LAB2GO: A PROJECT FOR SUPPORTING LABORATORY PRACTICE IN TEACHING STEM DISCIPLINES IN HIGH SCHOOL

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Abstract

The laboratory practice is essential for learning physics and scientific subjects: this is the core of the scientific method, whose first formulation is traditionally claimed in Italy, with Galileo Galilei and its experimental approach to the study of physical phenomena, from the observation to the abstraction of theories and models.

Unfortunately, the experimental approach is often overlooked in teaching, for several reasons: school laboratories may be not adequately equipped (obsolete or non-functioning instrumentation, poor assortment, lack in maintenance, missing catalogues); due to the combination of reduced number of hours in the weekly schedule and increased contents to be delivered for the final exam, some teachers may favour lecture style of instruction rather than hands-on sessions or other student-engagement practises; the teachers themselves may lack of laboratory training.

In order to establish a solid contact between schools and experimental science in academia, Sapienza Università di Roma and Istituto Nazionale di Fisica Nucleare (INFN) launched Lab2Go, an initiative in the framework of actions promoted by the Italian Ministry of Education (PLS, Programme for promoting Scientific curricula in the university; PCTO, Path for acquiring Transversal Competences and Orientate students' career), with the goal of spreading the laboratory practice among students and teachers in high schools.

Lab2Go was born in Rome and was focused on physics, however in just few years it has expanded across Italy from North to South, reaching a large number of regions and towns (and schools) thanks to the increasing involvement of INFN; meantime, it has enlarged its scope to other scientific disciplines (Biology, Botany, Chemistry, Robotics, Earth Science and History of Science). Moreover, for preserving the specific vocation of the project to promote hands-on learning despite the circumstances introduced in schools by the COVID-19 pandemic (on-line teaching and strong limitations in accessing laboratories in most of the schools), an innovative formula has been introduced: Lab2Go@Home, consisting in a series of on-line seminars aimed at showing experiments that can be made at home using easily accessible materials, and exploiting resources commonly available, as smartphone (with their integrated sensors, in combination with dedicated physics apps), or other devices and on-line tools, that can be employed as well for introducing programming and coding in a multidisciplinary framework. Initiated to mitigate the impact of the pandemic, Lab2Go@Home can aid at facing off some of the issues of school laboratories, since contents and instructions provided during the on-line sessions can indeed offer hints and suggestions for enriching the laboratory equipment and introducing new approaches in traditional classes.

Keywords: STEM, science, physics, experiments, school laboratory, laboratory practice, teaching practice, sharing, equipment, instrumentation, teaching, hands-on, smartphone, Arduino, coding.

1 INTRODUCTION

In recent years increasing attention has been paid by academic and research institutions to the so-called "Third Mission", that adds on the two traditional missions of universities, namely post-secondary Education and Research [1]. The Third Mission has been introduced for making more explicit the connection and the engagement of the academic centres with the society [2]: it consists in planning and delivering actions and initiatives aimed at the re-use and transfer to society of knowledge produced in the academic context, for meeting the societal needs that can be expressed in terms of technology and innovation, but also in terms of methods, culture and demands for instruction and learning. These goals are pursued by outreach initiatives for the general public and by programmes

and projects addressed to schools, the latter particularly important since they aim at producing a long-term societal impact.

In the vast scenario of Third Mission activities delivered to secondary schools, Lab2Go, beside its distinctive contents (namely, the promotion and support of laboratory practice when teaching scientific disciplines, in agreement with the dictate of the Galilean experimental method and aiming at complementing lecturing classes with hands-on sessions), stands out for three fundamental aspects: 1) the wide and heterogeneous target; 2) the continuous interplay between particular and general; 3) the sharing attitude. More details on these three points will be given in Sec. 2, while here in the Introduction we present a bit of history of the project (see also the Acknowledgements Session for further information on the project structure and the people involved since the very beginning). In addition, the timeline of Lab2Go can be recalled looking through the material archived in [3].

The idea of Lab2Go came out in 2016, in reply to a request risen by the Italian Ministry of Education that launched a programme called ASL (Alternanza Scuola Lavoro), a young apprenticeship programme aimed at including secondary students into internship initiatives in order to tailor their education for the society demands and get them prepared for the labour market [4]. The ASL programme was active in the three-year period 2015-2018, during which it was fully integrated in the school curricula and made mandatory for students, defining a fixed amount of hours that they were requested to spend in activities carried out at an hosting institution, thus “alternating” their presence between the school site and the host. ASL thus triggered reactions from public and private subjects, that applied for the role of partnering/host institutes, as site and source of training and professional experience for secondary students. In this scenario of work-related learning, it was more straightforward to propose and identify activities suitable for technical and professional schools, and more challenging to do the same for schools, like the Italian “licei”, where the attention is mostly paid to subjects aimed at orientating the students’ future university careers rather than to a direct connection with the labour market. Lab2Go was ideated and created as a project aimed at intercepting in the ASL scenario the needs of schools and students with a less expressed work-oriented vocation; the success of Lab2Go is testified by a mention received by the Italian Ministry of Education in the framework of the ASL programme [5].

The key to success for Lab2Go is its strong address towards practical hands-on activities, identified and promoted as the pivotal ingredients of experimental sciences, while keeping a priority attitude for methodology and education. This peculiar feature, i.e. coexistence and interplay of hands-on and education activities, made possible for the project a smooth and productive transition when the ASL experience concluded and was migrated, with a partial redefinition of its contents, goals and commitments, to the programme that now constitutes the labour-market oriented initiative in the secondary school curricula, namely PCTO, Path for acquiring Transversal Competences and Orientate students’ career [6]. While moving from ASL to PCTO, the number of participating schools largely increased, together with the disciplines involved and the number of people committed in the coordination and required for the management of such a large size initiative [7]. The original design of the project, originally focused on Physics and depicted in [8] as made up of sequential “phases”, each one corresponding to separate tasks to be assigned to participating schools depending on how long their involvement was, was partially revised. Indeed, if [8] still represents a sort of “manifesto” of Lab2Go, expressing its motivation, philosophy, basic structure and constitutive elements, the distinction in sequential phases was soon made less rigid in favour of a more flexible approach that integrates the project mission and constitutive actions with the peculiarity of each school community taking part in the initiative.

The same tendency of Lab2Go for evolving and adapting to mutated circumstances was called to action when, in March 2020, the school routine was deeply disrupted by the COVID-19 pandemic, that introduced a sudden and violent interruption of consolidated teaching and learning procedures, demanding for a quick and profound redefinition of methods and contents that involved both standard courses and complementary projects like the ones inserted in the framework of PCTO. Our reaction as Lab2Go coordinators was to immediately launch activities of on-line teaching, with the firm proposition of nevertheless preserving a vivid link with hands-on activities and the attention to scientific method. For Physics, the outcome of this effort is represented by Lab2Go@Home, described and documented in the project wiki [9] and consisting in a series of on-line lectures and seminars aimed at showing experiments that can be made at home using easily accessible materials, and exploiting resources commonly available, as smartphone (with their integrated sensors, in combination with dedicated

physics apps), or other devices (like Arduino boards [10]) and on-line tools. Examples of realisations ideated and carried out in the framework of Lab2Go@Home are illustrated in [11][12][13].

Initiated to mitigate the impact of the pandemic and carried out for two editions (school years 2019-2020 and 2020-2021, both deeply affected by the pandemic and characterised by strong limitations in accessing school laboratories), Lab2Go@Home is still relevant for the current school year (2021-2022) in which we are experiencing a gradual recovery of “normality” in school routine. Indeed, the Lab2Go@Home materials can aid at facing off some of the ever-lasting issues of school laboratories (obsolete instrumentation, poor assortment, lack in maintenance, lack in time to be dedicated to laboratory sessions), since contents and instructions provided during the on-line sessions can offer hints and suggestions for enriching the laboratory equipment and introducing new approaches in traditional classes. For instance, the perspective proposed by Lab2Go@Home can be employed for introducing programming and coding in a multidisciplinary framework, further fostering the development of transversal competences, problem-solving and scientific approach, and meeting the societal demands for a quantitative reading of reality.

2 METHODOLOGY

Several studies claim that introducing student-engagement practises in classes, like hands-on activities that can be carried out in the laboratory, is beneficial for learning, for every level of instruction. Therefore, the promotion of laboratory practice can be intended not only as a fundamental constituent of scientific disciplines, in agreement with the scientific method’s prescriptions of experimental observations and quantitative measurements, but also as a well-established and confirmed technique for stimulating the students’ participation during classes. In addition, the experimental approach increases learners’ attention, interest, and motivations, and has an impact in orientating their careers at university. Finally, the Lab2Go project enables contacts and establishes connections between secondary schools (students and teachers) and faculty members, enabling opportunities for enriching the educational offer provided to the school community.

As already mentioned, the constitutive elements of Lab2Go have been presented in [8], and can be summarised as: the inspection (check, repair, maintenance) and catalogue of the instrumentation in the school laboratory; the identification and execution of experiences that can be carried out using the assortment of the laboratory; the interplay between the inventory of devices and the corresponding inventory of experiences; the training attitude towards the school community as a goal of participant students and teachers, through the set up of training sessions and/or the delivery of documentation, reports and laboratory logs; the sharing attitude, expressed both by the creation of a shared digital archive and by the enabled network. An overview of current activities and some exemplary realisations have been illustrated in [14][15] and in [16][17].

Lab2Go possesses some distinctive features that are responsible for its longevity and its increasing diffusion across Italy; as anticipated in Sec. 1, they can be identified by: 1) the wide and heterogeneous target; 2) the continuous interplay between particular and general; 3) the sharing attitude.

Concerning the target, for each school participating in the project, we identify three categories of recipients: (a) students; (b) teachers; (c) the wider school community and the local community. Different from similar projects delivered by academic institutions and directed to secondary schools, Lab2Go addresses at the same time to all the actors of the educational process, associating to each category a set of primary objectives and deliverables. In details, while students are assumed to be the main addressee of the project, since they acquire new knowledge in the scientific subject they have enrolled for, and also general competences related to their personal and professional grow (like work planning, team working, management of tasks and deadlines, commitment, responsibility), teachers are as well to be considered a relevant target, since they gain the opportunity to enable actions that can contribute to their continuing professional development, like the creation of peer networks and the connections with academic agents. Furthermore, this element of education can be made structured and certified, through the S.O.F.I.A. platform [18], the system that the Ministry of Education set up for managing courses aimed at the continuing professional developments of its teaching staff. Indeed, in the objectives of Lab2Go there is also the delivering of laboratory courses for teachers, aimed at offering a training in experimental Physics (or other scientific discipline) tailored for the specific equipment that has been inventoried during the participation to the project. This objective is especially

addressed to target group (c), i.e. teachers of the scientific subject for which the school has enrolled who are not directly participating in the project. In general, one of the feature of Lab2Go is that a school enrolling in the project will receive advantages (in terms of learning and professional and personal grow) not only for directly involved target groups – (a) and (b), namely people that are actively participating in Lab2Go during the school year, planning and completing tasks in team with the academic staff – but also for the wider school community, since – and this could be intended as a summary of the project – the tasks that participants are called to complete with their involvement in Lab2Go aim at delivering a set of conditions for promoting and improving the usage of the school laboratory, meaning improving the frequency at which teachers and students use it during the school year thanks to measures like: the delivery of a revised and accessible catalogue of devices and instruments, the maintenance of the instrumentation; the definition and design of experiences tailored for the school equipment (and documented through the so-called “Schede Didattiche”, i.e. worksheets that La2Go students prepare for documenting the experimental procedure and results); the training of teachers and teaching staff. Elements of peer education can also be introduced, since students engaged in Lab2Go – target group (a) – can be employed as laboratory assistants in laboratory sessions during which a wider group of students not directly involved in Lab2Go – target gorup (c) – would carry out experiments among those inventoried and designed by Lab2Go students, using the Lab2Go worksheets as a guide for the execution of the experience.

So far, we presented actions and tasks that refer to the single school community; now we discuss another point of strength of Lab2Go, that is the interplay and balancing of local activities (i.e. those planned and carried out for a single school) with the overall mission of the project. Indeed, as already stressed, a distinctive feature of Lab2Go is its flexibility, meaning that enrolling in the project corresponds to receiving a common guidance (and a repository of lectures) and some common tools (like the access to the project documentation in the wiki), but not punctual instructions or directions to the single participants. This is because we believe that no unique set of instructions would fit the large variety of “school environments” that a project like Lab2Go could meet and face. In this scenario, the community of tutors play a crucial role, since they are responsible for enabling and maintaining the communication channel with the school community, and for identifying (in team with the school teaching staff) the action points that best fit the school requirements and needs, taking also into account the students’ profile and interests, in order to plan tailored activities while assuring that they well adhere to the general principles of the project and accomplish its mission. As a consequence, we experienced that a key ingredient for the local success of the project is to establish a fruitful collaboration and a positive relationship between tutor and teacher, tha acts as a booster in motivation for all the actors involved.

Finally, the sharing attitude of Lab2Go can be expressed at different levels. Locally, at the single school level, it consists of participants working as a team and releasing, in sharing mode, the catalogues of laboratory devices and corresponding experiences, enriched by worksheets that detail the experimental procedures; the produced materials and documentation are then shared with the entire school community. The outcome of the activities can be further shared with a larger community, for instance a network of schools located in the same geographical area, enabling procedures for sharing instrumentation and/or activating lab visits and common paths of instruction that join different institutes and curricula. This is related to the more general objective that aims at sharing learning strategies and teaching practises with the vast community of all the schools that are linked to the project, and beyond, with people (students, teachers, researchers) interested in the topic. The enlargement of scope and reach of Lab2Go is made available thanks to the web platform that Lab2Go has implemented, Lab2Go Wiki [19], based on the Dokuwiki software [20]. The adoption of a wiki application [21], e.g. a documentation collaboratively edited and managed by its own users, can be seen as the digital counterpart of the sharing attitude that Lab2Go has been including in its constituent principles since the very beginning.

The option of sharing outcomes and materials using a web repository has become more relevant and dominant in the latest years, partially linked to the increased weight of on-line teaching due to the impact of the pandemic. Nevertheless, we believe that the employment of on-line resources in teaching practises will not be strongly reduced with the recovery after covid-19 emergency; therefore we have been going to a great deal of effort in improving the contents of the wiki (through measures like: a deep revision of pages; a more accurate definition of the editorial team and of access control lists; the opening to external collaborators; increasing attention paid to credits and bibliography;

implementation of a Quality Control system [22] with separate editorial roles and assessment of the quality/level of maturity of pages in the wiki), in order to progressively make it a dynamic container of material to be proposed as a reference for the web audience involved in the topic of planning and delivering laboratory-based teaching strategies.

3 RESULTS

Here we sum up the status of the Lab2Go project, with the goal of giving a glimpse of its current size and of how the project has been evolving and has been continuously expanding for 6 years of operation.

3.1 Size and Diffusion of the project

Table 1 shows the evolution in size of the project, in terms of the number of institutions (academic centres and schools) and of people involved. An approximate estimate returns, on average, 12 students, 1 teacher and 1 tutor for each participating school, while the ratio of scholarship fellows per school is ¼; this gives an idea on how the number of people scales with the number of schools. We point out that during the period 2019-2021 we experienced a slight decrease in the number of schools, but the total number of students involved was about the same, since on-line activities enabled during the pandemic years allowed for a larger number of students per school to be included in the programme.

Figure 1 represents the diffusion of the project across Italy; symbols mark the position of schools that have been participating in the project and identify the subject the school enrolled for; the insert is a zoom of the Rome area. The figure is obtained as a snapshot of a web map that can be interactively navigated from t.ly/Vj4N, or through the link in the QR Code.

Table 1. Involvement of institutes and people.

	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Universities/INFN sections	1	4	4	4	6	12
Schools (all subjects)	20	50	62	68	61	78
Schools (Physics only)	20	30	48	37	33	49
Students (all subjects)	~250	~550	~800	~800	~800	~1000

Figure 1. Map of the schools that have been so far involved in Lab2Go. The map is incremental and includes both current and past participants.

3.2 Lab2Go Wiki and Lab2Go web presence

3.2.1 Size of the wiki: users, pages and monthly accesses

At the present date (13 January, 2022) the wiki has 557 users; users are assigned to groups, in order to define different access control lists for different wiki functions and namespaces. The policy we adopt is that accepted schools have to enrol their participants (students and teachers) through a registration form that results in creating and enabling the requested accounts; school accounts expire at the end of the school year. Other temporary accounts are activated for temporary collaborators as scholarship fellows. In addition to temporary accounts, the number of users also includes permanent accounts, usually attributed to tutors and collaborators. Therefore, the number of users is not an exact photograph nor of the manpower, neither of the target, but still is an indication of the size of the Lab2Go community active for any school year.

Table 2 gives an overview of the size of the web documentation, listing the number of wiki pages that are currently present on the repository.

Table 2. Size of Lab2Go wiki, number of pages

	Number of wiki pages	Total (subjects)	Total size of the wiki (subjects + schools + documentation pages + other)
Biology	207	2478	3548
Botany	52		
Chemistry	267		
Earth Science	101		
History of Science	663		
Physics	1146		
Robotics	30		
Schools	144		

Concerning the number of accesses and visitors in the wiki, we recursively collect statistics on a monthly basis, therefore current history includes about 2 weeks in December 2021 and 2 weeks in January 2022. In the examined period we have a daily average ~420 visitors, with a daily peak of 952, the monthly total is ~14000.

3.2.1 Website, web page, press releases and social media

The Lab2Go website [22] is the official public repository of the project documentation and it is managed and maintained from within the Lab2Go collaboration. Beside it, the web presence of Lab2Go is supported by the INFN communication office, which is in charge of the Lab2Go web page on INFN "Collisioni" [23] (the web portal dedicated to INFN outreach activities), of press releases, and of promotion of Lab2Go activities through INFN social media. On this, in particular, INFN usually hosts the streaming of Lab2Go events in the YouTube INFN Edu Physics Channel [24] (with 564 subscribers); video contents produced in the last school year (2020-2021) are grouped in a playlist, with 20 videos (including Lab2Go@Home webinars and activities) and a total, at the present date, of ~6000 visualisations.

To increase the size of the online audience, we plan to revamp and regularly update the Lab2Go Facebook page [25], presently with 145 followers.

4 CONCLUSIONS

Several projects are active worldwide aimed at promoting laboratory practice and constructive interaction between schools and academia. Some of them focus on teaching, i.e. reinforce the contents students receive during regular lectures ad schools; some focus on complementing curricular knowledge, complementarity being in delivered contents (e.g. topics beyond the standard prescriptions of curricula), or in teaching approaches (e.g. leveraging games, student-engagement practises or peer education), or both; finally, some focus on teachers, offering opportunities of continuing professional development. Different from similar projects that aim at promoting laboratory practice in secondary schools, Lab2Go includes in its constitutive principles all the elements listed above, addressing at the same time to all the actors of the educational process.

In addition, the extraordinary element in Lab2Go is its ability to “survive in a changing environment”, taking into account changes in the legislation and unexpected events (as the pandemic), and incorporating new trends and tools in teaching strategies, and to adapt to the large variety of cases that can be met when moving from North to South along Italy, or across different school curricula, or from the city centres to the outskirts, from public to private schools, from big cities to small communities.

Beside the already mentioned actions of carrying out a deep revision of the wiki contents and of increasing the presence on social media, next actions include: foster multi-disciplinary links, both in schools and enabling connection between Lab2Go subjects; elaborate effective and productive systems (e.g. surveys) for collecting feedback from participants and users, aimed in particular at measuring the impact of Lab2Go in producing an increase in the usage of school laboratories during classes.

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researchers, committed to the task of establishing an active connection with the school community, engaged in school laboratories in the classification, check and catalogue of instruments, and in the design and plan of experiences and activities tailored for the specific equipment of the assigned school. Last but not least, we thank the schools that have been so far involved: students, teachers, head teachers, some external collaborators that have been offering a boost to the contents… in short, we sincerely thank the whole Lab2Go community, that is at the same time both target and creator of the project and constitutes its strength and peculiarity.

We cannot mention here, one by one, all the current and past collaborators; a list of people currently involved in the management of specific tasks and in the coordination for disciplines and geographic areas is available on the Lab2Go Website [6].

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