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Cloud Ecosystem for Supporting Inquiry Learning with Online Labs

Creation, Personalization, and Exploitation

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***Abstract*—To effectively and efficiently implement blended science and technology education, teachers should be able to find educational resources that suit their need, fit with their curricula, and that can be easily exploited in their classroom. The European Union has supported the FP7 Go-Lab Integrated Project (2012-2016) and then the H2020 Next-Lab Innovation Action (2017-2019) to develop and disseminate inquiry learning spaces as open educational resources integrating online labs. This paper presents the technical ecosystem supporting these initiatives and combining loosely-coupled cloud services and platforms. The *golabz.eu* sharing platform is a repository offering online labs, scaffolding apps, and inquiry learning spaces created by teachers for teachers. The *graasp.eu* authoring platform is a social media enabling collaborative creation, agile personalization and secure exploitation at school, as well as exchange of best practices between teachers.**

Keywords—Learning Environment; Educational Repository; Inquiry Learning; STEM Education; Online Labs; Open Educational Resources; Learning Analytics; Creative Commons.

I. Introduction

With the aims of strengthening the interest of the young generation for science and technology, the European Union has supported the FP7 Go-Lab Integrated Project (2012-2016) and is now supporting the H2020 Next-Lab Innovation Action (2017-2019). These two projects promote inquiry learning scenarios, develop and disseminate inquiry learning spaces (ILS) as open educational resources [1] integrating online labs [2], and complement science and technology knowledge with reflective and social abilities. This paper presents the technical ecosystem supporting these initiatives and combining loosely-coupled cloud services and platforms. The *golabz.eu* sharing platform is a repository offering online labs, scaffolding apps, and inquiry learning spaces created by teachers for teachers [3]. The *graasp.eu* authoring platform [4] is a social media enabling collaborative creation, agile personalization and secure exploitation of open educational resources at school, as well as exchange of best practices between teachers, either through online interaction or in the framework of workshops or training events.

By the end of 2016, the *golabz.eu* sharing platform offered over 400 online laboratories, 40 scaffolding apps, and also over 400 inquiry learning spaces created by teachers in many different languages. The *golabz.eu* sharing platform had already a monthly average of 9'000 visits and around 7'500 teachers registered on the *graasp.eu* authoring platform More than 3'000 of them went to the next level of adoption and created one or more learning spaces themselves. About 700 of these teachers created a learning space and exploited it with more than 10 students. The students do not need to register to gain access to the resources prepared by their teachers. These figures show the increasing adoption of inquiry learning and online resources by science and technology teachers.

Inquiry learning spaces creation, personalization and exploitation are at the center of the Go-Lab [5] and Next-lab European digital education initiatives. As open educational resources targeting typically a single classroom session, they can be easily and freely integrated by the teachers in their own teaching scenarios for a single or more teaching activities. They are rich resources embedding a pedagogical structure, online labs, support apps, as well as learning analytics.

II. The Technical Ecosystem

The proposed ecosystem is a full-fledged solution completely operational and in production, i.e. available online 24 hours a day and 7 days a week and open worldwide to any interested user. In addition to the two platforms golabz.eu and graasp.eu which can be seen as **containers**, the online labs, support apps and inquiry learning spaces, which can be seen as interactive online educational **content**, are core components which are delivered as Web applications hosted by their developers or directly in the repository. A single sign-on service is provided by the *graasp.eu* platform to enable seamless navigation between the platforms by the users. A backend learning analytics service is also available for support applications requiring advanced and secure processing of the activity traces. Resources from external STEM repositories selected by lab owners or recommended by teachers can be exploited in the ecosystem thanks to a dedicated gateway (gateway.golabz.eu). Additional backend services for translation and wrapping Web apps in the proper format (composer.golabz.eu) are also available [6]. These platforms, services and components and their dependencies are described in Fig. 1. Additional advanced functionalities are under construction and are described below.

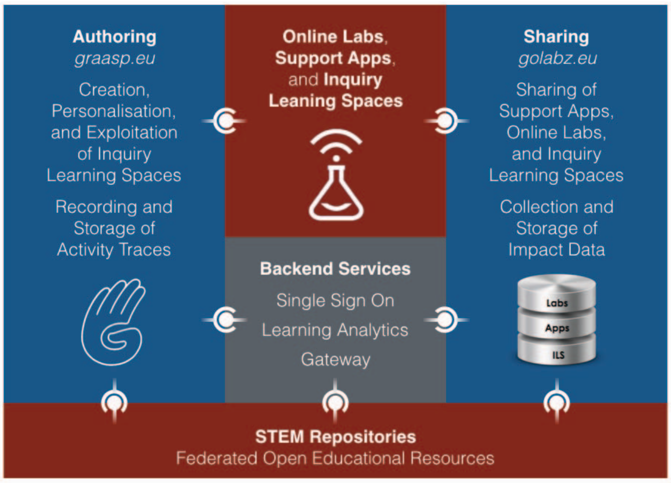

Fig. 1. Technical ecosystem for science and technology education at school.

Starting in 2017, the *golabz.eu* sharing platform will offer new apps and app categories supporting the acquisition of 21st century skills [7] (collaboration and reflection), the creation of system models of the world [8], as well as apps for self and peer assessment [9]. Additional social features to consolidate crowdsourcing and feedback will also be integrated. An incentive mechanism based on digital badges will also be implemented to promote adoption of the inquiry approach and engagement in co-creation. The architecture of the *graasp.eu* authoring platform will be extended to better handle ethical and privacy issues related to the data (learning analytics) and content (learning outcome) gathered from the students and shared with teachers and possibly parents in accordance with the upcoming European General Data Protection Regulation. Besides, new functionalities will be provided in order to let the students export their work and create their own ePortfolios.

The underlying development and exploitation methodology of the proposed technical ecosystem relies on four core principles enabling the adoption of innovative educational and technological solutions to reach a very large scale impact. First of all, solutions are **user-driven**, with the main users being pre-service and in-service teachers. This is achieved by iterative, participatory [10], and agile design approaches applied to the online services and apps. Second, the platforms and the resources are **open** to promote crowdsourcing and viral growth thanks to the dissemination of contributions which can be shared and personalized under creative commons licenses. Platforms and resources are also open to be exploited on any devices thanks to responsive design. Third, the cloud solutions are **federated** through a loose coupling between platforms and services enabling progressive deployment and extensive scalability, while building on validated but expendable platforms and services. Finally, **seamless** integration is possible in order to overcome typical accessibility problems related to the lack of equipment or infrastructure. This is made possible thanks to the fact that no infrastructure needs to be installed and no local support need to be provided by schools. Only computers or tablets with a regular browser are required.

In addition to enabling co-creation of learning spaces between teachers, the ecosystem also enables the co-creation of content by teams of students. Besides, for those students with high level of autonomy, additional authoring functionalities will be offered to enable advance collaboration (by means of collaborative spaces exploited as personal learning environments where they can share their ideas, carry out learning activities, co-create resources and generate reports) and peer-evaluation. The personalization of the open educational resources by the teachers is enabled at four levels (a) through localization, (b) through scenario and dashboard selection, (c) through adjunction of content searched within or recommended by the sharing or authoring platform, or (d) through the built-in domain-specific configuration of the integrated apps. In order to allow users to fully manage their learning spaces and adapt them to their own preferences and to the ethical and privacy restrictions of their educational context as recommended by Learning Analytics codes of practice, the *graasp.eu* platform enables a user-driven management of the privacy settings, with well-defined levels. Three main privacy levels are considered: (a) Learning spaces access for teachers, (b) Contributed content and learning traces for teachers and students stored in learning spaces and in learning analytics repositories, respectively, as well as (c) Content shared by group of students in learning spaces or stored in their ePortfolios.

III. Scenario of Use

To help understand how the proposed ecosystem can be exploited by teachers, a simple scenario of use is described below.

Using the faceted search available, a teacher discovers the **Gravity Force Lab** on the *golabz.eu* sharing platform. This lab is offered and hosted by *PhET* (phet.colorado.edu) [11] and linked to the ecosystem thanks to the *Gateway*. The description page mentioned similar labs and inquiry learning spaces (ILS) contributed by other teachers and exploiting the same lab (Fig. 2). The teacher can freely use one of these recommended ILS for demonstration purpose in the classroom without providing any identification (just by using the ILS preview mode).

The teacher decides however to create a new ILS to support a hands-on learning session based on the **Gravity Force Lab**. To do so, s-he uses the corresponding orange button (Fig. 2) and is prompted to sign up or sign in on the *graasp.eu* authoring platform (Fig. 3). Log in with *facebook* or *google+* credentials is also possible. Only an email address is required for authentication and credentials are immediately valid following the platform open access policy. With the *graasp.eu* account, the teacher can import as a copy any interesting resource from *golabz.eu* and personalize it or create a new one like described in this scenario.

Once the *Create an Inquiry Space* button from *golabz.eu* has been clicked and the credentials to sign up or sign in on *graasp.eu* have been provided, the teacher finds in her or his *graasp.eu* profile the corresponding new personal inquiry learning space named **Gravity Force Lab**.

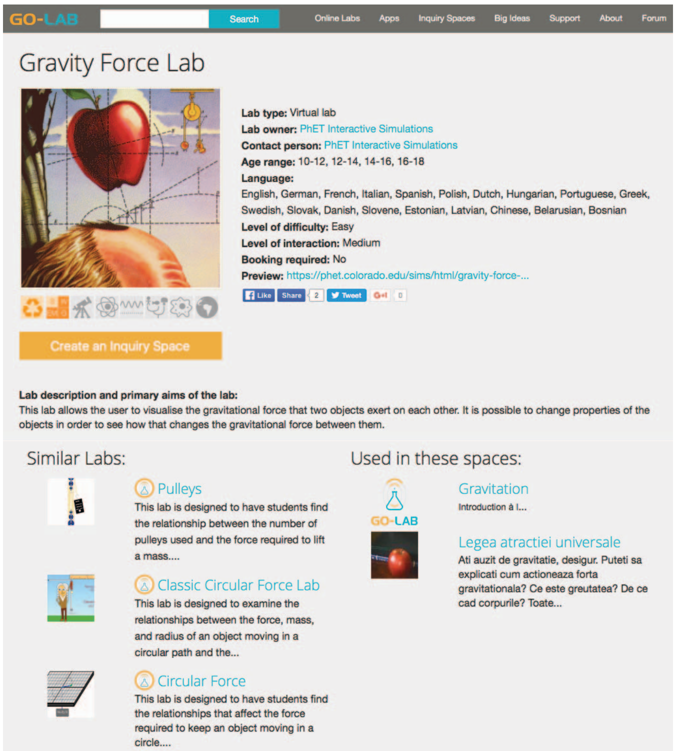

Fig. 2. Description of the **Gravity Force Lab** in the *golabz.eu* repository.

The space embeds the selected lab in the *Investigation* phase represented by a blue rectangle which is similar to an online folder. The five standard inquiry phases of the space which can be freely populated with legacy or cloud resources by the teacher are *Orientation*, *Conceptualization*, *Investigation*, *Conclusion*, and *Discussion*.

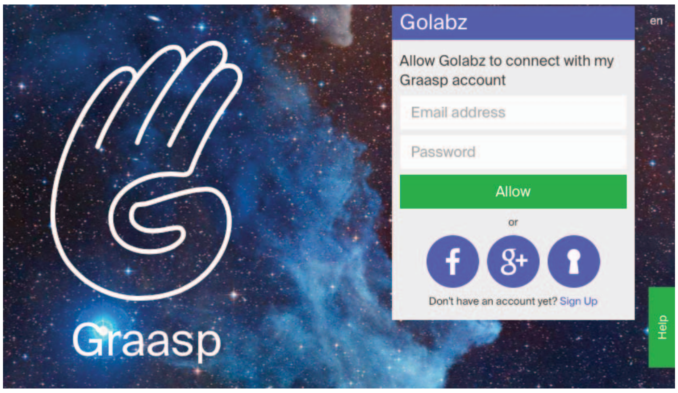

Fig. 3. The *graasp.eu* sign up or sign in dialog to import as a copy and personalize resources from *golabz.eu*.

An additional space dedicated to store settings, as well as the students' activity traces and production is provided as a *Vault*. The teacher is the owner of this private online space (Fig. 4) that can also be switched to public if preferred. The owner can invite colleagues to collaboratively contribute with additional content as co-owners (with the rights to invite additional people and add or remove resources) or editors (with only the right to add resources).

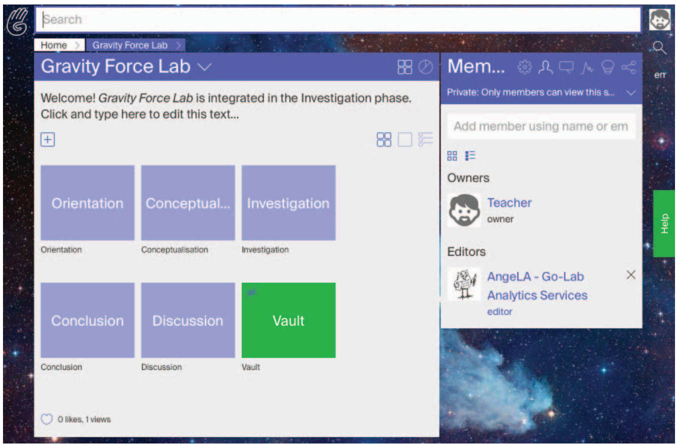

Fig. 4. An inquiry learning space with its 5 standard phases in *graasp.eu*.

Using the + button or drag-and-drop, documents, Web pages or resources from social media platforms like *YouTube* can be added in any phase (Fig. 5). Any element added in a phase can be set has hint to be displayed to students in a collapsed way. The text below the title of any space or subspace is a wiki which can be exploited to provide additional information and which can be formatted in bold (cmd **B**) or italic (cmd *I*) and where links can be added (cmd K).

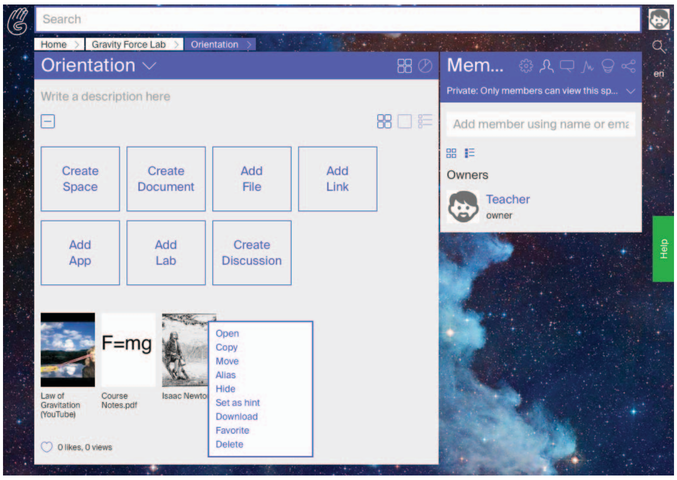

Fig. 5. Legacy and cloud resources added in the *Orientation* phase by the teacher (by drag-and-drop or by clicking on the relevant rectangle).

Support applications (apps) available in the sharing platform can be added directly in the relevant phases, knowing that inquiry learning is more effective if proper scaffolding is provided [12], either using the *Add App* button or using the phase-sensitive recommendation provided in the *Related* pane (Fig. 6).

Once all phases are populated with the relevant lab, support content, and apps, the inquiry learning space can be privately shared with the students as a standalone Web page using a secret URL displayed when clicking the *Show standalone view* button (it is secret in the sense that it is automatically generated and cannot be guessed by trying to type keywords or navigation paths).

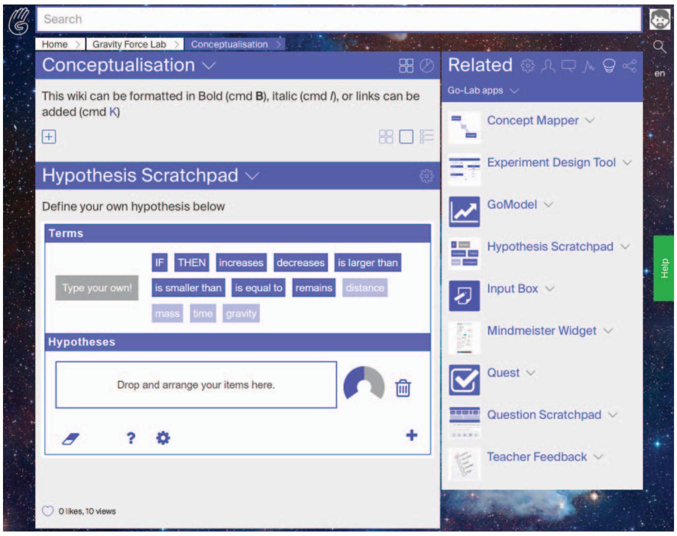

Fig. 6. Adjunction of support apps in the *Orientation* phase (or any others).

Access for students can be set in the *Sharing* pane (Fig. 7) as fully anonymous or a nickname can be requested. This is a way to avoid asking students to register while still preserving their privacy. As a matter of fact, this sharing scheme mimics the privacy setting of a physical classroom where the door can only be opened with the key (the secret URL) owned by the teacher, the latter being the only person able to identify the students with their nicknames. The language of the standalone page can also be set by the teacher and a QR code corresponding to the secret URL can be displayed to ease connection from mobile devices or tablets in the classroom.

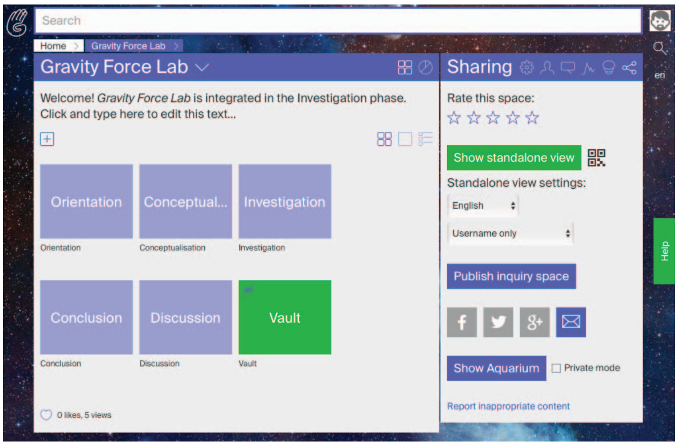

Fig. 7. *Sharing* pane to configure students access to the inquiry space.

Figure 8 shows the standalone Web page corresponding to the inquiry learning space as seen and exploited directly by the students using the secret URL provided by their teacher. In the spirit of inquiry learning, students can freely navigate through the phases which are represented by tabs in this view (each tab corresponding to a subspace populated earlier by the teacher).

The individual contributions of the students are automatically saved in their inquiry learning space and can be exported as a *pdf* file or as a *png* image using the top right *Printer* icon (this is the first step towards lifelong storage of their learning outcome and activity traces in ePortfolios).

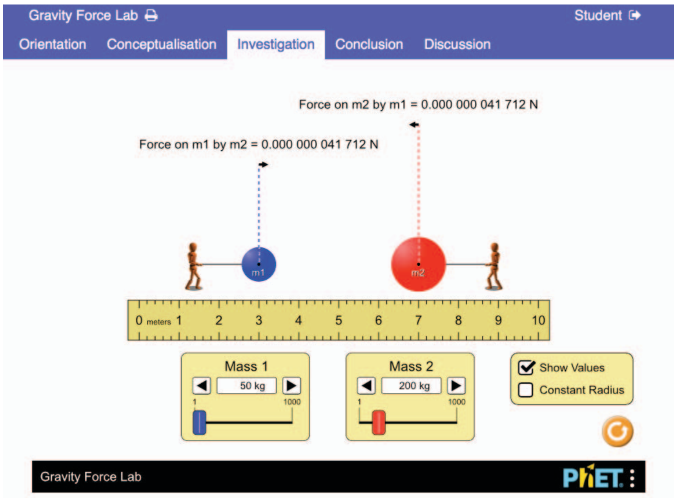

Fig. 8. Interface of the **Gravity Force Lab** as seen and exploited by students.

The teacher can also check in *Review Mode* (Fig. 9) individual production by clicking on the nickname of a student in the *Standalone Users* list of the *Member* pane. Some apps enable the teacher to make comments (bottom light blue area in Fig. 9), which will be visible to students inline if they open again their inquiry learning space. Discussions can also be added as a first step towards enhanced collaboration support between students blending the physical and digital spaces for interaction.

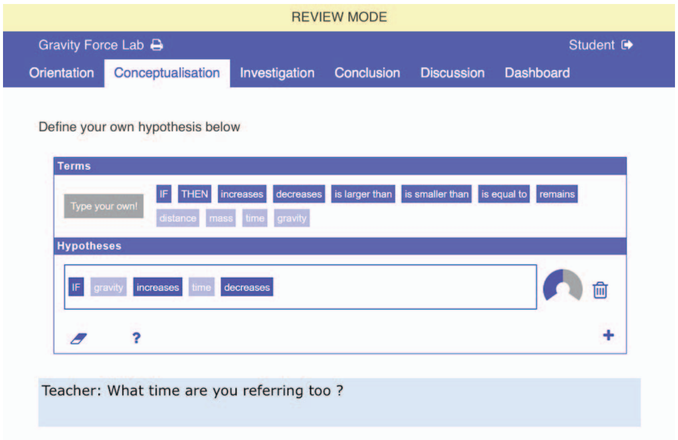

Fig. 9. Interface of the **Gravity Force Lab** in *Review Mode* for the teacher.

Apps which can be added in the various phases belong to a few categories, including **General** apps such as *File Drop* enabling students to submit a report or pictures taken during outdoor activities, or a *Quiz Tool*, **Collaboration** apps such as a *Shared Wiki*, **Inquiry** apps such as the previously mentioned *Hypothesis Scratchpad*, a *Concept Mapper*, an *Observation Tool*, or a *Report Tool* able to automatically gather inputs from other compatible apps, **Math** apps such as a *Calculator* and a *Function Plotter*. Last but not least, **Learning Analytics** apps supporting awareness and reflection as described in the next Section. All these apps can be previewed in the *golabz.eu* sharing platform.

Once an inquiry learning space has been fully developed by a teacher and typically also validated with students in a few classroom sessions, it can be publically shared worldwide with other teachers directly on the *golabz.eu* platform. This is achieved by clicking the *Publish inquiry space* button in the *Sharing* pane (Fig. 7). This action triggers the publishing process during which the teacher has to provide a minimal set of metadata and has to accept to share it publically under creative commons (creativecommons.org) licenses, usually CC-BY-NC (Attribution-NonCommercial 4.0 International). This license enables other teachers to translate inquiry learning spaces created by foreign colleagues in the language of their teaching and to personalize them. The resources submitted to the sharing platform are validated for technical and pedagogical consistency during a 24-hour grace period before being published.

IV. Learning Analytics Dashboards

Supporting inquiry learning with digital platforms enables to collect activity traces which can be exploited for self or class awareness and reflection by both teachers and students. Such traces can be processed and displayed as learning analytics in learning dashboards [13].

The proposed ecosystem fully supports the storage of activities traces as Activity Steams (activitystrea.ms) or xAPI (also known as Tin Can) statements (tincanapi.com). To comply with the European General Data Protection Regulation (EU 2016/679) which will come into force in May 2018, the traces are only collected with the approval of a teacher in her or his own inquiry learning spaces (each space can be configured independently). This approval is expressed by inviting the *AngeLA* agent [14] as a member of the space to collect Activity Streams or the *AngeLO* one to collect xAPI statements. These names refer to the concept of guardian angels for Learning Analytics and for Learning Objects, respectively. This scheme is consistent with the metaphor described previously and corresponds to the teacher being in control of who can enter and observe activities in her or his classroom and, in this case, in its digital counterpart (ILS). Currently, the traces are stored in a dedicated secure repository. In the future, it is environed to let the teacher select an institutional Learning Record Store (LRS) and possibly let the students select their own private LRS. The usage of a private blockchain [15] is also considered.

When traces are collected in a given inquiry learning space, they can be consumed only by learning analytics apps added in the same ILS. These apps are typically added in a subspace called the *Dashboard*. If this subspace is set as hidden, its content, i.e. the learning analytics apps and the visualized data, are only accessible by the teacher. Otherwise, the apps and data are also made visible to students. This scheme enables to freely design learning analytics dashboards combining relevant views. Some learning analytics apps are targeting teachers, such as the *Online users visualization* (Fig. 10) which shows for every phase in an ILS which users are currently active. Others are targeting students, such as the *Reflection Tool* which gives feedback about their use of an ILS.

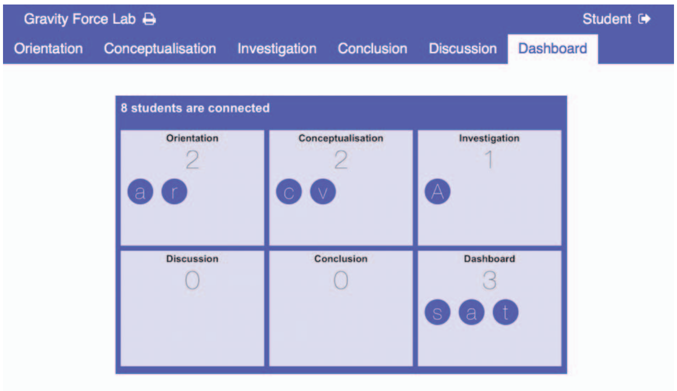

Fig. 10. A learning analytics app added in a self-reflection Dashboard visible to students.

V. Online Labs

Online labs are not limited to virtual labs based on simulation. Physical labs remotely accessible, referred as remote labs, are also important components of online education in science and technology. Even if they represent only a small fraction of the online labs offered on the sharing platform, they play an important role to make clear to students that the models exploited to build simulations are just a representation at a given granularity level of our current understanding of the observable reality and to show the disturbances and uncertainty to be handled by scientists in the real world. To support further integration and adoption of remote labs, standardization efforts have been carried out in the Go-Lab initiative and in the IEEE P1876 working group. Standardization layers enabling access to remote labs as services and as educational resources have been defined [16]. It is now possible to automatically generate Web apps to be exploited as remote observation and manipulation client for remote labs complying with these standards and integrating simultaneously a basic user interface and backend features to take advantage if their integration in inquiry learning spaces [17] such as the storage of activity traces or measurements in the *Vault*. An app is also available on the sharing platform for this auto generation purpose.

VI. Concluding Remarks

To effectively and efficiently support the adoption of inquiry learning and the usage of online labs at school, we propose an ecosystem relying on two core open access platforms, a sharing one (*golabz.eu*) offering open educational resources supporting science and technology education, and an authoring one (*graasp.eu*) enabling the construction and the personalization of such resources directly by teachers for teachers. The latter also enables the exploitation of inquiry learning spaces anytime anywhere and the secure collection of activities traces supporting awareness and reflection through learning analytics. The inquiry learning spaces exploit components of a large collection of targeted support apps designed by experts which can be combined with additional legacy or cloud resources.

The success of the proposed solution relies on a progressive adoption pattern. A teacher novice with the ecosystem can in three clicks start from an existing ILS discovered on the sharing platform to its personal copy used with her or his students in the classroom (click one: select the ILS, click two, create a copy, click three: share the standalone with the students). A teacher experienced with the ecosystem can create collaboratively with colleagues an ILS from scratch or carry out full-fledged personalization with translation, adjunction of advanced apps and integration of powerful leaning analytics.

The designed ecosystem only requires an Internet connection and a modern browser to be exploited in the classroom. Hence, it is not more complex to use an inquiry learning space than a *PowerPoint* presentation stored on *Dropbox*. The platforms and the inquiry learning spaces are also compatible with usage on tablets to support the bring-your-own-device (BYOD) paradigm.

The ecosystem is not limited to inquiry learning and education in science and technology. It also intends to bridge the gap between formal and informal learning, allowing the students to carry out and continue the learning activities seamlessly in the classroom and at home and to support the acquisition of 21st century skills.

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