Laboratory activities and the perception of students

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Abstract
The perception students have towards laboratory activities has been analyzed on the basis of the results of a questionnaire. It has been examined a sample of 99 High School students and about 270 university students, the latter attending the three years of the Physics Bachelor degree course at the University of Turin. It has been considered interesting to analyze the perception students of different ages and school levels have towards laboratory activities.
After a preliminary phase of study on the expectations and the perceptions of the students related to laboratory activities, we decided to conduct a more detailed analysis of the students' opinions evolution.
We investigated different aspects, such as comprehension of the concepts of Physics, interest in laboratory activities, complementary nature of laboratory activities and classroom lectures. Questions were gathered together into some main streams:

- The usefulness of laboratory to attain a greater comprehension of Physics;
- The interest in and the complementary nature of laboratory activities and classroom lessons;
- Increasing of the capacity to use other instruments, whether of an informatics type or others (not presented here);
- The usefulness and ease of use of the informatics instrumentation. (not presented here)

We then conducted an analysis for each question by means of a chi-square test, considering a null hypothesis, which followed a simple uniform statistical distribution. We also analyzed the elements that students considered as positive or negative in laboratory activities during their years of learning.
The analysis work conducted on the questionnaire responses has pointed out some considerations that offer several ideas, which could inspire future didactic programing.

Keywords
Physics education; Survey; Laboratory activities

Introduction

Within the teaching of scientific subjects didactic laboratory activities, are a fundamental way of learning for students thanks to their own distinctive complementary to classical face-on lessons, [see for example Schawb, 1962; DeBoer. 1991; Hofstein and Lunetta, 2003; National Research Council, 2006].
The objective of laboratory activities is not only the demonstration of concepts, laws and procedures. There are some other important achievements such as the attainment of a greater maturity and autonomy of thought by students, an enlarged capacity of cooperation and the use of multiple types of instruments in order to reach a result (Hodson, 1993). In the laboratory it is possible to develop learning modalities, such as that of "cooperative learning" (groups of students that collaborate/cooperate in a work of in-depth analysis and learning that leads to the building of new knowledge in order to reach a common objective- Johnson et al., 1981; Johnson & Johnson, 1985; Lazarowitz & Karsenty, 1990) and "learning by doing" (the action and experimentation of situations, duties and roles in which the subject, as an active participant, finds himself/herself in a position in which he/she must use his/her own resources and competences to elaborate and/or reorganize theories and concepts in order to reach an objective - Lazarowitz & Tamir, 1994).
Nevertheless, students (and on occasion some members of the teaching staff) often give greater importance to those subjects more closely related to on-face activities than to the laboratory ones. This tendency is shown sometimes in High School, where not all the students are interested in scientific subjects, and where teachers are often not prepared to plan or conduct laboratory activities and frequently underestimate their importance (see for discussion Tamir, 1989; Yung, 2001; Loucks-Horseley & Matsumoto, 1999). Unfortunately, teachers' education does not give enough weight to how a process of information acquisition is obtained, nor a correct idea of the hierarchies that exist between the various activities proposed to students is given. As Hofstein and Lunetta (2003) argue, the lack of information on best professional practices and the misunderstanding of rationale behind such suggestions influence students' perception and their behavior in laboratory. It is indisputable that the teacher can create intelligent and educational activities for students only after having learned the essential concepts, methods and technologies (Wenning, 2011; Domin, 2007; Redish et al., 1998, Hammer, 1989, 1994a , 1994b; Hart et al., 2000).
The Italian High School reform has established the teaching of Physics from the first year of higher education (14 years old students, on average), when the students have not developed a mathematical knowledge and maturity strong enough to allow them to deal with complex topics in a rigorous way. In this sense laboratory activities become important in order to improve the knowledge of concepts and principles through the result of concrete experiences (Freedman, 2002). Laboratory activities in fact engage students in events in which they can investigate, identify problems and try to suggest modelling solutions. They can also learn to express results in different languages (natural and formal, both analytical and graphic) and

to interpret them in the light of their previous knowledge, getting to understand how to initiate/inhibit a process or how to vary the behavior of a system (Sassi & Vicentini, 2009).
Laboratory sessions can become a general learning moment, because of the broad possibilities of increasing students' autonomy of actions in various fields. Elawady and Tolba (2009) report that in hands-on laboratory all the educational goals (Conceptual understanding, Design Skills, Professional skills, Social Skills,) are present with a strong emphasis on the first two(Conceptual Understanding and Design Skills). It could therefore be important to value all these different aspects in the educational curriculum, gradually proposing activities and requests that would make it possible to put into practice all the mentioned skills, and to assess them in a suitable way. Lab reports offer to students the chance to depict more aspects of their laboratory work (Haagen-Schuetzenhoefer, 2012). Laboratory activities can play an important role in growing inquiry capabilities and scientific understanding as well (Hofstein, Shore, & Kipnis, 2004). Experiencing what research activities mean allows students to develop possible potentialities (Chiappetta & Koballa, 2006) which could also be important for future choices. Deacon and Hajek (2011) present all these and even more reasons in their work.
However, the current restriction of funds and technical staff in Italy, together with the increasing number of students in each class and the reduction in the hours reserved to the various activities, makes more and more challenging for teachers to carry out teaching based on laboratory activities. The gap between what we propose as necessary for a adequate teaching of Physics and what teachers are actually able to do so increases. Textbooks do not help very much: the sections dedicated to the presentation of problems connected to experimental activities, to the correct analysis of data, to the writing of results or the drawing and reading of a graph, are very restricted and often relegated to the first chapter, without any connection to what the text develops later on. The experimental method thus becomes an historical/philosophical part of the scientific learning and development process, and not a work methodology according to a succession of mental and practical steps.
Even at a university level, the importance of laboratory activities often appears more established on paper than in the real belief of the teaching staff. Perhaps the high demand on space, instructors' time (mostly for scheduling) and experimental infrastructure also contribute to this situation.
In this context we considered interesting to analyze the perception that students have towards laboratory activities by submitting a questionnaire to students of different ages and school levels, from the last years of high school up to the third year of university.

Preliminary study

Starting from 2005, the activities proposed as part of the Scientific Degrees Plan (PLS),with the aim of attracting High School students to scientific degree courses, allowed hundreds of young people to have part in numerous activities in the areas (very often the laboratories) of the Physics Department, University of Turin. At the end of the activities the students filled in a questionnaire to investigate, apart from the appreciation or lack of appreciation of the experience, some topics of general nature: how much time they spend in laboratory with their teachers and what they would have liked to know and study in more depth through the study of Physics. These activities involved more than 3000 students in the last years of High School during consecutive years.
Limiting the attention to the aspects of interest for this study, the averages for the questions on 'interest in the activities' and 'their usefulness for the comprehension of Physics', is 3.4 and 3.2, respectively, with a correspondence of 1 for "certainly no" to 4 for "certainly yes", with options of 2 "more not than yes" and 3 "more yes than not".
We developed a subsequent approach with some of the students who frequented the first year of the Physics degree course (about 50 responses) over the 2010-11 academic year. They had undergone at least 4 sessions in the laboratory, with the relative data searches and analysis. These students were given a form to fill in between the first and second modules of the Physics Laboratory I course (the first year introductive course on the management and analysis of experimental laboratory data). The questionnaire had the purpose to investigate the expectations of students and any possible disappointment compared to their previous expectations, after the first didactic period with a laboratory course. The first emerging factor was that after this first period of activity the expectations referred to having a "more interesting and applicative" course, even if the clarity of explanation was good (75%). Students also considered "of good clarity" (78%) the arguments presented by teachers but only 25% of the students declared that "the subjects were interesting". 86% of the students stated that they would have preferred a greater development of the applicative part. A preliminary interpretation of the results thus reveals that they were not aware that, in order to obtain information from experimental data, they must be able to analyze these data according to methodologies that they can only acquire through a theoretical course. The second consideration is that the instrumentation used in the first year laboratory is delicate and students cannot manage it autonomously. They have to follow codified operations under the prescriptive control of an older student during the first part of the activity, and of a member of the teaching staff during the analysis phase: this fact undoubtedly reduces the attractiveness of the activity itself.
After these preliminary phases of study on the expectations and perceptions of students related to laboratory activities, we decided to conduct a more detailed analysis of the evolution of the opinions related to this type of activity.

Statistical survey characteristics

The objective of the study was to follow the temporal evolution of the approach to the laboratory and its different components, starting from the students of the IV and V years of High School and going on to students attending the III year of the degree course in Physics.
We made the analyses mainly during the 2011-12 academic/scholastic year and in particular during the spring-summer of 2012. University students participated in a further part of the analyses during the subsequent academic year. There were fewer responses in the second year than in the first year of investigation. A comparison of the distribution of the responses related to the same laboratories given during the two academic years (considering that during that period some teachers changed) showed that the situation remained nearly uniform, from a percentage point of view, enough to allow us to consider the responses of the students from the two cohorts together for each of the frequented laboratories. As for as the students from the High School, 99 pupils attending the IV and V years at the “Cocito” Scientific High School in Alba (Province of Turin) filled in the questionnaire.
In the secondary school, classes had not often the opportunity of directly participating in experiments, and the occasion offered by the PLS, to couple classroom lessons with laboratory activities, led to an increase in interest and in the expectations of the students. The teacher presented the subjects related to the thermodynamic cycle and to the operating principles and technical capabilities of a thermal engine before the laboratory activities. A significant number of students had greater experience in the laboratory than others; however, all students had taken part in laboratory experience focused on themes related to the transformation of energy and the use of renewable energy.
The participants in the investigation at the University were 270 students attending the first, second and third years of the Physics Bachelor degree at the University of Turin, where 6 obligatory laboratories are in operation (2 for each year of the course). Every student answered for the two laboratories of the year and some 3rd year students answered about I and II year laboratories also.
Laboratories are moments in which experiments refer to themes as close as possible to the subjects of the parallel face-on courses. The laboratory courses have also the objective of acquiring operative autonomy and coordination in the group, together with the capacity of using methods and technologies, to perform critical analyses and to obtain communication competences.
During the first year, the first laboratory session, which is held simultaneously with the Mechanics course, gives the basis for the analyses of experimental data and mainly deals with kinematic and dynamic experiments. The experiments are not complex and the pupils simply study the links between physical variables. The activities take place in the laboratory with groups of 4-5 students, under the control of a tutor (an older student from the Master degree course at university) and of the teacher. The laboratory instructional environment is the expository style (Domin, 2007; Dunne & Ryan, 2011), with a predetermined outcome and a procedure to follow. During the second laboratory session of the first year course, students have acquired the notions of *Mechanics* and they are developing those of *Thermodynamics, Fluids and Mechanical Waves* in the classroom context. This second laboratory session involves more elaborate experiments using a deductive approach, where the relationship between the variables is not always direct; they concern thermodynamics, fluids and acoustics and require a more reasoned application of the principles of Physics presented during the lessons.
During the second year, after the *Electricity and Magnetism* course and the *Electromagnetism and Optics* course, students take part in activities related to circuits (third laboratory session), and to geometrical and physical optics (fourth laboratory session). In the laboratory session dedicated to circuits, the greater simplicity of the instrumentation that they have to use leads to an increased autonomy for students, who can therefore feel more involved and responsible for the development of the experiments.
The activities proposed in the laboratory session of the third year require students to have a greater capacity of autonomy in the mounting and calibration of the instrumentation, through the use of supplied manuals: the laboratory instructional environment is problem-based style, with students responsible for generating their own procedure. In the parallel course *Atomic and Solid State Physics* and *Introduction to Nuclear and Sub-nuclear Physics* teachers introduce the theoretical related subjects.
Overall, 99 responses were obtained from the high school, and more than 600 from the university students, which were divided into around 350 for the first year laboratories, more than 150 for the second year and about 100 for the third year laboratories. Not all students replied to all questions, so we reported the results as percentage of the total number of students in each laboratory that answered the question.

Analyses of the questionnaires

The administered Likert style questionnaire (agree – disagree) was similar to that proposed to university students in Canada (Deacon & Hajek, 2011).We decided to exclude some questions as they were less suitable for the examined sample, thus the number of questions was reduced from 23 to 15.
As already pointed out in the Deacon and Hajek (2011) research, we gathered the questions together into some main streams:

- The usefulness of laboratory to attain a greater comprehension of Physics.
- The interest in laboratory activities and the complementary nature of laboratory activities and classroom lessons.
- Implementation of the capacity to use other instruments (informatics or not informatics).
- The usefulness and ease of use of the informatics instrumentation.

The questionnaire also included two open questions on "What I like" and "What I do not like" in laboratory activities.
We analyzed the responses according to the four main streams indicated in the previous section and studied the percentage distribution of the responses for each topic/question, divided according to the year of attendance of the students. In the conclusions, whenever possible, an interpretative consideration with some suggestions for the next few years is given.
There were two series of values for each year for the university students, one for each of the proposed laboratories. The responses were catalogued with reference to 5 possible choices that were given in the question text: from "*certainly yes"*, that is, complete agreement with what was stated, to "*certainly no"*, that is, complete disagreement with the proposed reference statement. We did an analysis for each question, through a chi-square test, considering a null hypothesis, which followed a simple uniform statistical distribution. Therefore, the non-acceptance of the null hypothesis shows the presence of a diversified response which points out a change in opinion over the years, or a more positive opinion (or more negative) than the one foreseen for a pure proportional distribution.
Here we present only what concerns the first two points, where themes result related to each other; they examine the connections between what students study by face-on lessons and what they study in depth through laboratory activities.
For the three statements: "*The laboratory activities contribute to the enlargement of my preparation in Physics*", "*The conducted activities are interesting*" and "*The part carried out in the classroom and that conducted in the laboratory integrate each other in a harmonious manner*" student can express their degree of approval on the formulated hypotheses through the five choices that were given.

Usefulness for a greater comprehension of Physics
As far as the first question is concerned, the activity surely is considered useful in order to gain a greater comprehension of Physics: the responses that assert the non-usefulness or the complete non-usefulness of the laboratory activities for the comprehension of the subject have been irrelevant. The unsure responses show a maximum of about 12%.
When considering the trend of complete agreement (clearly yes) compared to agreement (yes), passing from the High School pupils to those of the third year of the degree course, a non-uniform inversion of opinion can be observed, which has also been pointed out in the chi-square test (p=0.005), and which is illustrated in Figure 1. The pupils in the High School agree (64%) and complete agree (32%), while the students in the third year of university indicated the opposite trend (28% of "yes" against 55% of "clearly yes"). The percentages of the two responses are more or less uniformly distributed for the first and second years of university (p=0.93).
In the Canadian research the percentage of agreement was about 50%, while complete agreement was about 25%. It is possible to hypothesize that the positive assessment of the laboratory activities is undeniable, but also that it becomes stronger as time passes and with a greater knowledge of the subjects, which tend to become more and more difficult to concretize without the aid of laboratory activities.

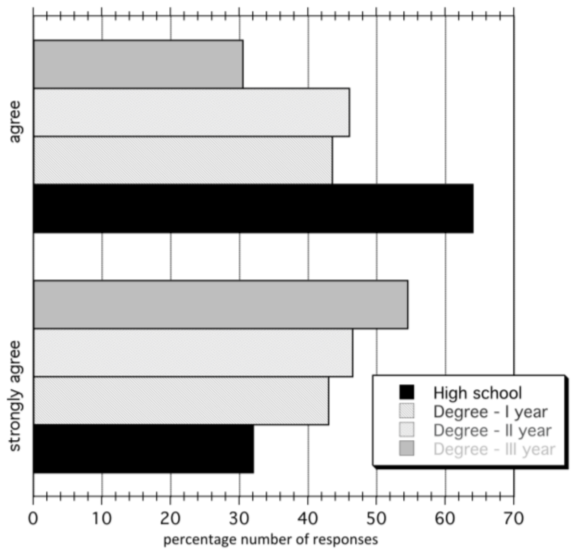

Figure 1. Trend of the percentage number of clearly positive and positive responses to the question "*The laboratory activities contribute to the enlargement of my preparation in Physics*" accord to the year of attendance.

Interest in the laboratory
As far as the question related to interest is concerned, the responses are not distributed overall according to a uniform trend (p=0.0006). Table 1 presents the distribution of answers to the question relative to interest in laboratory activities.

Table 1. Distribution of answers to the question '*Are the laboratory activities interesting ?*'

year	Laboratory	number of answers	cleary yes (%)	yes (%)	yes and not (%)	no (%)	cleary not (%)
High School	1	99	28	58	14	0	0
1st Univ. Year	1	222	20	48	28	3	1
	2	121	18	52	28	2	0
2st Univ. Year	1	149	32	44	21	2	1
	2	67	28	31	39	1	0
3st Univ. Year	1	54	35	43	13	7	2
	2	52	33	42	15	8	2

In order to understand which cases are more distant from a uniform distribution, and if the disagreement is positive (I was more interested than expected) or negative (I was less interested than expected), we decided to group the responses into two categories (content: "clearly yes + yes, "and not content: "yes and no + no + clearly no"; see Figure 2). The following points emerged:

- Satisfaction in the High School was greater than expected.
- Less satisfaction was expressed at the University, although the result was not far from the uniform distribution ($p=0.16$), and showed a higher degree of dissatisfaction for the first year students and a lower degree for the third year ones.

Therefore we confirm once again what emerged before: the expectations of first year students are different, and only some of them are able to accept the fact that laboratory activities have also the function of acquiring knowledge and competences related to the analyses of experimental data. During the third year, the activities reveal more their characteristics of experimental verification of what the students acquire in the study of the theory of Physics, and this makes the analysis more corresponding to the expectations of interest of the students. So the mismatch between students expectations about the laboratory work and the teachers' pedagogical intentions (Hart et al., 2000; Hodson, 1993; Hodson, 2001) decreases with time because of a greater maturity and a instructional style less focused on completion of tasks.

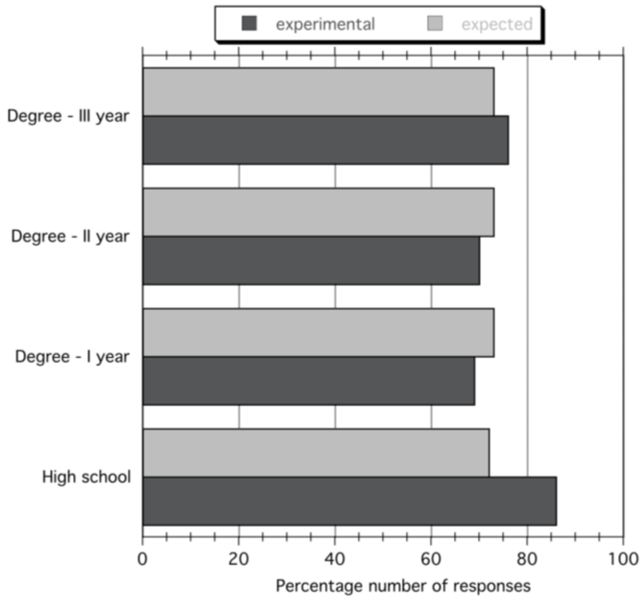

Figure 2. Comparison between the experimental values and the expected values concerning the satisfaction of the students, divided according to school, relative to interest.

Complementary nature of laboratory and classroom lessons

The same result emerges from the question related to the completion between the part in the classroom and that conducted in the laboratory "*The part carried out in the classroom and that conducted in the laboratory integrate each other in a harmonious manner", (*the results are reported in Figure 3). If we consider the harmonization of the two paths, it is possible to observe that, with the passage of time, the students obtain a better perception of the situation, although there is a certain degree of oscillation. The chi-square test has shown, with p=0.0003, the significance of the percentage variation of complete agreement from High School (5%) to last university year (20%).

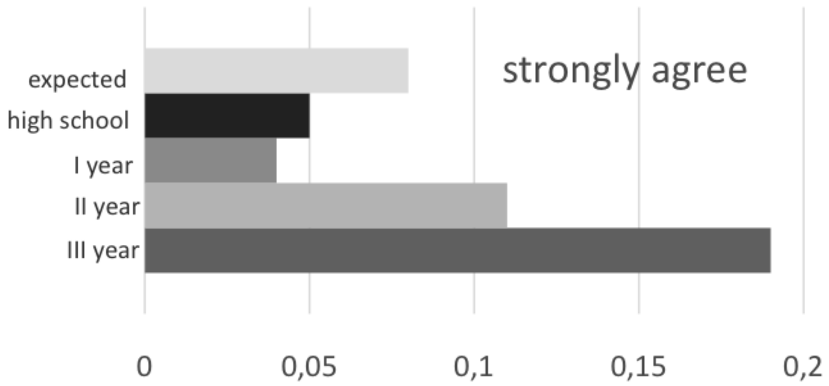

Figure 3. Distribution of the 'completely agree' to the question "*The part carried out in the classroom and that conducted in the laboratory integrate each other in a harmonious manner*", versus the year of attendance.

When we analyze the distribution year by year, we find that in the first year of university there is a distancing from a uniform distribution (p=0.04) in a negative way: the students expected a greater coordination between the two didactic parts, which they clearly did not find. In fact, as it has already been pointed out, the laboratory courses in the first year include not only activities relative to the parallel Mechanics, Waves, Thermodynamics and Acoustics course, but also all the parts pertaining to the introduction to statistics and data analysis, which the students feel as not closely connected to the teaching of Physics. In the third year, they completely refused uniform hypothesis ($p=7\ 10^{-5}$), but in a positive sense: the students recognized a clear complementarity between the two parts, which they consider to integrate and enlighten each other.

Open comments

Eventually there were the comments to open questions concerning laboratory practices that were considered enjoyable and those considered not enjoyable, how they were structured, how they were examined (Table 2). We can divide the responses by some fundamental characteristics that concern the proposed practices, the group work and data analysis modalities, the available technical material and the availability of the teaching staff and tutors.

Table 2. Grouping of the free responses to the question "*What do you like about the laboratory?" and "What do you not like about the laboratory?"*.

What I like about the laboratory	What I do not like about the laboratory
To experiment and verify the theories studied during the lessons, to obtain a greater comprehension of Physics and to develop manual skills.	The burden of the requested work (both for the measurements and for the analyses); physical and mental fatigue due to the 4 hour sessions; conflict with other courses
To understand the problematic nature of the experimental measurements and of their analyses	Lack of time and of the possibility of conducting experiments in an autonomous manner (first year)
Group work, acquisition of a critical mind, collaboration, contact and relationships with teachers/tutor, informal atmosphere	Boring practices, with very complex data analyses or excessive number for the considered didactic period
Autonomy in the management of the practices, construction of apparatus; possibility of varying the parameters in order to increase comprehension; more modern and interesting practices (in the second and third years)	The bad preparation of some tutors, lacking/obsolete/incomplete didactic material, laboratory data sheets not complete; obsolescence of instruments
	Groups are too numerous or with non-collaborative members
	Adequacy of what is required in the laboratory with what is explained during the lessons; too many technical aspects are taken for granted
	Very short times for the handing in of reports for the examinations; different software programs used in the different laboratories

High School students very often pointed out the concreteness of the activities in the enjoyable features of the laboratory, as well as the possibility of "seeing" what had been explained during the classroom lessons in a theoretical way relative to physical laws. At the same time they indicated among the negative features the necessity (often not clearly understood) of

the need to repeat the measurements and the "heaviness" of the data analyses with the drawing up of reports about procedures, results and comments.
In the first year, among the negative points, the reduced operative autonomy came first, together with the lack of appeal of some of the proposed practices. In the subsequent years, there were more negative written replies concerning the lack of suitability of the teaching material (both relative to the lessons and to the data sheets and the instrument manuals in the laboratories), and pertaining to the instrumentation, which in some cases was considered obsolete. Students instead always judged positively the possibility of conducting experiments on the theoretical laws explained during the lessons, the group work modality and the closer and less formal relationship with the teaching staff, compared to lessons and exercises conducted in the classroom.

Discussion

Different considerations arise from the analysis of the responses to the questionnaires. In the preliminary phase of our investigation with first year university students, we noted their hope of having a "more interesting and applicative" course: 86% of the students stated that they would have preferred a greater development of the applicative part. This difficulty lowers with time; in particular, during the third year laboratory, the practices refer to physical laws not experienced directly on a daily basis, unlike what occurs in most of the Mechanics and Thermodynamics laboratory sessions. This fact produces a natural greater interest and curiosity among students and they more easily realize the aspect of having to concretize what has been learned during the face-on lessons. In any case, harmonization between the teachers of the classroom part and those of the laboratory part become fundamental in order not to loose the positive aspect of concretization of theoretical laws during laboratory activities.
What further emerge from students indications is that they do not like neither the presence of tutors (who further reduce their leeway) nor the methodological part of the course. It would be preferable for students to understand, starting from the High School, that they can obtain results only from the analysis of data and not simply from the conduction of experiments, perhaps experienced in a passive manner, nor from the collection of data without a connected discussion. From laboratory activity, students must understand what there is behind a result. Moreover, this experience has not to be reduced to a series of attempts conducted in a random manner, but it should be highlighted that actions must be predefined by an experimental idea of what should occur. Only in this way, through a priori hypotheses on the expected behavior (problem focusing phase), is it possible to plan suitable experimental procedures (planning phase, data collection and analyses) – (Sassi & Vicentini, 2009).
Without going into too much detail on the analyses, it is important that students acquire the concept of the inherent experimental error in measurement operations, whether connected to the instrumentation itself or to their incorrect behavior. Hence, they have to know the essential instruments for the correct data analyses. Currently the average situation in High Schools does not seem to be at this level as there is a lack of laboratory activities. Even when the laboratory activities take place, there is a limited development of what allows them to establish an appropriate basis of data discussion. Therefore the positive feedback of the students to the laboratory activities they have done, as well as the negative feedback concerning the necessity of analyzing data according to exact rules, are not surprising results.
Also in the university laboratories there is the risk of not attributing the right importance to the planning of the experiences and to the critical analysis of the results. The expectations of students who choose a scientific course, such as Physics, sometimes are not satisfied in the first year of university due to the needs of educational path. Students often consider the laboratory activities of secondary importance, compared to the parallel theoretical courses, and so they perceive as excessive the commitment required for their presence in the laboratory and, above all, for the analyses of the data and the drawing up of reports. After their first laboratory course, examination must investigate not only the acquisition of theoretical data analysis techniques but also, and above all, all the laboratory activities. Laboratory aspect has therefore to be valued and kept into account in the same way as the acquired capacity of correctly carrying out Mechanical problems or Analysis exercises.
What is also observed is that students progressively overcome the initial difficulties and the lack of interest in acquiring basic methods for the statistical analysis of experimental data. The partially negative opinion expressed in the first year, mainly concerning the interest, gradually changes. Above all, students develop a great awareness about the acquisition of instruments relative to data analysis as a compulsory step towards the achievement of usable information gained from experimental activities. In order to reinforce this awareness it could be useful to introduce a moment of experimental activities involving direct contact with a research group. In our headquarters, the preparation of the thesis at the end of the three years Bachelor's degree engages many of the students in this way. Acting independently, they come to understand how the knowledge they have acquired is actually usable and necessary, not only in order to pass a specific exam. The

preparation of the Masters' degree thesis (for which 45 educational credits are reserved), throughout guided research work and elevated autonomy and critical capacity, strengthen these convictions.

As for the aspect of autonomy in the management of experimental activities, which has resulted to be important for a great number of students, it appears to be difficult to realize for first year large cohorts at university. Unfortunately, the instrumentation is often expensive and it is not always able to come up to the students expectations, as can be seen from their answers. Moreover, the Mechanics and Thermodynamics laboratories generally use delicate instruments, which make necessary the constant presence of technicians and tutors. Electricity course (carried out during the second-year laboratory sessions for the examined sample) offers to students the possibility to work autonomously and makes the laboratory work more interesting and amusing. Independent laboratory experiences should also be exploited in order to make students learn how to plan what they want to obtain, and then to verify that they have acted correctly to reach the proposed objective. Whenever possible it would be useful, when working with relatively small groups of students, to leave them free to analyze data in an autonomous way according to their previously gained knowledge. It would be possible then to discuss what emerges and guide them towards the necessity of conducting a more detailed study of the theory that underlies the correct analyses of the experimental data: a "lab" means not only manipulating equipment, but also ideas (Hofstein & Lunetta, 2003).

From "*What do you not like about the laboratory?*" we find as answer the work in group, especially with not always collaborative members in the group. Laboratory activity gives the possibility to introduce students to team work. Teachers have to be careful to the dynamics installed within a group made up of students who did not know each other before. Students have to learn (as in a work environment) how to organize and "take advantage of" the different expertise of each member of the group, concerning both the analysis and the result production time. The questionnaire responses have highlighted that if the group is too numerous or with non-collaborative members students find difficulties in enjoying the team work and list it among the unpleasant features of the laboratory activities. On the contrary, it could be important to point out the educational value of team work, considering it together with all the other elements evaluated by teachers in the overall assessment during the examination. Overall, the planning activity of the experimental procedures should become a fundamental moment of the group work. During the third year laboratory sessions, students have to deal with the necessity of utilizing manuals that describe the properties of a used instrument, acting in a slightly more autonomous way. The group work of the third year requires students to increase their capacity of positive interaction, although at this stage the process becomes easier due to the fact that students know each other better (and thus can make choices that can favor interaction and collaboration).

Other interesting observations can be made looking the open comments as well. In particular, students emphasized *"the bad preparation of some tutors, lacking/obsolete/incomplete didactic material, laboratory data sheets not complete; obsolescence of instruments".* Students often complain about tutors' preparation. It could be important to take care of the preparation and the activities of tutors; although not compulsory, it can be a real moment of development of their competences and ability (Ryan, 2014). The preparation of tutors could therefore go beyond a simple "training" and involve codified operations, thus becoming an educational moment which would later improve their activities with their younger companions.

In a similar manner teachers have to dedicate a deep attention to the preparation of the laboratory material according to the different needs of each year of their courses. Laboratory data sheets should be able to guide students in the correct execution procedures when the length and complexity of activities connected to the gathering of data require certain guidance, considering the limited time students are present in the laboratory. It could be useful to start from very simple practices for which only the strictly necessary information should be supplied, and then to ask students themselves to draw up a laboratory data sheet containing the information they believe as necessary for a correct conduction of the experimental steps. Teachers have to present detailed datasheets as a necessity in order to reach the objective, because when a preparation error occurs, students do not gather all the elements necessary for the analysis in the time available for the laboratory exercitation.

Conclusion

In this research we study the students approach to the laboratory, starting from IV and V years of High School and going on to students attending the III year of the degree course in Physics. We used a questionnaire and had answers from 99 students from the High School and 270 students attending the first, second and third years of the Physics Bachelor degree at the University of Turin.

The analysis work carried out on the questionnaire responses has pointed out some considerations, which had already been shared by the teaching staff, and offered some starting points which could inspire future didactic programing.

The main result from the questionnaire is that the way of working in groups, the autonomy in the management of the laboratory activities, the capacity of utilizing information and instruments in a critical manner and the experience of writing a correct and complete scientific report, all seem to be attainable during the typical laboratory educational activities of the three-year degree course. In conclusion, we can confirm that, through the analysis of the responses made, we are able to point out some critical points on which to work over the next few years, in order to maintain the educational aspect of laboratory courses and at the same time to broaden their educational capacity and the positive acceptance of them by students.

References

Chiappetta, E. L., & Koballa Jr., T. R. (2006), *Science Instruction in the Middle and Secondary Schools*, 6th ed., NJ: Pearson/Merrill Prentice Hall.

Deacon,C., & Hajek, A. (2011). Student perceptions of the value of Physics Laboratories. *International Journal of Science Education*, **33**(7), 943-977. DOI:10.1080/09500693.2010.481682

DeBoer G.E., (1991), *A history of ideas in science education: implications for practice,* Teachers College: New York

Domin D.S., (2007), Students' perceptions of when conceptual development occurs during laboratory instruction, *Chem. Educ. Res. Practice*, **8**(2), 140-152

Dunne, J., and Ryan, B.J. (2012). Learning in the Science Lab: a New Approach. *Irish Journal of Academic Practice*, **1**, Article 2

Elawady, Y.H. & Tolba,A.S. (2009). Educational Objectives Of Different Laboratory Types: A Comparative Study. *Int. J. Computer Sci. and Inf. Security*, **6** (2), 89-96. arXiv:0912.0932v1

Freedman, M.P. ,(2002), The influence of laboratory instruction on science achievement and attitude toward science across gender differences , *J. Women Min. in Sci. Eng*., **8**, 191 - 200

Haagen-Schuetzenhoefer, C., (2012), Improving the Quality of Lab Reports by Using Them as Lab Instructions. *Phys. Teach*. **50**, 430-433, doi: 10.1119/1.4752052

Hammer, D.,(1989), Two approaches to learning physics, *Phys. Teach*. **27**, 664–670

Hammer, D., (1994a), Epistemological beliefs in introductory physics, *Cogn. Instruct*. **12**, 151–183

Hammer, D., (1994b), Students' beliefs about conceptual knowledge in introductory physics,'' *Int. J Sci. Ed*. **16**, 385–403

Hart C., Mulhall P., Berry A.,Loughran J.,Gunstone R., (2000), What is the purpose of this experiment? Or can students learn something from doing experiments?, *J. Res. Sci. Teach*., **37**, 655-675

Hofstein A and Lunetta V.N., (2003), The laboratory in Science Education: foundations for the twenty-first century, *Science Education*, **88**, 28-54

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education*, **22**, 85–142.

Hofstein, A., Shore, R., & Kipnis, M. (2004). Providing High School chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: A case study. Research report. *Int. J. Science Education*, **26**, 47-62. DOI:10.1080/0950069032000070342

Johnson, D.W., Johnson, R. T., Maruyama, G., Nelson, D., & Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta analysis. *Psychological Bulletin*, **89**, 55–63

Johnson, D.W., & Johnson, R. T. (1985). *Learning together and alone: Cooperative, competitive, and individualistic learning* (2nd ed.), Engelwood Cliffs, NJ: Prentice Hall

Keys,C.W., Hand, B., Prain, V., & Collins,S., (1999), Using the Science Writing Heuristic as a Tool for Learning from Laboratory Investigations in Secondary Science. *J. Res. Science Teaching,* **36**, 1065-1084

Lazarowitz, R., & Karsenty, G. (1990). Cooperative learning and student academic achievement, process skills, learning environment and self-esteem in 10th grade biology. In S. Sharan (Ed.), *Cooperative learning, theory and research* (pp. 123–149). New York: Praeger

Lazarowitz, R., & Tamir, P. (1994). Research on using laboratory instruction in science, In D. L Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 94–130). New York: Macmillan

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. School Science and Mathematics, **99**, 258– 271.

National Research Council, (2006), *America's lab report : investigations in high school science*, Washington, DC: National Academies

Redish E.F., Saul J.M., Steinberg R.N., (1998), Student Expectation In Introductory Physics, *Am.J.Phys*, **66**(3), 212-224; doi:10.1119/1.18847

Ryan B.J., (2014), Graduate Theaching assistants;critical colleagues or casual components in the under graduate laboratory learning? An exploration of the role of post-graduated teacher in the sciences, *Eur. J.Sci. Math. Educ*., **2**, 98-105

Sassi E. & Vicentini M. (2009), Il laboratorio nella didattica della Fisica. *Giornale di Fisica,* **50**,225-240. DOI: 10.1393/gdf/i2009-10111-0

Schwab J.J., (1962), The teaching of science as inquiry. In *The teaching of science*, Schwab, J.J. and Brandwein, P.F.; Eds., Harvard University: Cambridge, MA, pp 1-103

Tamir, P. (1989). Training teachers to teach effectively in the laboratory. *Science Education*, **73**, 59–69

Wenning, C.J., Wester, K., Donaldson, N., Henning, S., Holbrook,T.,Jabot, M., Truedson,J., (2011), Professional knowledge standards for physics teacher educators. *J. Phys. Tchr. Educ. Online*, **6**, 1-7

Yung, B. H. W. (2001). Three views of fairness in a school-based assessment scheme of practical work in biology. *International Journal of Science Education*, **23**, 985–1005

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