ENVISAGE

ENhance VIrtual learning Spaces using Applied Gaming in Education

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D1.2 - Data structure and functional requirements

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Abstract

The current document first presents a general compilation of behavioural data collected from virtual learning labs in the framework of the Go-Lab project and their analysis. The comprehensive analysis of the available data provided several deeper qualitative and quantitative understandings of the user behaviour. The experience gathered from the analyses of the available data is directly transferred to the ENVISAGE project in order to guarantee that more effective, thorough and comprehensive metrics will be implemented to collect the behaviour of each user, teacher or student, during the usage of a virtual lab in science teaching and learning. In this context we discuss and propose a list of main metrics that can be collected by the analytics service, their definition and rationale of use. We also propose that the structure of the analytics data and its aggregation level to permit analysis and interpretation similar to the one that is conventionally done in the actual school environment. We also discuss the functional requirements that the virtual lab authoring environment of ENVISAGE should accommodate. These are presented mainly from an end-user perspective being a science teacher. Finally we give a short overview to describe some

basic functionalities and use cases of the Go-Lab system in the framework of which we obtained the raw log data of user actions in its authoring environment. This dataset is now available to partners of ENVISAGE for study and analysis. The description of its content is given to help the application of machine learning algorithms and practices for extracting baseline and deeper information on how the environment was utilized.

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Executive Summary

The current document first presents a general compilation of behavioural data collected from virtual learning labs in the framework of the Go-Lab project and their analysis. The comprehensive analysis of the available data provided several deeper qualitative and quantitative understandings of the user behaviour, such as its development and evolution through time and across countries, on how and to what extent users utilized the offered services, whether they followed the proposed educational framework, etc. The experience gathered from the analyses of the available data is directly transferred to the ENVISAGE project in order to guarantee that more effective, thorough and comprehensive metrics will be implemented to collect the behaviour of each user, teacher or student, during the usage of a virtual lab in science teaching and learning.

In this context we discuss and propose a list of main metrics that can be collected by the analytics service, their definition and rationale of use. We also propose that the structure of the analytics data and its aggregation level to permit analysis and interpretation similar to the one that is conventionally done in the actual school environment. By following similar structure and interrelations and by providing visualization at similar aggregation we believe that the task of its interpretation by the teachers will be greatly facilitated.

We also discuss the functional requirements that the virtual lab authoring environment of ENVISAGE should accommodate. These are presented mainly from an end-user perspective being a science teacher. Finally we give a short overview to describe some basic functionalities and use cases of the Go-Lab system in the framework of which we obtained the raw log data of user actions in its authoring environment. This dataset is now available to partners of ENVISAGE for study and analysis. The description of its content is given to help the application of machine learning algorithms and practices for extracting baseline and deeper information on how the environment was utilized.

The document is structured as follows: a short introduction is given in Chapter 1. In Chapter 2 we are presenting the behavioural data collected from the Go-Lab virtual learning labs and environments, its analysis and concluded remarks. In Chapter 3 we are proposing and discussing the functional requirements that should be implemented in the design of the authoring environment and that will allow the development and realization of the shallow and deep analytics services and related metrics. In Chapter 4 we provide the description of the telemetry raw data that was collected in the framework of the Go-Lab project and that are now available for analysis by the partners of the consortium. The document is summarized in Chapter 5.

Abbreviations and Acronyms

ILS	Inquiry Learning Space
ICT	Information and Communication Technologies
GUI	Graphical User Interface
WYSIWYG	What You See Is What You Get
URL	Uniform Resource Locator

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1 Introduction

1.1 The ENVISAGE Concept

The overall concept of ENVISAGE is based on iterating the process of improving virtual labs through a structured and well-defined process. The first phase starts from the current available version of a lab that may be already in use in real classroom setting and the collection of preliminary shallow analytics extracted from user behavioural data. The next step is to dig deeper into the obtained analytics using machine learning methods. Then, it follows the integration of the concluded information and pedagogical insights into the authoring tool which will be employed by teachers and educators to build an improved version of the virtual lab and accompanying educational scenarios. The above process can be iterated until the final version is reached. The whole approach of ENVISAGE is illustrated in Figure 1.1. First simple statistics on tracked data (shallow analytics) are collected to monitor the activity of the users, both teachers and learners, in order to model their current behaviour and general practices. Further analysis with the application of machine learning methods follows in order to reliably predict the expected behaviour of the users. Both of these approaches are combined with visualization methodologies that will offer insights to educators and to lab developers on what features are important and what functionalities users expect to find in a virtual lab. These insights will allow the optimization of the design of the virtual lab, will facilitate its implementation and finally achieve the enhancement of the learning process.
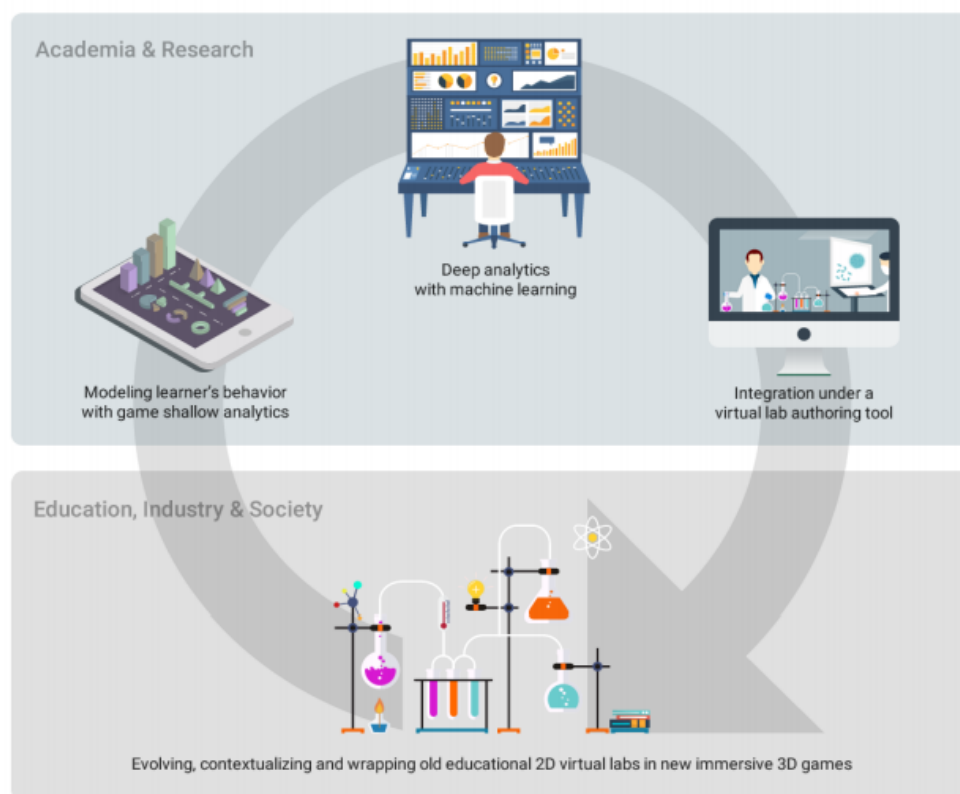

Figure 1.1: *The ENVISAGE virtual lab enrichment strategy through a staged iterative approach.*

1.2   Scope of the current document

The current document aims to present a compilation of behavioural data collected from virtual learning labs and their analysis, to discuss and propose a list of metrics, its basic structure and the functional requirements of the authoring environment of ENVISAGE. Their incorporation in the design of the interfaces and the offered services will enable the implementation of the aforementioned approach of the ENVISAGE project. The document is structured as follows: in Chapter 2 we are presenting the behavioural data collected from the Go-Lab virtual learning labs and environments, their analysis and concluded remarks. In Chapter 3 we are proposing and discussing the list of metrics and the functional requirements that should be implemented in the design of the authoring environment and that will allow the development and realization of the shallow and deep analytics services and related visualization tools. In Chapter 4 we provide a description of the telemetry raw data that was collected in the framework of the Go-Lab project and that are now available for analysis by the partners of the consortium. The main points of the document are summarized in Chapter 5.

2   Behavioural data collected from virtual learning labs

In the framework of the work done in the Go-Lab project (**http://golabz.eu**) EA was responsible in performing analysis of the collected user data [1]. The primary aim of the analysis task was, on one hand, to monitor the large-scale implementation pilot activities and, on the other, to provide objective proof of extensive usage and sustainable uptake of both the educational approach and the online offered services of the project. In addition to that, the comprehensive analysis of the available data provided several deeper qualitative and quantitative understandings of the user behaviour, such as its development and evolution through time and across countries, on how and to what extent users utilized the offered services, whether they followed the proposed educational framework, etc. It should be noted that in the project's scope there was no goal to provide individual learning analytics although an analytics engine was partially integrated in the authoring environment. Nevertheless, the experience gathered from the analysis of the available data will be transferred to the ENVISAGE project in order to guarantee that more effective, thorough and comprehensive metrics will be implemented to collect the behaviour of each user, teacher or student, during the usage of a virtual lab in science teaching and learning. In the following we discuss the main findings of the analysis of the data of the Go-Lab system [2].

2.1   Analysis of usage from system data

2.1.1   Time evolution of usage

The system raw log data and their thorough analysis offered an independent and objective way to study the actual usage of the system, its main characteristics, how and when online Inquiring Learning Spaces (ILS) were created, authored and implemented, how the overall population of users evolved in time, etc. In this context, our analysis shows that, from Oct 2014, and since the migration to a new and more user friendly system and authoring environment, until the end of Jul 2016, 6517 new users registered and created an account in the authoring environment, of whom 3877 became creators and authors of 1470 ILSs as counted with minimum quality criteria (e.g., ILSs with all inquiry phases according to the proposed Go-Lab inquiry cycle, with at least five standalone student views, etc.). These figures show a more than 100% increase when counted from Oct 2016, as can be seen in Fig. 2.1. When compared to the total number of teachers participated in the partner trainings, we see that we reached a multiplication factor of 3.85 with respect to the number of registered users per trainee, and 2.29 with respect to the number of content authors per trainee. This reflects the fact that more experienced and advanced teachers were training and tutoring their less experienced colleagues, which is in line with what national coordinators and partners had observed during their interactions with participants at the various training workshops offered in that period of time.
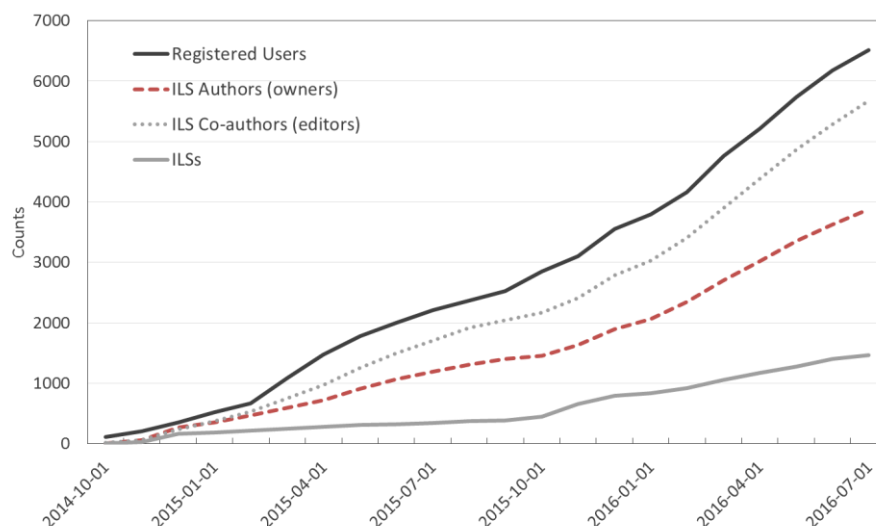
Figure 2.1: Time evolution of registered users, authors and editors, and ILSs created in the authoring environment.

Figure 2.2 shows more qualitative parameters and how they evolved through time for the last two in-school large-scale pilot implementation phases. We observed that the number of registered users that correspond to an author of inquiry content quickly improved since the start of trainings from Oct 2014, and stabilized to an average value of 1.68. This means that on average about 2 out of 3 users actively used the authoring environment and the offered tools to adapt or create their own ILSs. In the same figure, the curve of authors per ILS shows a more seasonal behaviour, which coincides with the periods that schools and teachers are in duty. It had a variation between about 2 and 4, with an overall average value of 2.64. This reflects the fact that teachers were gradually and actually sharing content with 2 or more other users or/and worked collaboratively with colleagues in the design and development of their ILSs.

In addition to above, a more significant qualitative change in the behaviour of users and how the system was utilized in practice is shown with the curve "standalone viewers per author". The term standalone viewer refers technically to the action of viewing an ILS by students that access it with nicknames or passwords given by their teacher. As can be seen there was a clear and distinctive rise after summer 2015 and since the start of the corresponding school year that spanned the last implementation phase. This constant increase shows clearly that progressively more and more teachers are utilizing their ILSs with their students. At the end of the phase it reached the value of 9.4. Taking into account that on average a typical school classroom consists of 20 to 25 students this means that on average about 2 students are sharing a PC to login and access the ILS taught. This is consistent with observations from national coordinators and partners and in particular from those who organized and implemented themselves activities with students in school classroom settings. The summative reported numbers for the activities that conducted by partners are 4283 students from 218 schools, which corresponds to an average of 19.6 actual students per classroom.
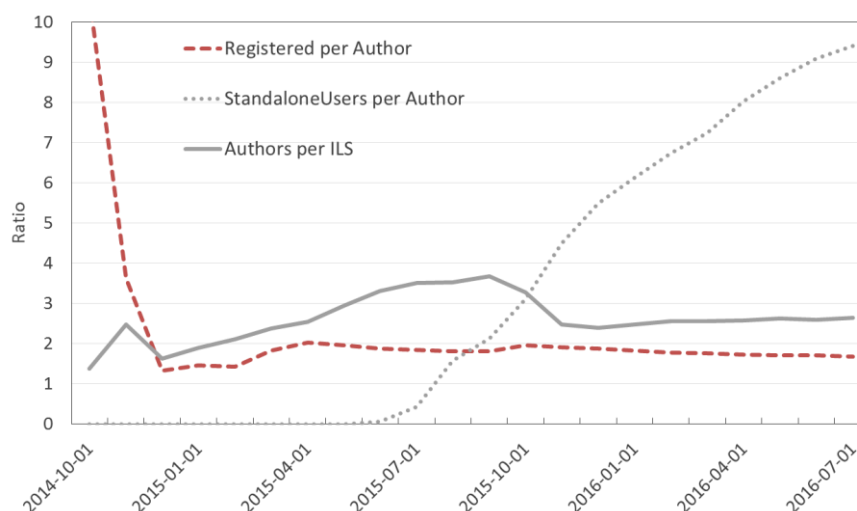
Figure 2.2: Time evolution of the number of registered users per author, standalone viewers and authors per ILS.

The abovementioned quantitative and qualitative change in the behaviour of users and the overall achieved usage of the system is a combination of several factors, among others: 1. maturity and proficiency of users; 2. consequent creation of a significant critical mass of teachers who produced in abundance a large variety of high quality ILSs in various languages, subjects and complexity levels; 3. abundance and variety of online labs and supportive apps in the portal; 4. technical improvements that made the system and the authoring environment more user-friendly.

2.1.2 Usage of inquiry learning spaces

The system log data gives us also the opportunity to analyse and estimate the overall usage of ILSs, time duration, repetition rate, etc. The analysis was based on 768 ILSs that passed a set of strict quality criteria (e.g., threshold value of standalone viewers of more than 10, usage of all phases of inquiry, minimum time of ILS usage of at least 15 mins) that were applied to the raw database.

The distribution of the selected ILSs as a function of how many times they were used (in settings of at least 10 standalone viewers, which correspond to 10 connected PCs or equivalently to at least 20 students) is shown in Fig. 2.3. We observe that the ILSs are implemented with on average about 50% of cases are a single time, about 30% are 2-3 times, about 11% are 4-6 times, about 8% are more than 7 times. On average, this corresponds to a mean repetition rate of 2.8 times that an ILS is implemented. In total, these ILSs were implemented with 21420 standalone viewers which roughly correspond to more than 40000 actual students. It should be noted that these estimates are on the conservative side if we take into consideration the fact that in many instances school classrooms were equipped with less PCs or equivalently had a higher ratio of students per connected PC.
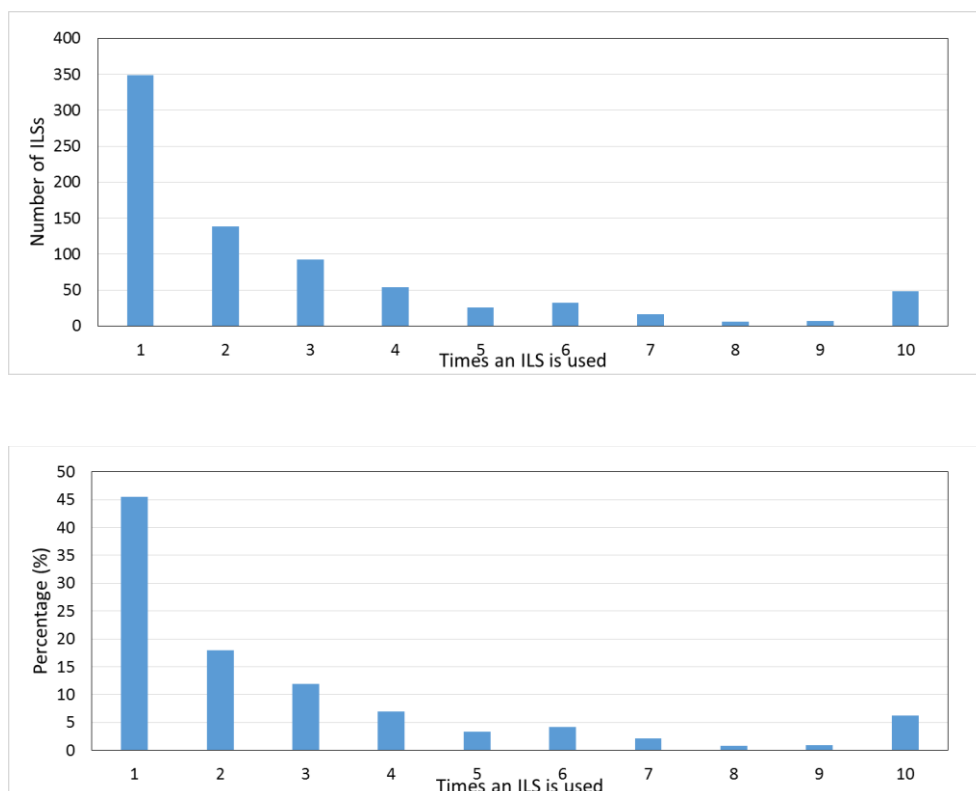
Figure 2.3: (Top) Number of ILSs versus how many times were used in classroom settings of at least 10 PCs which correspond to about 20 actual students. (Bottom) Percentage of ILSs versus how many times were used. (Note: last bin refers to values more than 10)

The results of the analysis of data with respect to duration of usage of an ILS is shown in Fig. 2.4 below. As can be seen from the upper curve overall in about 60% of the cases the duration of usage of an ILS is for about 43 mins. The long tail is understood due to cases where an ILS is partially implemented during classroom hours and then its usage were continued by students as homework, or for added assignments or in extra-curriculum activities. If one considers only in-school hours, typically from 8:00 until 15:00, then about 44% of the cases fall in this category as shown in the lower curve of the graph. This is well consistent with data from surveys of teachers about how they used Go-Lab services. It should be also noted that both curves are reproduced by power law distribution functions with long tail. This is typically expected to describe a dynamic system of large size of, e.g., physical, biological or social nature.
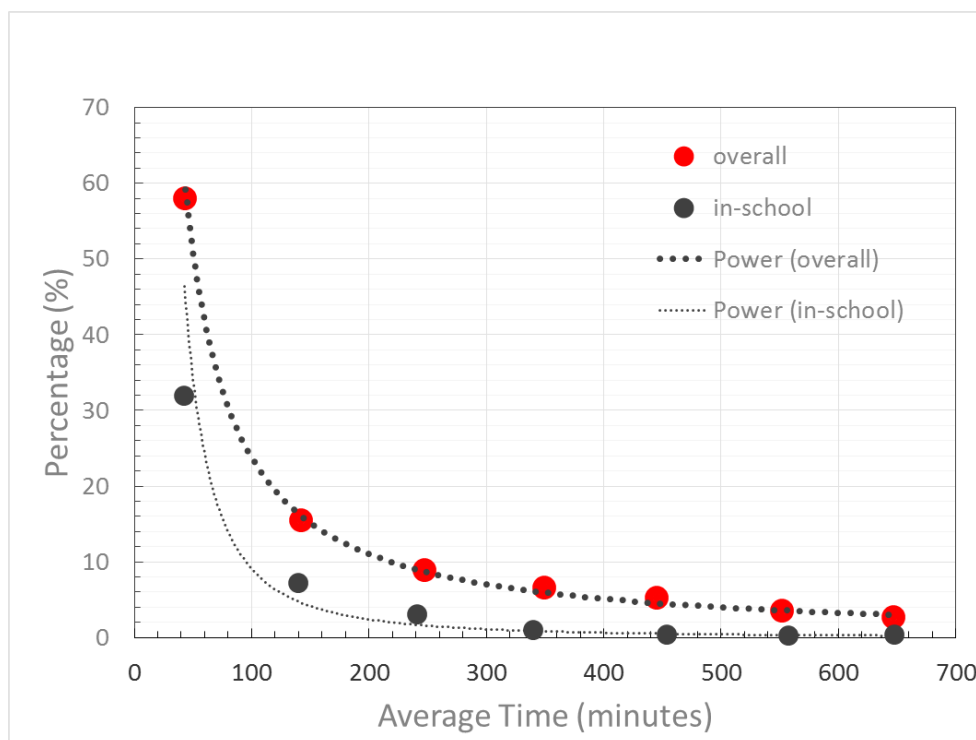
Figure 2.4: Distribution of average duration time an ILS is implemented.

2.2 User groups, their perspectives and main findings

Virtual lab developers, teacher trainers, science curriculum designers and advisors: The design of a virtual learning environment, an online lab for science education and its successful and effective incorporation in the school curriculum is usually a very complex procedure that can be affected by several factors. A well-designed, user-friendly and functional authoring environment can facilitate greatly the achievement of the educational and learning goals that a teacher or educator sets. However, as different types of users or stakeholders might have different expectations from the same environment and its offered functionalities or their importance in the learning process, there is usually a significant difference between the opinions and expectations of teachers, i.e., actual authoring users, and the view of lab developers or instructors on what is a good and effective virtual lab for real in-classroom usage. In the framework of the Go-Lab project, this difference or gap was minimized through extensive workshops during the design process, the so-called visionary and participatory design workshops and seminars, where the end-users' experience, professional insight and intuition was collected. This was then transferred in iterations in the overall enhancement of the authoring environment which greatly facilitated the uptake of its usage. Accompanied by thorough teacher trainings across countries, a widespread significant change of the behaviour of teachers was observed and achieved. From using occasionally the system but not implementing it in their classrooms, teachers progressively utilized its full services and became independent creators of online inquiry educational content of high quality. This behavioural change is captured in the analysis of the system data as discussed in the previous section which offered an objective proof of the effectiveness and impact of the followed strategy. In the framework of ENVISAGE, a similar approach is followed to guarantee its success from an early stage. Teachers are involved in the decision making

process regarding the design of several aspects of a lab and the authoring environment as early as possible and will provide designers with a means to have a more effective development cycle in terms of time and cost and more smooth in terms of realized educational objectives.

Authoring end-users, teachers, educators: We distinguish teachers and in general educators between: users of already made educational content and developers or creators of authentic educational material. The majority of them initially are in the former group and progressively as they gather experience and confidence they move into the latter. This evolution was also gathered in the system data discussed above. Furthermore, as they mature and become content creators, they are changing perspective and they utilize more regularly learning analytics functionalities that are integrated in the system. In general, from the perspective of a teacher, student behaviour metrics monitored in a constant basis provide insights directly into their knowledge cycle and facilitate their assessment. Offering these services in a user-friendly, easily accessible way with abundance of semi-automatic built–in visualization options will reinforce the flexibility of teachers to quickly adopt and adapt their teaching methodology according to their students' needs and skills at individual basis.

End-users, students, learners: One of the main drawbacks of the design of the Go-Lab log system was that it did not offer the possibility to monitor and track end-users at individual student level. As a consequence the offered learning analytics services was not used by teachers as they contained no real useful information to improve their teaching practice and practically had no value apart from showing basic statistical information. In addition, it did not offered any opportunity to implement and monitor students' competency levels, problem-solving skills, etc. ENVISAGE clearly has a different approach by providing student metrics that will allow the constant monitoring and tracking of the student behaviour, needs and difficulties during the learning process in the virtual environment. This will greatly help teachers to quickly profile their classroom audience and personalize their teaching approach. At this point it should be emphasized the importance that personalization features should not only be part of the analytics functionalities but also of the authoring environment. Features of the authoring and end-delivery environment, such as easy or personalized change of font size, font style, colour schemes, etc., can be crucial for how a virtual lab is perceived by students of different age or gender. Furthermore the inclusion of visualization of progress or achieved results at student level or student groups will also facilitate student self-assessment, self-paced learning and teaching methodologies that put emphasis in collaboration and work in groups.

3 Metrics, data structure and functional requirements

3.1 Introduction

In this chapter, we are presenting and discussing the data structure, aggregation level and related metrics that could be provided from the ENVISAGE service. We first present and propose a list of metrics, their definition and rationale of use. We then continue with a proposal regarding the main data structures and their interrelations, and the functional requirements of the authoring environment. Where appropriate, we briefly discuss a scenario of use or scenario of expected analysis in order to better justify their importance and clarify the context with respect to different user perspectives.

3.2 List of proposed metrics for ENVISAGE

In this section, we are presenting a list of metrics that can be collected by the analytics service. Some of them were already mentioned in detail in D1.1 along with examples from actual implementations in the scope of other projects. The reader is encouraged to read also this particular section of D1.1 for completeness.

3.2.1 Time-on-task

Definition: Time-on-task is defined as the total time that students spend engaging in a task that is related to outcome measures of learning or achievement [3]. In a lesson plan or educational activity that follows a structured inquiry-based model the time-on-task refers to the time that is spent within the specific phase of the inquiry activity. Based on the time-on-task paradigm, which is a simple but powerful framework to explain students` achievements, it may be possible to draw conclusions about the effectiveness of the ENVISAGE approach. However, this paradigm does not only represent the time students spent on learning, but it also represents an academic commitment [4]. The students show academic behaviour, they observe phenomena, draw conclusions, write reports or reflect on scientific questions.

Challenge: The time-on-task is more meaningful and valuable reference metric when the learning activity follows a staged approach or a linear sequence of predefined tasks. In cases where the learning activity has a circular structure or is done with iteration of some tasks, it may give misleading results. In such cases, the user should be notified about its usage. It should be also noted that this metric can be defined at student level as baseline reference data but it will also be useful to be available for analysis and visualization at group or class level. This will facilitate class profiling, class-to-class comparison analysis, etc.

3.2.2 Time-to-completion

Definition: This metric is similar to the time-on-task metric, the main difference is that the emphasis is on measuring the overall time students spent from a starting point until they complete the whole sequence of tasks that compose the learning activity. In this respect, it is more useful reference metric in case of circular activities or where students are assigned with tasks that can be repeated several times until a satisfactory outcome is reached. It offers also valuable information of the learning behaviour of students in case of homework assignments. In this case it is useful for teachers to monitor and know whether their

students do their work in one step or in multiple steps or iterations.

3.2.3   Class categorisation profile

Definition: In this metric, students are categorised in three categories according to a well-defined categorisation scheme, e.g., PISA 2012 (see [5-8]). The metric is calculated by considering the lowest level task per phase for the completed task. For example, students in the context of an educational activity have to solve two specific tasks that are connected with the specific partial ability. If a student completes successfully the two assigned tasks, he/she gets on a high level. In case the student is not able to solve neither of the tasks, then his/her profile value will be on the low level in that phase. However, if the student's answers were high or moderate, then his/her profile value will be moderate. By this procedure the specific study underestimates the real performance but such a process will minimize the risk for interpretations when comparisons are included.

Challenge: On an empirical perspective, the problem-solving questions should be designed in a way that only 10% of the students answer on a high level, 45% on a moderate level and 45 % on a low level. We can claim, in such a case, that the specific approach is supporting students to develop from the moderate level to the high, but clearly the tools and the approaches used cannot have significant impact to low performers.

3.2.4   Perceived, expected and actual general class or group profiles

Definition: In this metric, students are asked to assess themselves or their groupmates according to a categorisation scheme provided by their teacher. The metric can be calculated either at task per task level or once for the whole activity. The expected profile is measured by the students' answers before the learning activity or task is done. The perceived profile is the one after the activity or task is completed. These profiles are then compared with a more objective metric obtained by measuring the actual performance results. By comparing perceived and actual performance or opinions, students are motivated to improve their learning and develop further skills and competences related to communication, collaboration, presentation tasks, etc.

Challenge: This method of profiling a class or group is more meaningful and valuable when the learning activity is performed by students in groups or when the collaborative aspect is important in the learning process. Otherwise, it may be significantly misinterpreted by students and lead to opposite results in terms of motivation, engagement, self-esteem, confidence or self-respect. In this context, it may also lead to results that underline certain gender-related stereotypes [9].

3.2.5   Levels of proficiency

Definition: This metric could offer an opportunity to teachers for direct comparisons with country average or other standardized scores, e.g., OECD average scores [5-7]. Additionally, the continuous use of such assessments from the teachers for the same class could act as a very effective method to monitor students' skills development. The level of each task is added for every problem-solving question in each phase of the inquiry activity and is then divided by the number of tasks. This method is offering the opportunity to have a clear view of the students' performance as there is no need to select among the task level when the

student performance is not the same in the task of each phase. Then the percentage is calculated. The example of the average of high, moderate and low levels of proficiency calculation are compared with OECD Average or other reference data. The findings can demonstrate whether the use of the virtual lab has helped students to outperform OECD average or other standard level.

Challenge: As in the case of the class categorisation profile mentioned above, here, the proper design of the problem-solving questions plays the most crucial role.

3.2.6   Mastery index

Definition: This metric could offer pedagogical insight and guidance to teachers to better profile their students in learning activities in which he/she did not set any explicit time constrain for them to complete them or in which students have ample time to work on them. However, there is a threshold learning goal which should be reached or overpassed in the end in order for a task or activity to be considered completed. The index is defined as the normalized ratio of the shortest time in class or sample of students spent to reach the threshold over the time spent by the student. A student who acquired content or/and concept knowledge more quickly is expected to get a higher index value. In other words, it measures the rate of learning and mastering a new subject. It may stay constant or increase/decrease as the student progresses into more complex learning tasks or concepts.

Challenge: Most educational systems across levels and countries are still exams-oriented. Teachers are challenged to teach certain curriculum subjects within fixed school times which is one of the main constraints. In this model, students are asked to proceed and to learn new subjects even without mastering the previous ones at adequate level. In this way, they only widen their knowledge gaps that may possibly have as time goes on. However, the advancements in ICT technologies and related services, their ubiquity and ease of access give numerous opportunities for new channels and models of teaching and learning to be implemented and utilized at large scale. Practices like distance-learning or asynchronous or self-paced personalized learning are widespread and their uptake is emphasizing the importance of mastery-oriented model of practice [10].

3.2.7   Travel-path related metrics

Definition: The travel-path is defined as the sequence of actions that a student follows within a learning activity. Metrics related to that can be the overall length in time, critical path to completion, loop time, transition density, etc. The measurement and monitoring of such metrics are more important in learning activities which are action-oriented rather than results-oriented. This is the case in inquiry based education methodologies in which students go through inquiry phases that in a sense simulate the scientific method of investigating phenomena and acquiring knowledge. In these methodologies, the focus is on students to understand and master the process rather than to reach certain results per se [11, 12]. In this context, the visualization of travel-path related metrics will help teachers to identify students that have difficulties or cases of possible disorientation where intervention and guidance is needed.

Challenge: Proper visualization is of high importance to facilitate correct interpretation of these metrics.

3.3   Data structure and aggregation level

We propose the structure of the analytics data and its aggregation level to permit analysis and interpretation similar to the one that is conventionally done in the actual school environment. In this context, the overall structure will resemble the one that is depicted in Fig 3.1. In this view, the school entity is composed of teachers. A teacher can develop several learning activities using virtual labs which then are implemented in the teaching of his/her classes. Each class is composed of students or group of students. For each student a record of progress is kept. By following similar structure and interrelations and by providing visualization of the collected analytics with similar aggregation we believe that the task of its interpretation by the teachers will be greatly facilitated. This will lead them to utilize the offered analytics services to further extent and take full advantage of them for guidance in their teaching and for improvement of the expected learning results for their students.
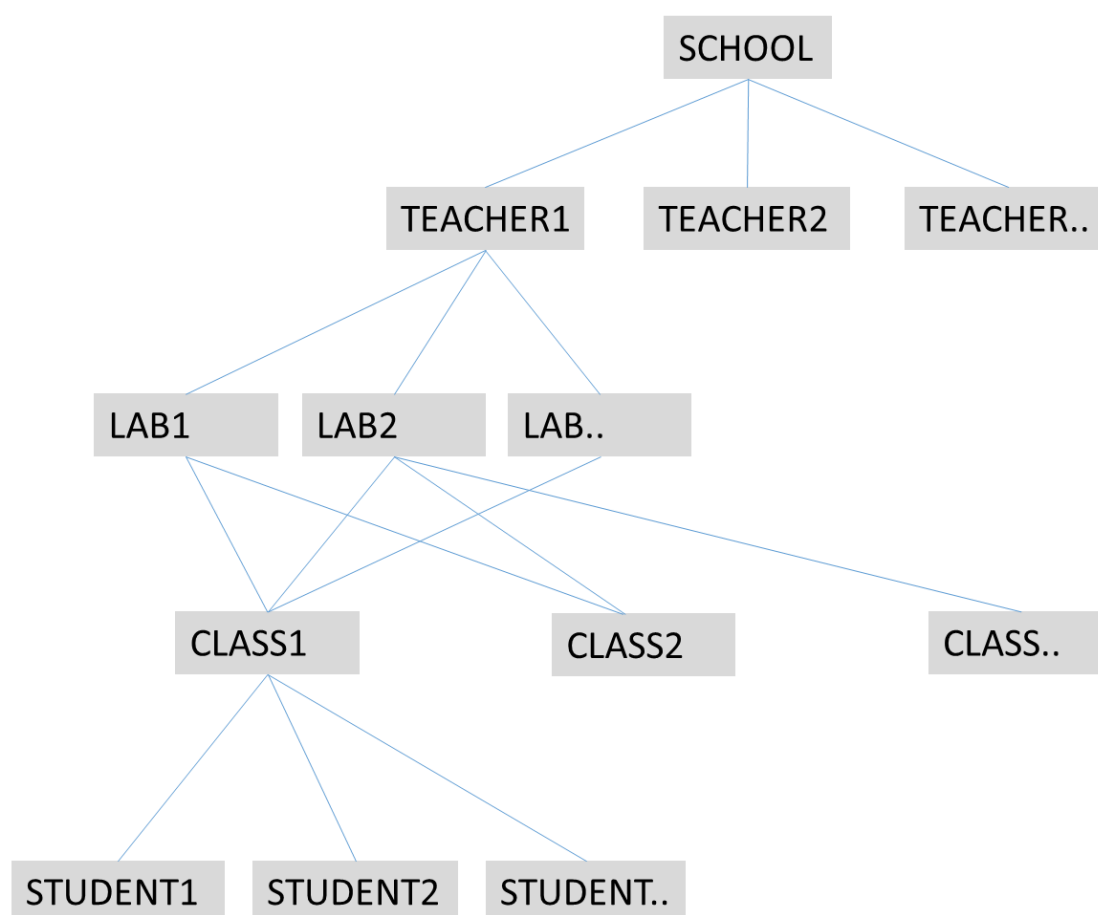
Figure 3.1: Data aggregation levels and interrelations resembling the structure of a real school

In the following, we list a set of questions or actual use scenarios to which the analytics and visualization services may provide straightforward answers even at real-time. The list is based on compilation of interviews and discussions during the school year 2016-2017, with teachers of primary and secondary education in EA and elsewhere who have utilized virtual labs in their teaching or have basic experience in online learning management systems and

related analytics services.

- A teacher would like to visualize in real-time the progress of its class in terms of percentage of tasks completed and intervene accordingly.
- A teacher would like to assess and compare progress in using a virtual lab activity between different classes on average or between individual students.
- A teacher has developed several versions of a lesson plan with the same virtual lab. He/she tested them with a small group of students and would like to know which version is best to use in full classes according to a certain set of criteria.
- A teacher would like to get a quick profiling of the class and adapt the teaching methodology accordingly.
- A teacher shared a virtual lab activity with a fellow teacher. They would like to compare whether they achieved similar learning results with their classes.
- A teacher would like to measure more objectively the complexity of a series of tasks by monitoring the average percentage of progress or overall time spent.
- The head master of the school would like to compare the ratio of students per connected device and how much time in total the virtual labs were used for teaching between two different semesters or year terms in order to better plan the distribution of available resources, e.g., to increase the number of computers in the classroom.
- This year the activities with virtual labs are scheduled close to lunchtime hours. Last year, they were scheduled early in the morning. Is there a measurable significant difference on the average learning outcomes?
- Several learning activities with virtual labs were assigned as homework to students. The teacher would like to monitor progress and know how much time they actually spent at home for the completion of the tasks.
- A teacher would like to identify low and high achieving students form past progress data to accordingly provide extra support and guidance or assign advanced tasks respectively.
- A teacher designed an educational activity where students can choose or not to get automated feedback for self-assessment during each phase or in total at the end. He/she would like to see how many students chose the offered option, whether this influenced their motivation or whether the learning results differed between the two groups.
- A teacher proposed three different virtual labs of similar complexity to his/her students that they can freely choose to use for their project work. He/she would like to monitor the popularity of each lab in terms of total time spent or number of students and whether the choices of their students were gender-balanced or not.
- The headmaster and the teachers of the school wanted to conduct a pilot study to assess their strategy to best promote collaborative work among their students. They designed a virtual lab activity which was implemented in all classes and in which students worked in pairs. In one class, students were free to form pairs as they like,

in another class the teacher made the pairs as learning tandems or learning pendulums. In one case, students were obliged to form pairs of same gender and in another of opposite gender. In one class, the pairs were formed at random and their learning results were considered as control set. The learning outcomes in each case, as collected and visualized by the analytics services, provided the needed guidance on which strategy is expected to have the best overall results.

3.4 Functional requirements

In this section, we present and discuss the functional requirements that the virtual lab authoring environment of ENVISAGE should accommodate. It is mainly written from an end-user perspective, i.e., a science teacher. Basic requirements were collected from teachers before, during and after the test piloting run in January 2017 in EA primary school. In the piloting, the "Wind Energy Simulation" virtual lab (**http://windenergy.ea.gr/**) was extensively implemented with students of 6th grade. In this respect, as a practical example we primarily focus on requirements that, on one hand, are related to possible enhancement of existing functionalities of this virtual lab and, on the other to the design or development of new features.

3.4.1 User interface

We distinguish between the user interface of the authoring environment and the user interface as delivered to students. The former is defined as the interface that the author, i.e., teacher, is using to design the educational activity incorporating various educational contents, such as theoretical background information, definition of tasks and instructions of usage, input requests and questionnaires, and finally the use of a virtual lab. The latter is what the student practically sees and uses to execute the educational activity. He/she interacts with it but cannot change its layout, its functionality, its content, etc. For convenience and as a general requirement a WYSIWYG design principle between authoring and delivery interfaces should be followed.

3.4.2 Authoring environment with multiple display frames

The authoring environment is composed of multiple main display frames. The frames can be arranged as vertical or horizontal tabs, as seen in Fig 3.2. This arrangement allows the teacher to structure the educational activity in separate steps or, e.g., inquiry phases. The teacher can Create, Copy, Move, Rename, Delete and Hide a display frame. All frames that are not in Hide mode will be displayed in delivery and can be seen by students. For example, a teacher creates a frame with title "Analytics" that contains the visualization of the collected analytics. It sets it in Hide mode so that students cannot see its content during the learning activity.

Figure 3.2: The starting display frame of the existing "Wind Energy Simulation" virtual lab. Additional frames of content with instructions, configuration, etc., are arranged as vertical tabs.

3.4.3   Display frame

Each display frame is composed of textual content, multimedia content and embedded online resources. A display frame may be divided in sub-frames, as seen in Fig 3.3, where they are arranged horizontally in subtabs. In such arrangement, for example, the teacher writes the instructions (textual content), adds a schematic or animation or video (multimedia content) or even embeds the content from an external website with the inclusion of a URL address (online resource). In a separate frame, the virtual 3D lab application is embedded along with its configuration interface as discussed below. Visualization content with respect to lab simulation results may be displayed in a different frame for better clarity and for the facilitation of further analysis.

A frame or sequence of frames may be lockable. This means that students can view the content shown therein only if they have completed correctly a given set of tasks or followed the whole path of inquiry phases in previous frames.

The teacher may have the possibility to set accordingly the basic aesthetics of the content of a frame. We refer here to general change of display settings such as font size, font style, font colour, background colour, dimensions/position of multimedia or embedded content.
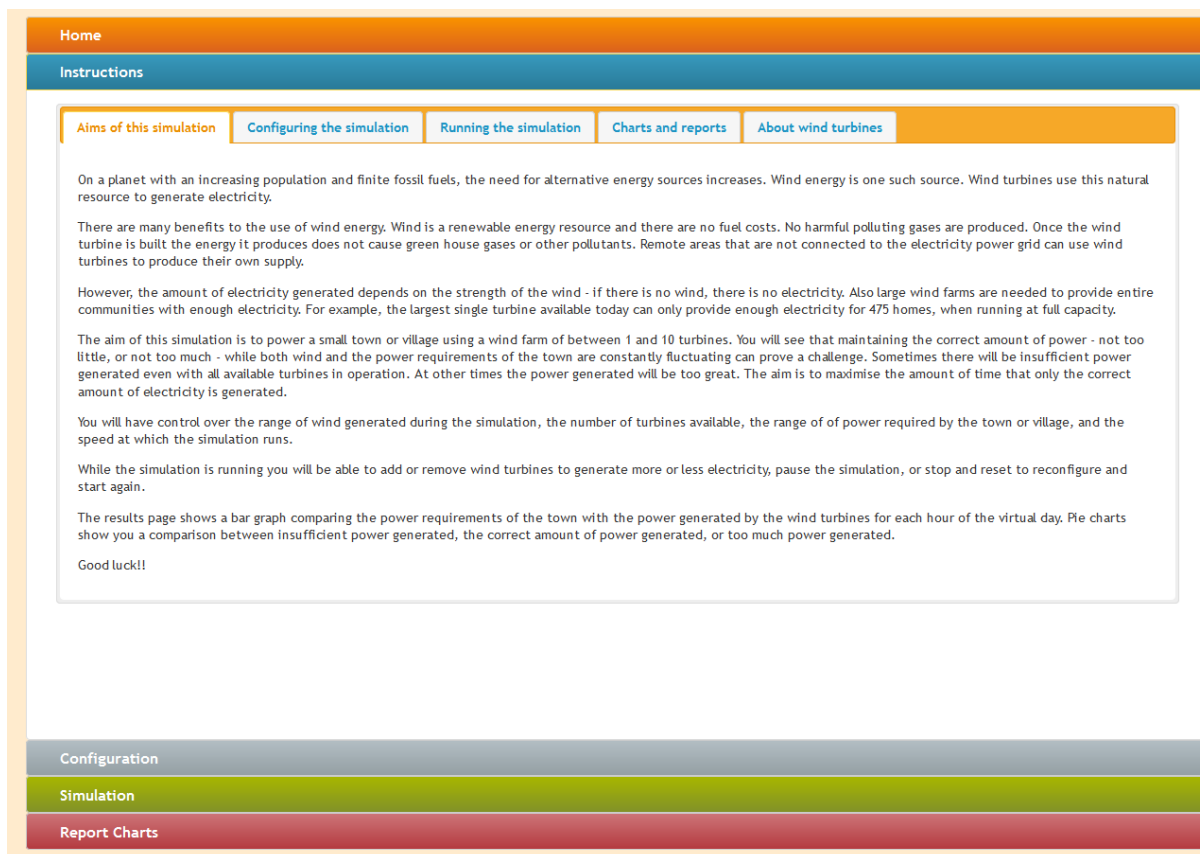
Figure 3.2: The Instructions display frame of the existing "Wind Energy Simulation" virtual lab. Additional sub-frames of content within the same frame are arranged as horizontal sub-tabs.

3.4.4   Virtual 3D lab application

We propose the virtual 3D lab application or scene to be contained in a frame with default and fixed display parameters for best visualization depended on screen resolution. The configuration parameters and main settings of the lab and its components may be also included in the same frame, e.g., as a menu tab or embedded in the scene, for better and easier interactivity. Usual functions to change the 3D scene are expected such as Zoom in/out, Translation, Rotation, Standard projections. When a lab is composed of separate distinct components, the author/teacher should be able to change their position in the scene. There should be an option that the components' positions are pre-set by the teacher and either are fixed so that students cannot change them, or can be changed by students during the learning activity. As an example, and in particular in the case of the "Wind Energy" lab, which was actually piloted and implemented in real classroom environments, these options turned-out to be of significant importance for the design of learning activities of increased complexity. In this context, also, the general scene layout is of importance since the more realistic a 3D scene is the more appealing is for students. In this respect, for example, the overlay of a realistic 3D map of a seaside or mountainside or lowlands is more engaging in the case where students are assigned to study and investigate where is best to locate a wind energy plant given certain constraints.

3.4.5 Analytics and visualization services

We propose the learning analytics and visualization services to be altogether contained and displayed in a distinct frame which by default is hidden from students. The teacher can choose which parts may be shown to students so that they can monitor or self-assess their progress during or after a learning activity. In this particular frame, that may contain a series of subtabs if appropriate, the teacher will access a basic interface to make further analysis of the collected data, to visualize historical data, to change aggregation level, etc. Fig 3.3 depicts an example dashboard of analytics the content of which is visualized in various ways and is accompanied by short descriptions to help its interpretation by the user.
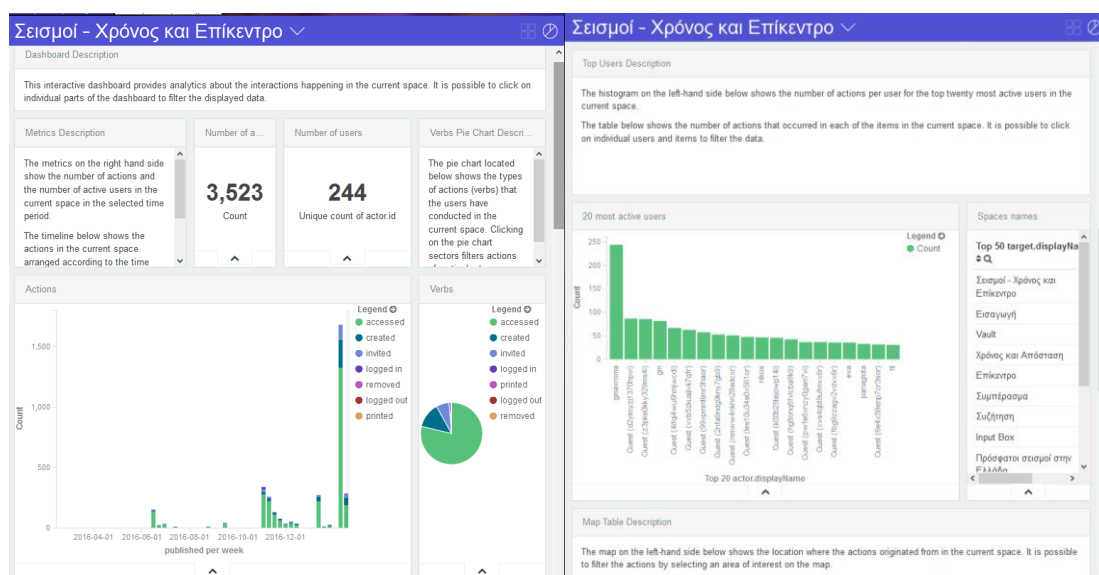

Figure 3.3: An example dashboard of analytics the content of which can be visualized in various ways. Short descriptions to help its interpretation by the user are also included.

3.4.6 An educational activity as a top level container object

An educational activity or lesson plan is the composition of several inquiry learning phases or/and problem-solving steps or tasks that are designed and arranged accordingly by the teacher in separate frames using the authoring environment. As already discussed above it contains all instructions, background information, questions, tasks, input requests, lab simulation applications, visualization of results that will be delivered to students. In a nutshell, it is a comprehensive online and interactive worksheet or, in other words, a metaphor of the conventional paper worksheets in school. As such, it basically is considered as a top-level container object which can be edited, copied, renamed, and deleted by the owner author/teacher.

4 Telemetry dataset

In the framework of the Go-Lab project, we obtained the system raw log data of user actions in the authoring environment. The dataset corresponds to the 18-month period of usage from March 2015 until July 2016. In the following, we first give a short overview to describe some basic functionalities and use cases and then the description of the content is given. The purpose of this description is to help the application of machine learning algorithms and practices in order to extract deeper information on how the environment was utilized, to identify patterns of usage, to categorize or cluster users or use cases etc.

4.1 General overview

The Go-Lab project developed a portal (**http://golabz.eu**) of online educational resources that includes a collection of online labs for science teaching, a set of supporting and scaffolding applications and a repository of online lesson plans/educational activities that were developed by users and teachers. The online lesson plans, called Inquiry Learning Spaces (ILS) in the project terminology, followed a templated structure of certain inquiry phases according to a standard inquiry teaching and learning model that was developed and documented by the project. The proposed inquiry model is composed of five phases, namely 1. Orientation, 2. Conceptualization, 3. Investigation, 4. Conclusion and 5. Discussion. In each phase of an ILS, the user or teacher can add and edit textual content, multimedia content and online labs, applications and resources using the authoring environment. A teacher may add additional inquiry phases, change their standard order or choose to hide or show some of them depending on circumstances, e.g., to shorten an educational activity due to time constraints. When finalized, an ILS can be viewed by students through a common web-link. Fig 4.1 shows a screenshot of an example ILS which contains several subspaces of content that correspond to different inquiry phases. The user can add content in each subspace creating a structured lesson plan – educational activity. Fig 4.2 depicts the final delivered ILS for in-classroom implementation and as viewed by students. The ILS's subspaces are arranged and shown in separate tabs and correspond to the different inquiry phases of the educational activity.
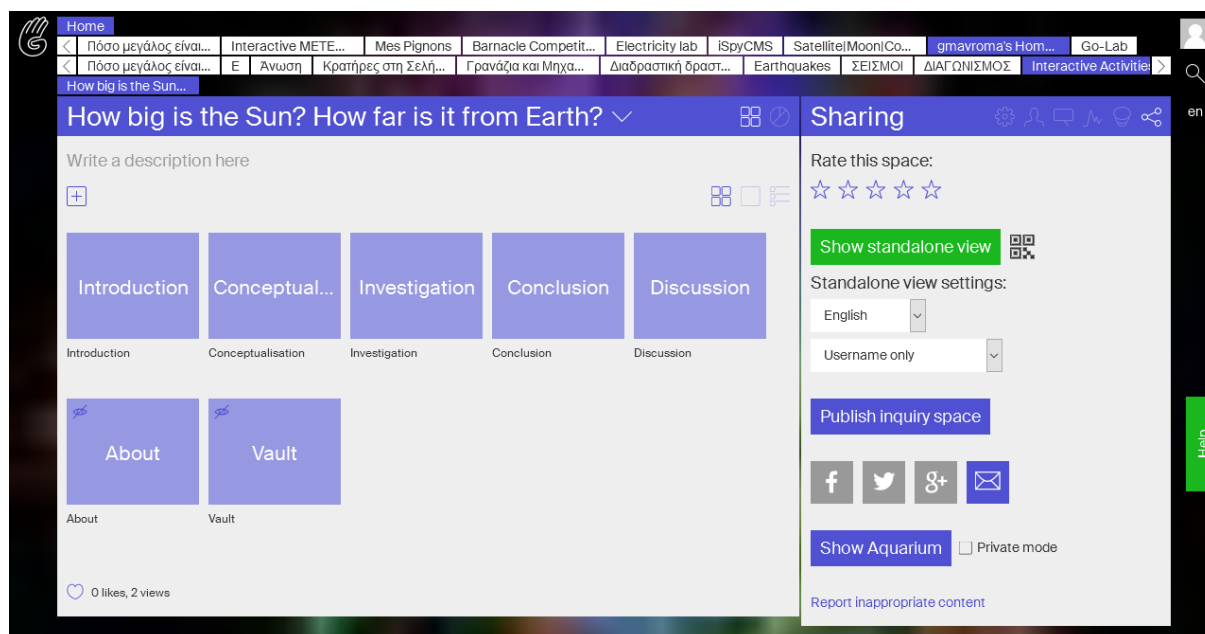
Figure 4.1: An example of an Inquiry Learning Space which contains several subspaces of content that correspond to different inquiry phases.
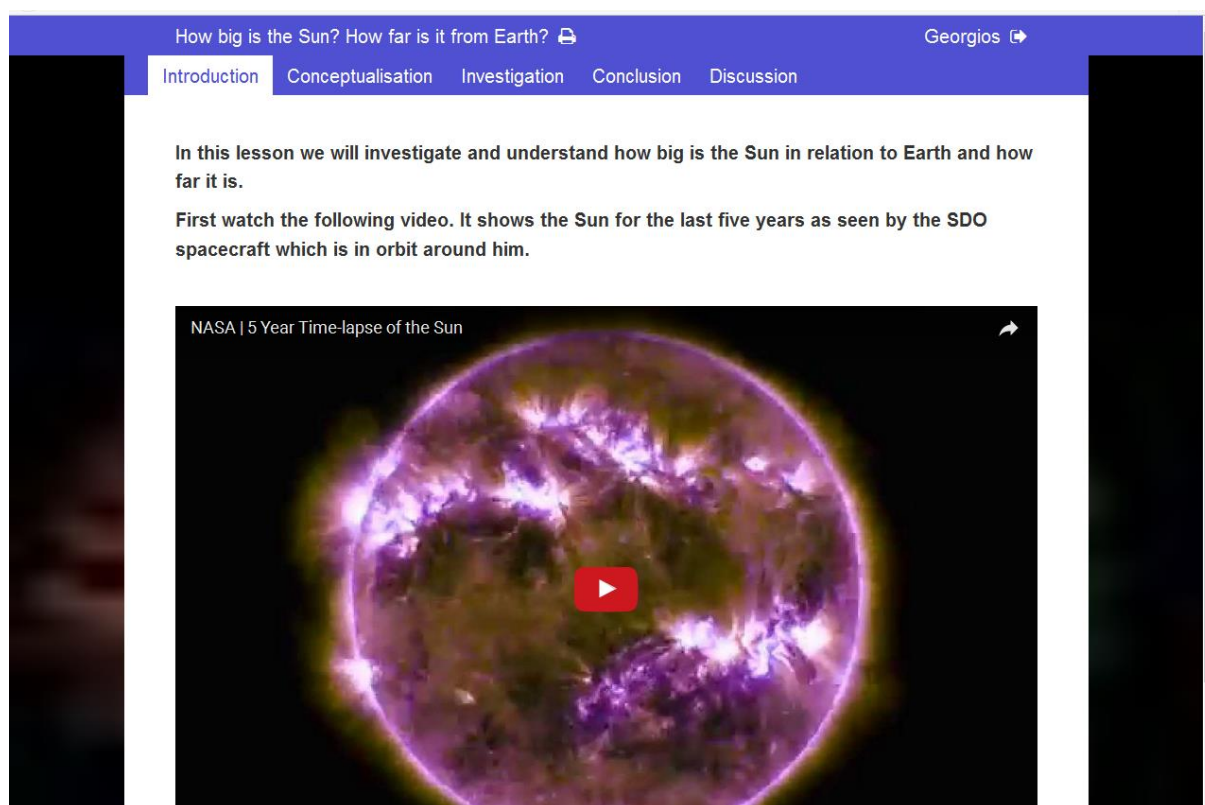

Figure 4.2: An example of an Inquiry Learning Space as delivered to students for in-classroom implementation. The ILS's subspaces are arranged in tabs and correspond to the different inquiry phases of the educational activity.

An ILS can be accessed in student-view mode by a nickname or a password set by the teacher. Each student is going through each phase and completes the corresponding tasks.

The system timestamps and logs each action. A basic analytics engine may retrieve the collected data and display in real-time or offline general overview information like number of logged-in students/viewers, time spent in each phase etc. In general, this functionality was not utilized by teachers as it was partially integrated and underdeveloped during the large-scale pilot in-school implementation periods of the project.

An ILS in technical terms is a container. It can be published to the public repository and from there other users can copy it and make their own clones, or, it can be shared between users in private and then be co-authored as a common lesson plan. A user of an ILS can be a viewer (can only view an ILS but he/she cannot edit, copy it or alter its content), or an editor (can view and edit an ILS but cannot delete it), or owner (can do all previous actions and also has permission to delete the ILS).

4.2   Description of content

The dataset of logged actions is available in .csv format (the corresponding filesize is 190 MB when zipped) and is stored in an online storage site. It can be downloaded by partners for study and analysis in the framework of ENVISAGE. The datafile contains 8 variables arranged in columns, as shown in the excerpt in Fig 4.3, these are as follows:

Id   : is the unique identifier of action

verb   : is the type of action carried out by the user

published   : is the timestamp of the action

actorId: is the unique identifier of the user who carried out the action

actorType   : refers to owners (0), editors (1) and viewers (2)

targetId   : is the unique identifier of the container of the action object

objectId   : is the unique identifier of the action object

ilsRef   : is the unique identifier of the ILS

id	verb	published	actorId	actorTyp	targetId	objectId	ilsRef

Figure 4.3: An excerpt of the content in the datafile.

5 Summary

We presented a general compilation of behavioural data collected from virtual learning labs in the framework of the Go-Lab project and their analysis. The comprehensive analysis of the available data provided several deeper qualitative and quantitative understandings of the user behaviour, such as its development and evolution through time and across countries, on how and to what extent users utilized the offered services, whether they followed the proposed educational framework, etc. The experience gathered from the analyses of the available data is directly transferred to the ENVISAGE project in order to guarantee that more effective, thorough and comprehensive metrics will be implemented to collect the behaviour of each user, teacher or student, during the usage of a virtual lab in science teaching and learning.

In this context, we discussed and proposed a list of main metrics that can be collected by the analytics service, their definition and rationale of use. We also propose that the structure of the analytics data and its aggregation level to permit analysis and interpretation similar to the one that is conventionally done in the actual school environment. By following similar structure and interrelations and by providing visualization at similar aggregation, we believe that the task of its interpretation by the teachers will be greatly facilitated. We also discussed the functional requirements that the virtual lab authoring environment of ENVISAGE should accommodate. These are presented mainly from an end-user perspective, he/she being a science teacher. Finally, we gave a short overview to describe some basic functionalities and use cases of the Go-Lab system in the framework of which we obtained the raw log data of user actions in its authoring environment. This dataset is now available to partners of ENVISAGE for study and analysis. The description of its content is given to help the application of machine learning algorithms and practices for extracting baseline and deeper information on how the environment was utilized.

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