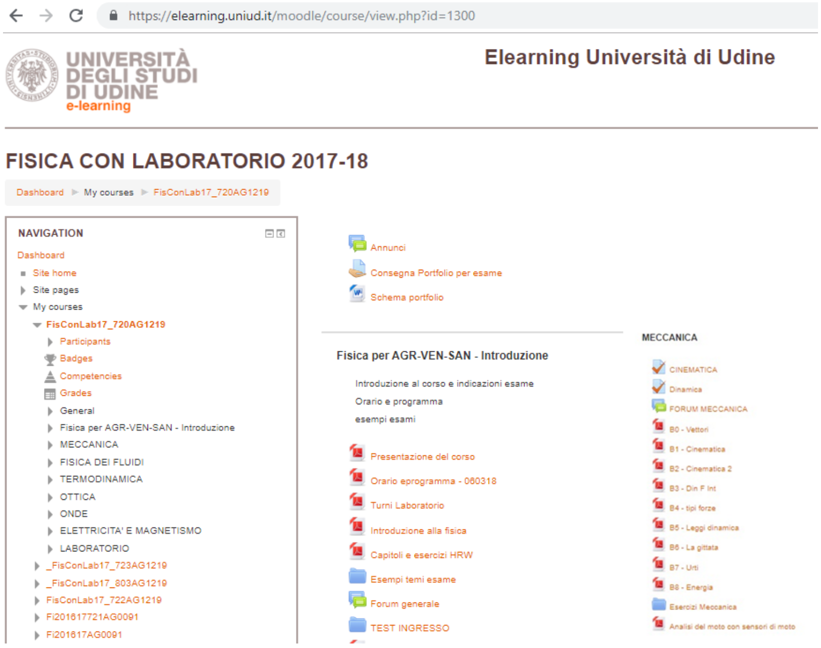
To support the classroom activity an e-learning environment was activated. Figure 1 shows the entry page of the Moodle platform of the on-line course, implemented according to the frame designed by the University of Udine. An entry section offered to students a presentation of the course, suggestion for study and examination (including examples of written examination), references and an introduction the physics as a physical way to look at phenomena.

For each topic, students find on the e-learning platform different educational materials and activities supporting they home work:

- The slide used during the lessons
- Exercises/problems/questions/applications (proposed in presence and on line)
- Learning objects presenting the demonstrative experiments performed during the lessons
- Web-questionnaires
- Forum where discuss specific topics, contribute to other students question/request.

Exercises and items of the questionnaires were examples and base for written examinations (some question was proposed exactly in the same form, some other more often was re-elaborated).

Web questionnaires and contribution on the forum were request for the exam portfolio. The discussion in the web forum was activated suggesting different questions: proposing scientific paper (see for instance [16-19]), asking: “which kind of physics content/competency do you need to understand the paper?”; suggesting an issue (i.e. friction; the Descartes devil) and proposing: “Where and how do you find such phenomena in your area of study and future work? Analogous questions were proposed in the final written examination asking a short open composition.


https://elearning.uniud.it/moodle/course/view.php?id=1300

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NAVIGATION
Dashboard
Site home
Site pages
My courses
FisConLab17_720AG1219
Participants
Badges
Competencies
Grades
General
Fisica per AGR-VEN-SAN - Introduzione
MECCANICA
FISICA DEI FLUIDI
TERMODINAMICA
OTTICA
ONDE
ELETTRICITA' E MAGNETISMO
LABORATORIO
_FisConLab17_723AG1219
_FisConLab17_803AG1219
FisConLab17_722AG1219
Fi201617721AG0091
Fi201617AG0091

Annunci
Consegna Portfolio per esame
Schema portfolio

Fisica per AGR-VEN-SAN - Introduzione
Introduzione al corso e indicazioni esame
Orario e programma
esempi esami
Presentazione del corso
Orario eprogramma - 060318
Turni Laboratorio
Introduzione alla fisica
Capitoli e esercizi HRW
Esempi temi esame
Forum generale
TEST INGRESSO

MECCANICA
CINEMATICA
Dinamica
FORUM MECCANICA
B0 - Vettori
B1 - Cinematica
B2 - Cinematica 2
B3 - Din F Int
B4 - tipi forze
B5 - Leggi dinamica
B6 - La gittata
B7 - Urti
B8 - Energia
Esercizi Meccanica
Analisi del moto con sensori di moto

Figure 1. The entry pages of the e-learning Moodle platform and list of material for mechanics.

The final section of the e-learning environment includes the materials supporting the experimental lab:

- Presentations operative indication for carrying out data collection and elaboration in each of the four sections of experiments,
    - Measurement of volume, mass and density of regular and irregular objects
    - Calibration of thermal sensors and measurement of thermal conductivity of an aluminum bar
    - Reflection and refraction law and image formation using parallax method; Malus law; spectral analysis of the light emitted by a gas lamp
    - Measurement with on-line sensor and analysis of the single slit diffraction pattern
- Aspects of the experiments to be documented in the reports related to the four sections:
- Assignment Folder (students' reports on lab experiments, requested for the portfolio)
- Grid for experiment reports

Figure 2. Students involved in the experimental lab activity.

6. Data

To account the impact of the project, in the present section we report some data concerning the outcomes related to the cohort 2017/18, which are however examples of the three-year of experimentation. First of all we can consider table 2 reporting the student attending the physics courses and the percentage of students passing the physics examination and the students attending the second year of the degree.

Table 2. Number N of enrolled students to the 1st year of the cohort of students 17/18 (1stY), percentage of student performing the final examination (FIS), percentage of student passing the physics examination (FIS OK), percentage of students following the study in the second year of the degree (2ndY).

Degree	1stY (N)	FIS (%)	FIS-OK (%)	2ndY (%)
AGR-AGRicultural science	91	78	68	65
VOE-Viticulture & OEnology	103	77	55	52
SEN-Science for Environment & Nature	78	77	70	68

Physics Course A AGR+FOE-SEN	272	77	64	61
Physics Course B FST - Food Science & Technology	166	74%	55	52
TOTAL (Course A + Course B)	438	342	60	58

Comparing the last two columns, it emerges that the number of students passing the physics examination approximates per excess the number of students attending the second year of the courses, showing that the physics examination is not an obstacle for the prosecution of student careers and do not contribute to the students dispersion. The formative success arises for almost the 70% of the student effectively involved in the examinations, and in some case the percentage was close to the 90%.

This result alone would not be particularly significant if it were not accompanied by adequate qualitative outcomes. Therefore we consider other indicators that emerge from the comparison of the results of the pre-test (table 3) with the results of the final exams (table 4).

The pre-test, administered on the first day of each course, consisted of 22 items for a total of 25 questions including 16 multiple choice questions and 9 open questions, on methodological aspects (7 questions) and on specific contents related to the phenomenology of the mechanics (5 questions), of the thermodynamics (4 questions), of the fluid physics (3 questions), of the optics (2 questions), of the magnetism (1 question). From the evaluation of the pre-test (normalized to the maximum evaluation of 30/30 as illustrated in tab 3) it emerges that the initial competences were of low level and particularly lacking in the case of last year cohort, both the methodological competences and these involved in the phenomenologies considered in the test.

Table 3. Results of the pre-test (the evaluations related to a maximum of 30/30).

	Course A						Course B					
a.y.	N	Mean	σ	Median	Max	Min	N	Mean	σ	Median	Max	Min
2015/16	228	17,0	3,2	16,9	26,3	6,3	146	14,3	3,5	15,0	22,5	2,5
2016/17	188	14,3	3,9	15,0	24,4	5,6	119	13,9	3,4	14,4	23,8	5,6
2017/18	207	12,4	3,5	12,2	22,2	3,3	114	11,8	2,9	11,7	20,0	5,3

This result is consistent with the students' school formation, taking into account that more than half of them attended an upper secondary schools including any physics course or just 1 year course of physics.

The results of the final written exams are summarized in tab. 4, normalized at a maximum of 30/30 as usual in Italy. These exams consisted of three questionnaires each composed by 18 items (15 multiple choice questions and 3 open questions). The contents of the questionnaires concerned similar methodological aspects and contents related to the phenomenologies considered in the pre-test and also included simple exercises and problems, as already proposed to the students during the course in presence or in the network or more often re-elaborated by them.

Table 4. Results of the 1st summer session of the final evaluation (the evaluation related to a maximum of 30/30).

	Course A						Course B					
a.y.	N	Mean	σ	Median	Max	Min	N	Mean	σ	Median	Max	Min
2015/16	233	23	4	21	30L	18	125	22	3,7	22	30L	18
2016/17	179	22	3,5	21	30L	18	101	21	3,8	22	30L	18
2017/18	271	21	3,4	21	30L	18	112	21	4,2	21	30L	18

The mean score obtained in the single items was 55% of the maximum for the Course A and 46% for the course B, including all students attending the final examinations: the students obtaining an evaluation of 18/30 or greater, passing the examination, and the students obtaining an evaluation lower than 18/30,lower than the minimum positive evaluation. It emerges that almost all students attending the course acquired basic competencies in physics, concerning the topic involved in the questionnaires. In particular here we can make explicit the results considering the aspects that was particularly problematic in the pre-test: the competence in graph lecture and extraction of information passed from 30% to 45%; the competence to construct the image produced by a lens pass from less than 20% to 76% (but remained problematic the case of a lens partially covered), the recognition of the role of vapor tension in everyday situations pass from 10 to 55%; the competence on role of Archimedes force in buoyancy pass from less than 30 % to 55%. Problematic remained the role of tension-actives (i.e. soaps) in reducing water tension passed from less tham10 % to 21%.

We can consider the role of attending the lessons looking at table 5, where the results in the final examinations are splitted in two groups: who attended more than 50% of the course, and who attended less than 50% of the course. The outcomes are significantly better, both for what concerns the percentage of students who have passed the exam, both for what concerns the evaluation obtained. This is an important indicator of the role of active student engagement during the lessons.

Table 5. Results of the final evaluation divided in two groups: who attended more than 50% of the course (N50+), and who attended less than 50% of the course (N50-). N: number of students obtaining positive evaluations; NN: number of person with negative evaluation

	N50+	%	N50-	%	N100-80	%	N50	%
Tot	159	100	27	100	68	100	13	100
N	112	70	16	59	54	79	5	38
Mean	21,7		19,7		21,6		19,9	
Max	30 L		26,0		30 L		21,7	
Min	18,0		18,0		18,0		18,0	
NN	47	30	11	41	14	21	8	62

The activities carried out in the e-learning platform and that carried out in the experimental laboratory have certainly had an important impact in the course, even if it is difficult to univocally identify their role. In the first two years of the project these activities have been developed by offering them as optional support to the students. In this case, there were positive outcomes both in the opinions of the students on the significance and effectiveness of the activities and in the correlation with the examination results, significantly better for those who had attended the laboratory and had carried out the activities on the net. In the last year of experimentation, these activities have become mandatory and therefore all the students have carried out them. This resulted in a useful interaction between students, whose contributions in the forums were more than 100 for forum in the course A (maximum number 170 and 244 participants) and 45 in the course B (maximum number 145 and 127 participants).

The contributions were: in the 27% of cases argumentative discussion of the proposed context that significantly enrich the scenario proposed in the classroom and by the interventions of the colleagues; in 67% of cases, a simple list of examples of situations, half of which replicate situations already proposed by others; in 6% of cases, didactic interventions (e.g. on friction types). The more original contributions are almost entirely concentrated in the first half of the interventions. All the last 20% of interventions are lists of contexts. The high number of students and the inability to control how the activity is carried out on the net prevent the use of the activity and the materials produced by the students on the net for an effective evaluation of their impact on their formation.

However, it is possible to point out some elements that must be investigated with further studies. There is a significant correlation between the quality of online contributions and the results of the exam. Similarly, a significant correlation between the quality of the results and the completeness and quality of laboratory reports could be documented. However, it is not clear if it is the best general preparation to produce better laboratory reports and interventions in the network, or if it is precisely the commitment required in carrying out the activity in the e-learning environment and in the laboratory that produced the improvement in preparation. Here we can only hypothesize that the impact of the different activities and tasks required for the student portfolio was positive for the students' preparation, when the e-learning activities, including reports on laboratory experiments, was performed as a preparation for the final examination, recognizable, for instance, by the personal contribution, by the quality of the interventions, by the results of the questionnaires carried out on the web, by the times and the number of connections. Some opinions expressed freely and anonymously by some students at the end of the course support this hypothesis.

On the other hand, there is also a negative correlation between engagement in the e-learning activity and the results in the exams, but again it is difficult to establish an unequivocal causal relationship. It seems reasonable to assume that the impact of the activities carried out has been marginal for the students who have dealt with laboratory and online activities as an act of presence, as an obligatory task to be performed, without effective personal involvement. A further consideration relates to role of the educational materials offered online and the proposed activities. Although these material and activities were designed to support even non-attending students, the latter are among those who have benefited less from the opportunities of e-learning as it emerges both from the type of forum contributions, both for times, periods and modality of connection.

7. Conclusion

From three years, a project was carried out at the University of Udine for innovation in teaching/learning physics in the degrees of agronomy, science of food, oenology, natural science and technology. The project aims to enhance the formative success, the student's preparation, the construction of knowledges and competences in physics usable by students in their own study and future job. The challenge was to promote active learning and engagement of students also in the case of big groups of students with very poor preparation in math and phys. Different tools and strategies both in presence and in e-learning platform was activated. New approaches to content were adopted, starting from problem specific of the study areas to recognize the concepts of physics involved. Cohorts of more than 400 students per years were involved. The results collected both on the basis of the self-assessment tests, the intermediate and final written exam tests show: good results on formative success; significant learning level of students of the main concepts dealt with; competence in the use of physical concepts in the analysis of daily phenomena and specific to their respective fields of study.

Significant correlation was observed between results in the final examination and the effectiveness of in presence and on web educational activities. The web activities were not completely adequate to intercept many of students do not following lessons and attending the activity on the web just as compulsory penance. The interventions in the web forum highlights the importance of defining precise tasks so that the online activity translates into effective formative path, but also in this case the effectiveness is related to the effective involvement of students.

The positive results obtained, documented here both for the reduction of the dispersion and as well as for the improvement of the students' preparation, are also supported by the feedback from the colleagues of the degree courses. However, in future it will be necessary to develop new tools and to study new strategies to actively involve both non-attending students and the many students who have interpreted the task only as boring obstacle to passing the exam, instead of understanding the role for their own preparation.

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