



GIREP SEMINAR 2016

August 30 – September 3, 2016
Jagiellonian University, Kraków, Poland



**RESEARCH-BASED PROPOSALS FOR IMPROVING
PHYSICS TEACHING AND LEARNING
– FOCUS ON LABORATORY WORK**

Proceedings

GIREP SEMINAR 2016
August 30 – September 3, 2016
Kraków, Poland

50th Anniversary GIREP

**Research-based proposals
for improving physics teaching and learning
– focus on laboratory work**

Organized by:
International Research Group on Physics Teaching (GIREP)
Faculty of Physics, Astronomy and Applied Computer Science
of the Jagiellonian University in Kraków

Editor
Dagmara Sokołowska

Editorial Secretariat
Anna Gagatek



Honorary patronage

We greatly appreciate the honorary patronage of:

Prof. dr hab. Andrzej Białas
President of the Polish Academy of Arts and Sciences (PAU)



Jarosław Gowin
Minister of Science and Higher Education



Ministry of Science
and Higher Education

Republic of Poland

We would like to acknowledge the financial support from KNOW grant no.
62/KONF/DS/2016.

Published by the Faculty of Physics, Astronomy and Applied Computer Science of the Jagiellonian University in
Kraków, prof. Stanisław Łojasiewicz Street 11, 30-348 Kraków, Poland
http://www.fais.uj.edu.pl/en_GB/start-en

ISBN 978-83-945937-4-2



PREFACE

The Proceedings present selected contributions from the international conference GIREP Seminar 2016, organized by GIREP vzw organization and the Faculty of Physics, Astronomy and Applied Computer Science at the Jagiellonian University, Kraków, Poland. It was our great privilege to host GIREP members and friends in the year of the 50th Anniversary of GIREP organization. The first day of this event offered an opportunity to recall special memories and to thank everyone that has contributed to the growth of GIREP during the last half-century.

The general seminar topic **Research-based proposals for improving physics teaching and learning – focus on laboratory work** emphasized the importance of laboratory activities in physics education. The overall aim of this seminar was to highlight the various aspects of laboratory work involved in establishing an environment where physics teaching and learning can take place, and in particular the development of physics literacy. Several topics have been discussed in order to line out a wider view of laboratory work at all levels of physics and science education, from primary school to physics courses at the university.

The format of this seminar was proposed in the style of the old-time GIREP meetings – with keynotes, oral presentations and poster presentations focused on six themes, followed by in-depth discussions in small groups of researchers and practitioners in sessions led by leaders of six Working Groups (WG). The contributions from six keynote speakers, widely respected in the community of physics education, as well as a comprehensive variety of oral and poster contributions, offered an unforgettable occasion for a fruitful exchange of thoughts and ideas.

The impact of physics education research on the educational design and practice of physics laboratory was the focus of WG1: *Experimental Lab in Introductory Physics Courses*. Presentations showed studies of students' learning in the laboratory and difficulties they come across, as well as, teaching proposals for specific topics at secondary schools, colleges and the first years of university. In WG2 two topics were encompassed. *Advanced Experimental Laboratories*, rarely addressed by instructors and researchers, who are focused more on introductory physics labs, was chosen to fill this gap and open a broader discussion on the role, goals and examples of the advanced laboratories in physics student education during their bachelor and master studies. *Modern Physics* topics being of the most interest of learners at all ages, appear to be rarely addressed in high school and during the first years of physics studies due to time limitations and the lack of teachers' competences. Contributors taking part in discussion tried to answer the question how to translate complex theories and highly-advanced experiments into language understandable and appreciated by less advanced students.

Since a modern laboratory can barely be operated without ICT, thus the design, evaluation and characterization of resources and environments for physics teaching and learning with use of ICT was addressed in WG3: *Lab Work and Multimedia*. Participants focused in particular on online learning environments, simulation and modeling tools, virtual laboratories and open sources. Self-regulation, reflection and collaboration in digital learning environments in context of lab work were discussed. WG4 *Conceptual Lab and Mathematization* addressed theories, models, and empirical results on conceptual understanding, conceptual change and development of competences in context of laboratory work, as well as methodology for investigating students' processes of concept formation and concept use on the basis of experiments and strategies to promote conceptual development throughout laboratory activities. A broad meaning of the term *mathematics* that includes all kinds of structuring and ordering physical processes: using abstract methods like idealization and modeling, as well as using a broad range of mathematical elements such as diagrams, graphs and formalized sketches (e. g. arrows) and equations was discussed in the context of physics laboratories.

A specific role and character of laboratory activities encourage the teachers to search for non-standard assessment strategies. In lab more than in other physics learning environments the formative assessment for



GIREP 2016



development of research skills and conceptual understanding plays a dominant role. A detailed discussion on that topic was the core of WG5: *Assessment for learning through experimentation*.

In order to attract more students, attention for science should be brought naturally, with use of everyday materials and in everyday context. Understanding of physics and appreciation of its beauty starts when observing usual but at the same time – amazing phenomena around. Traditional laboratory environment is extended nowadays beyond the lab space. Experiments are shown and tried out during numerous shows, festivals and other experiences outside the classroom, including those organized by institutions other than schools. Simple experiments should serve as the ignition of ideas, concepts and the notion for development of intuition in physics, not only at early ages, but across entire education. These aspects of learning, additional to traditional education, were the point of discussion in WG6: *Low Cost Experiments and Inquiry*.

The seminar was attended by 115 participants representing 28 countries. The scientific seminar program offered altogether 6 invited talks, 63 oral and 42 poster presentations. After the seminar 54 papers were received on all seminar topics. The articles went through a rigorous process of in a double-blinded peer-review, involving members of the Editorial Board and twelve additional referees in order to guarantee the quality of the content of this contribution. As the result two publications are issued, the book *Focusing on Lab to improve Physics Teaching and Learning. Research Based Proposals*, published by Springer and GIREP Seminar 2016 Proceedings book, presented here.

The organization of the seminar would not have been possible without help and co-operation of many people. First of all, we would like to thank Prof. Marisa Michelini, GIREP President, for her constant help and support. We sincerely thank the members of the Advisory Board and colleagues on the Local Organizing Committee for their dedication and commitment to this event. We are also deeply thankful to all reviewers, Working Group Leaders and the Head of all Leaders, Dr. Ian Lawrence. We would like to express our gratitude to six invited speakers for their valuable presentations that served as the foundation for the group discussions throughout the entire seminar. We are also deeply indebted to Prof. Paul Black who joined the anniversary day of GIREP with his special talk on-line and to Dr. Seta Oblak and Dr. Zofia Golab-Meyer for their contribution to the seminar on the history of GIREP and its impact on physics education research and development.

We would also like to thank all the participants of the GIREP Seminar 2016, for submitting proposals, advance preparations for discussions and sharing their ideas with the GIREP community. We hope that these Proceedings will give the reader an opportunity for deeper comprehension of the Laboratory Work aspects to improve physics teaching and learning.

Kraków, Poland

Dagmara Sokołowska



BEST PRACTICES FOR A GOOD LABORATORY EXPERIENCE

Daniela Marocchi, Marina Serio, Marta Rinaudo

Physics Department, University of Turin, Italy

Abstract

After the investigation on students' perception towards the laboratory activities, presented at GIREP-MPTL International Conference 2014 (Marocchi, D. & Serio, M., 2015), we conducted a new analysis concerning the aspects of support and enhancement of the teaching activity in laboratory.

We investigate i) how students prepare the laboratory activities, ii) the importance of the presence of teacher, technicians, tutors throughout the entire laboratory process, iii) the usefulness and ease of use of the informatics instrumentation.

This second phase involves first year students during the academic year 2015/16. Results of questionnaires highlight the importance of teaching methods used, as well as of all the professional figures involved during the educational laboratory experience.

Keywords

Laboratory, Educational design, Operative practice

INTRODUCTION

The perception that students have towards laboratory activities has been presented in a previous work (Marocchi & Serio, 2015), based on results of a questionnaire for students of different ages and school levels. In that case, we paid attention to the development of laboratory interest and capabilities starting from high school up to the third university year of study. We investigated several aspects, such as comprehension of the physics concepts, interest in laboratory activities, complementary nature of laboratory activities and of classroom lectures. However, within the open comments of questionnaires, other aspects seem to need further attention: for example the didactic material and the laboratory data sheets, the preparation of students that help as tutors (in our case the tutors are university students who help in the acquisition of data) and the presence of technicians. In particular, we want to analyse the importance of various professional figures present in laboratory and the utility of the educational path proposed to the students: didactic and computer materials, on-line homework, auto evaluation tests, etc...

In this paper, we examine the formative impact of student-tutors and of technicians, which in laboratory are complementary to teachers. Students, although they sometimes regret the possibility of managing autonomously the practical part, are well aware of the necessity of a guide. Nevertheless, in order to achieve maximum understanding from the students, it is crucial to know how tutors and technicians work in relationship with them. We also study the use and utility of the assessment tools in on-going and final evaluation. Other analysed questions are about the possibility to use the instruments and the usefulness of computer equipment.

We wrote a questionnaire for students of the first year of Physics during the academic year 2015-2016 at Turin University (Italy). The survey was limited to the 150 first year students in order to assess also the impact from the different teaching methodologies used in high school. We also proposed a questionnaire to the other persons that are present in laboratory during the course, i.e.: technicians and tutors. We present and discuss here the results, in order to highlight how teaching methods as well as all the persons involved in the experience of educational laboratory are important.

STUDENTS' OPINION

The laboratory course proposed to our first year students lasts overall six months, with two periods each lasting ten weeks and a central pause of four weeks. The contents are a theoretical part on 'statistics and data analysis techniques and a laboratory part with twelve laboratory experiences'. The purpose of the experimental part is double: it gives both the possibility to apply statistical methods to real data (instead of doing theoretical exercises on not-real data) and to verify some important laws presented in the parallel Physics course. The laboratory experiences proposed in the first and in the second module differ in the complexity of the analysis needed to reach the results. In fact, in the first module, the objectives of the experience are often the outcome of direct measurements; in the second module, the results derive from many direct measurements assembled. In both cases, it is required that the students have the capability to apply the techniques of data analysis presented during the course. A second important objective of the laboratory activities is to increase the ability of working in-groups, to organize the work, and to reflect on the obtained results.

We administered a questionnaire at the end of each learning period, articulated according to the characteristics of each module. The laboratory course of the first year at Turin University is very demanding: 12 ECTS out of 60, which is the total number of ECTS required during the completely academic year. The difficulty is even higher given that many students have never had any experience of laboratory activities during high school (see also Marocchi & Serio, 2015).

Within the studied sample, 33% of students had never attended a laboratory activity before enrolling in the university and that 13% had done some lab work but had not needed to complete lab reports on that work; 60% had never used a spreadsheet for analysing and graphically showing the results. Only 19% of the students said that they often wrote laboratory reports in high school. For the other students (80%) the principal reason was that they had never gone to the laboratory or that they had seen only qualitative experiences carried out by the teacher.

The relationship with all the people involved in the laboratory activity results are very important. More of half (60%) of the students appreciate the availability of people like tutors and teachers, while technicians remain marginal in their experience (Fig. 1).

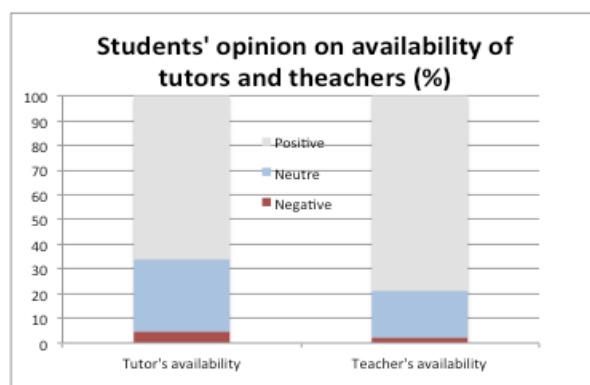


Fig. 1. Students' opinion on availability of tutors and teachers

In the questionnaire, part of the questions concerned the general aspects of laboratory activity such as:

- the development of practical activities (such as the ability to correctly use scientific instruments, to properly measure and estimate the error to be associated, to graphically report the results, to critically review the results of the statistical analysis);
- the type of experience (physical laws to verify through data analysis);
- the weight of the course, in terms of time and personal student work;
- the appropriateness of lesson's contents for the performance of the experiences.

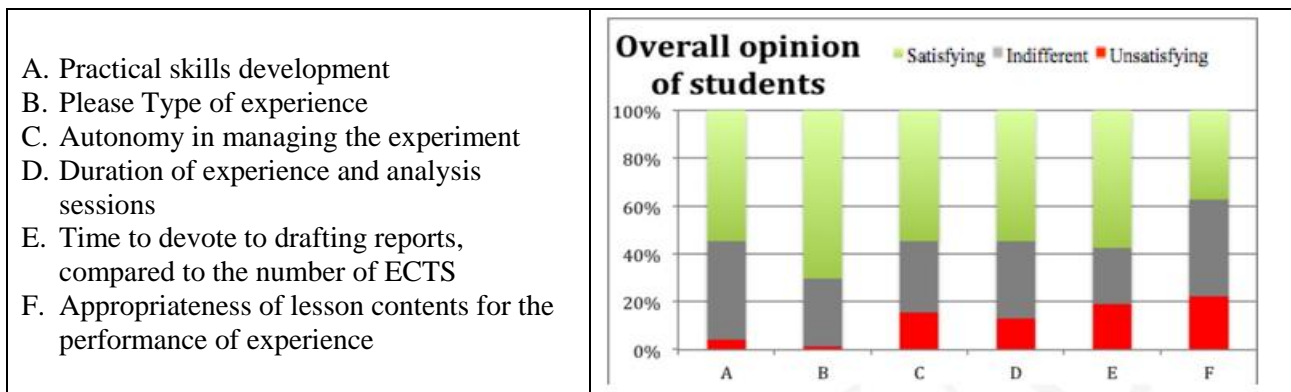


Fig. 2. Student's opinion related to general aspects of laboratory activities

Some aspects (Fig. 2) are judged partially inadequate (from 15% to 22%): in particular the time spent for writing the reports, the little autonomy in managing the experiments and the appropriateness of the explanation provided during the lessons for the implementation of the laboratory experience. Our considerations as regard these critical points are:

- It is the first experience in report writing for many students, so they perceive the report preparation to be hard and laborious, both in the first and in the second writing after the teacher correction. In fact, it often requires revisions concerning not only numerical data but also linguistic expression in the scientific field.
- As for the autonomy, taking also into account the poor experience of the students and the complexity of the used instrumentations, the proposed experiences require a tutor for the experimental part and the presence of the teacher for the robust analysis phase.
- Appropriateness of the explanations provided during the lessons is a very delicate point. The theoretical presentation of the experiences takes place before the start of the laboratory sessions. Since it is impossible to move the instrumentation into the classroom or to be in the laboratory with the students, it is very difficult to provide operational details. Moreover, due to the number of students, shifts have to be established and a part of the students performs the laboratory experience even a few weeks after the explanation.
- A self-assessment questionnaire was prepared for each experience with 5-6 multiple-choice questions and immediate feedback. In the questionnaire are non-present open questions because they require a longer time for compilation. Questions concern the goals of the experience and some of the operating procedures presented in the lessons. The student must answer the questionnaire before going to the lab. Students also evaluate this self-assessment activity: 80% of them (Fig. 3) consider the self-assessment questionnaires and the feedback useful to help the review of the lessons. The questionnaires are now under review to improve clarity.

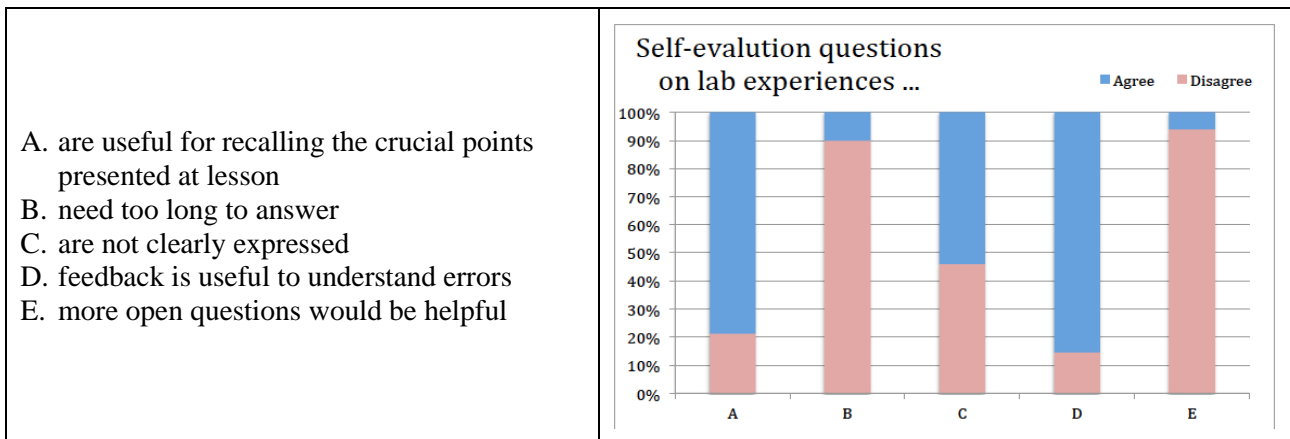


Fig. 3. Student's opinion on self-evaluation questionnaires regarding laboratory experiences

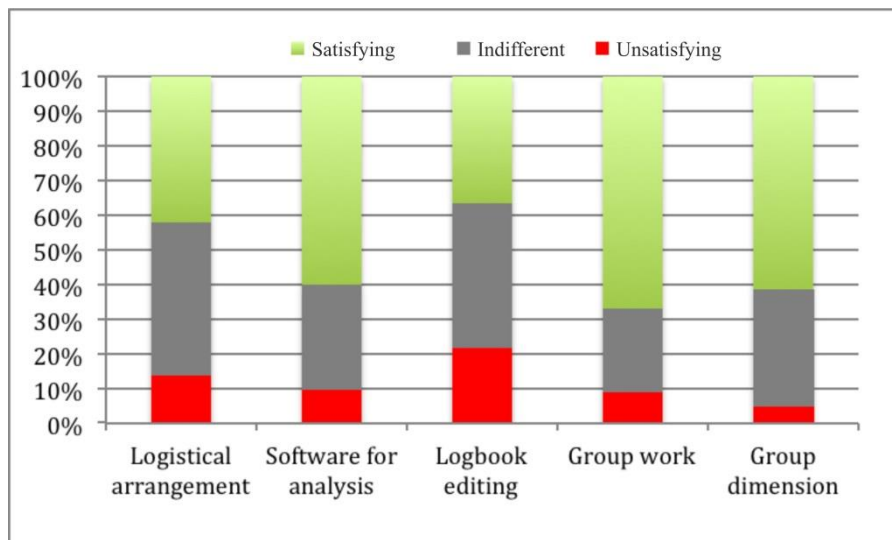


Fig. 4. Student's opinion relative organizational aspects of laboratory activities

Finally, we investigated some organizational aspects of the laboratory (Fig. 4): the logistic arrangement, the group-working mode, the logbook editing and the software for the analysis. The two aspects considered inadequate by more than 10% of the sample are logistics and logbook editing. Indeed, during the 2015-2016 courses, the Department considerably rearranged the spaces reserved for the laboratory, with a real discomfort for both students and teachers. As far as the logbook is concerned, many students are not accustomed to report in a concise but complete way what happens during the experience. They often consider only important to record the numeric data directly on Excel spreadsheet or Mathematica notebook to make analysis with the computer. Hence, they usually forget to note details that may be useful during the analysis phase, the discussion of results and the critical conclusion of the work.

TUTORS' OPINION

Tutors are bachelor or master students in Physics who receive a scholarship to assist students in the laboratory practical tasks, since teachers cannot follow all the students at the same time.

During the academic year 2015-16, half of the student-tutors had performed this task for the first time.

Before the start of the course, they attended an educational training on technical aspects of the laboratory experiences, which is their main task. This preparation period is brief but balanced. Moreover, technicians are available to help with every technical problem encountered during laboratory sessions. Furthermore, students know that, as for problems in the analysis of measured data, they have to refer to the teachers. Tutors' opinion on the effectiveness of this initial training is not uniform: half of the student-tutors think to be not able to explain the importance of some measure procedures (50%), or to clarify the in-depth analysis (88%) that students are requested to do, or to have the correct didactic approach.

The work of the student-tutor does not only represent a source of help for teachers and technical staff. There is a common understanding (71%) that it can also be an important formative training for those students who become tutors. So many student-tutors ask a specific formation in software and in didactic procedures. They express that, by being tutor, they have a deeper comprehension of physics topics and that they have the opportunity to become leaders of a working group. Some students that work as tutors perceive as important also a specific training on didactic aspects because they are interested in understanding better the work of a teacher. These answers reveal the usefulness of this experience for their future working choices.

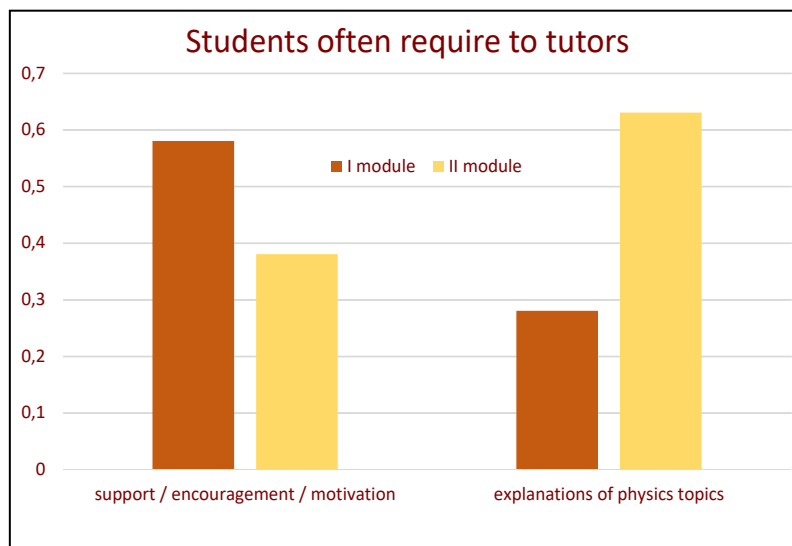


Fig. 5. The figure shows the different type of request from students to tutors during first and second part of laboratory course

With regard to the differences observed during the two course modules (Fig. 5), tutors reveal that during the first part of the laboratory sessions they often have to encourage students at their first laboratory experience (58%). Instead in the second part of the course the more important role is a guide during the technical operations (63%) because of the greater complexity of the experimental task.

Tutors positively note the presence and efficiency of technical staff during the laboratory sessions (71%), and the availability to give further indications (83%). Tutors have noticed the revised laboratory-sheets (100%), the clarity of instructions (83%), and the availability of the teachers to explain in depth the practical tasks relative to the laboratory activities (67%). They have (50%) an uncertain opinion on the teacher's availability to give educational didactic training; therefore, this point needs to be improved.

TECHNICIANS' OPINION

Persons who have PhD in Physics and participate to research groups in Physics Department compose the technical staff for this laboratory course at Turin University. Therefore, they are very special persons. Their role includes i) the correct preparation of instruments and ii) the technical formation of tutors (Fig. 6).

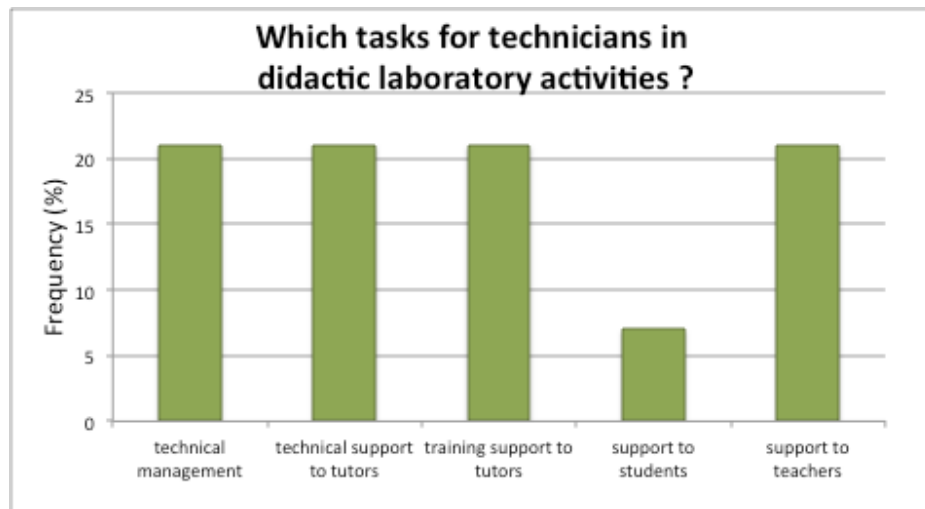


Fig. 6. The figure shows what technicians think about their laboratory task

Even if technicians say that the didactic laboratory is a very interesting task (100%), they also declare that it is not satisfying their expectations and capabilities. Moreover, they (60%) desire more knowledge in educational subjects and a greater didactic collaboration with teachers (60%) in order to be familiar with the educational objectives of various laboratory experiences. Furthermore, technicians (80%) propose to have a wider possibility of interaction with students, not only with tutors.

MATERIALS

In order to focus on the materials that we used as support for the teaching activity in laboratory, we inserted in the questionnaire for students several questions on laboratory materials and on procedures

Students think (80%) that the didactic material (available on e-learning platform Moodle) has good quality and that it is complete (Fig. 7).

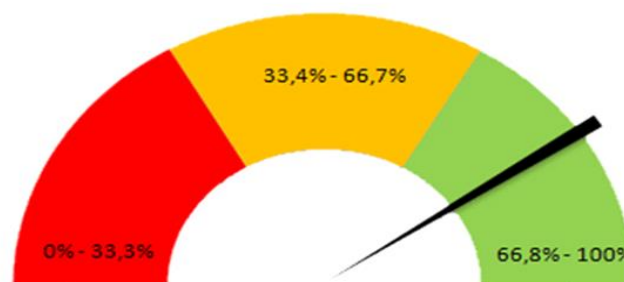


Fig. 7. Students' opinion on didactic material is essentially good

One element of paramount importance for a positive laboratory activity is the preparation of students before the laboratory sessions. Moreover, it is also an important factor for the success of the experience. Some instruments used in didactic environment are self-evaluation tests, online exercises, open questions, etc. In particular, students have the possibility, before the laboratory session, to read the monograph, which reports the physics of the experience and some technical procedural notes. This material is available on-line. Among the students, 90% use the monograph and 82% answer to self-evaluation tests, 72% reads lesson notes and 64% asks for information from other students that have previously done the same experience.

In order to test the competences acquired, we have prepared multiple-choice on-line tests for every experiment: students had to answer to these questions before the laboratory session. Feedback helps (87%) students to evaluate their preparation: the time needed to answer is not too long (87.5%), so they can easily do it after the class lesson and before the laboratory session. About 57% of the sample judges that some questions are not sufficiently clear. Hence, teachers will have to make an effort in revising them. The mark of these tests does not enter in the final valuation, but we note that they are an important incentive to increase the attention of students, which feel interested in going more prepared to laboratory. The tutors (83%) who noticed an improvement in students' competence after the use of multiple-choice tests have confirmed this impression also.

We thought the auto-evaluation tests to prepare students before the laboratory work and the questions essentially concern the method with which they have to operate. Students considered them useful also for the preparation of the final exam (87%), but some students say that they would prefer technical questions (27%) or questions of physics (48%).

We note a correlation between a good and regular execution of the multiple-choice tests and examination result. Table 1 shows that all the student of the course that had the maximum results (30 cum laude in Italian University) did well all the auto evaluation tests. At the same time, none of the students with bad results in the auto evaluation tests has reached the maximum examination result; Fig. 8 shows the results for student of the B course versus the number of auto evaluation tests completed.

Table 1. Number of valuation 30 cum laude during the exam (maximum evaluation in the Italian University) versus number of well-done auto-evaluation tests (course A)

number of well-done tests	number of valuation: 30 cum laude
0	0
1 to 3	0
4 to 5	0
all	6

In addition, students considered the correction and the return of the first three laboratory reports before the final report useful for a good preparation (96%), but part of the students (25%) encounters difficulty to complete the reports during the didactic period.

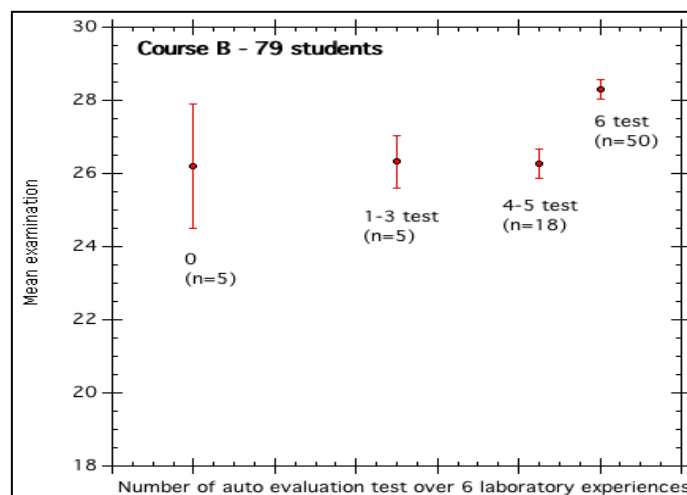


Fig. 8. Results of the examination versus the number of auto-evaluation tests done (course B)



CONCLUSION

We have examined, through a questionnaire offered to 150 students, student-tutors and technicians, the importance of all the professional people involved during didactic laboratory sessions. The results of the questionnaire have stimulated a reflection on formative activity, so we have introduced some good practices in the course during the present academic year: we present them briefly, considering them useful for teachers in their work in class.

In the course, students appreciated the type of physics experiences proposed, the development of practical skills, their increase of informatics capabilities by using PC for the analysis of the data, group work and availability of tutors and teachers. For 33% of them this course is the first laboratory activity and 60% of them had never used a spreadsheet for analysis nor have used graphics to show some results. For this reason, students have many difficulties in writing the reports. To support them in this task, we have prepared for the first experiment an online format in which student can insert data, results, comments, and in-depth analysis. We organized the format in sections that correspond to the different items of a scientific report, so it can help as a guide for the writing. Therefore, we will provide the students with some old reports and the revision form used by teachers for correction and evaluation. In this way, students can see what the teacher looks for in the text and in the analysis. They can use the form to mark the old report and then as a guide to correctly compose their own.

The importance of a logbook and of its correct compilation will be highlight during lessons and tutors have to control its proper use. During the pause between the first and the second module, the teacher marks the logbook and gives it back. In the future, we think it will be useful to consider tools such as Google Drive or Google class, to share online files and generate an e-logbook easier to manage. The high number of students attending the course is currently the greatest limitation of this solution.

The work of the student-tutor not only acts as a help for teacher and for technical staff, so the use of student-tutor has to be encouraged. There is a common understanding (71%) that it can also be an important formative training for those students who become tutors. So many student-tutors ask a specific formation in software and in didactic procedures. To improve the tutor training, we decide that each tutor becomes an expert on one of proposed laboratory experiences. The training ends with a presentation of the experience made in front of the teacher before the beginning of laboratory sessions. During this presentation, the teacher also discusses with the tutor the didactic aspects of the experiment.

All the technicians say that the didactic laboratory is a very interesting task; furthermore, they want a greater didactic collaboration with the teachers (60%) in order to be familiar with the educational objectives of various laboratory experiences. Therefore, we engage also the technicians, interested to deepen the didactic content of the experiments, in the final step of tutors' training.

Students substantially appreciate (80%) the laboratory team and the quality of materials offered on Moodle platform. We note that auto-evaluation tests are a good instrument for student's preparation before the experiments, but students considered them useful also for the preparation of the final exam (87%) and we note a positive correlation between a good and regular execution of the multiple-choice tests and examination results. A statistical analysis has shown which pre-experience questions are less clear. We have set up a review of the questions and subjected the new versions to a small sample to verify the clearness of the text, with particular attention to the formulation of the incorrect answers. During the laboratory session, the teacher shows and discusses with the student wrong answers in order to strengthen the effect of automatic feedback. Just at the start of the first period teacher informs the students that every partial evaluation is important for the final one. Therefore, we want stimulate a regular study. We are now developing an appropriate evaluation form to take into account all the partial results correctly.

The relationship with high school teachers is very important to support them in the hard work of moving their student close to the physics laboratory activities. The starting situation revealed by the questionnaire push us



GIREP 2016



to share our formative thoughts with high school teachers, to encourage them to a greater use of laboratory teaching, and in November 2017, we realized a meeting where we have discussed with them the problems encountered during laboratory activity.

REFERENCES

Marocchi, D. & Serio, M. (2015). Laboratory activities and the perception of students, *Proceedings of GIREP-MPTL International Conference 2014*, 1059-1070.