ENVISAGE

ENhance **VI**rtual learning **S**paces using **A**pplied **G**aming in **E**ducation

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D1.1 -Educational scenarios and stakeholder analysis

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Abstract

The aim of this document is to present the initial requirements from a group of stakeholders (teachers, teacher trainers and school advisors) and to provide a definition of the types of educational scenarios that the authoring tool should support. Analysis of the stakeholders involved in virtual labs. An updated version of the educational scenarios will be delivered on M14. More specifically we have defined the stakeholders involved in a learning situation involving virtual, online learning environments such as virtual labs, focusing on the teachers and learners but also considering other relevant groups in the design/development and learning process (teacher trainers and school advisors). We are analysing the requirements of the different groups of stakeholders in terms of a) behavioural analytics and b) online authoring environments. The stakeholder analysis was based on a workshop with 20 participants, followed by interviews and reviews of best practices with a series of online labs (presented in this document) that EA is already employing in the framework of the offered services (lessons, labs or PD activities). Based on the stakeholder we are presenting a series of educational scenarios that will serve as a pool for the prototype demonstrators. These scenarios are organised at three levels, referring to the complexity level of the tasks that are assigned to the students while using the online labs. These scenarios will feed into WP5 for specifying the virtual labs to be designed and developed using the authoring environment (WP4) and will provide the test bed for evaluating the effectiveness of the developed technologies in WP2-4 to address the stakeholder requirements.

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Executive Summary

The current document aims to present the requirements of the different target groups. The requirements elicitation process is mainly based on an extended literature review on the use of the virtual labs, their potential to support students learning, a series of innovative assessment methods to identify students' competence proficiency, the current barriers that prevent the up-take of such tools in the current school settings. The document also presents a series of shallow and deep analytics and their potential value in the ENVISAGE service. The ENVISAGE virtual labs, integrated to full educational activities and lessons could provide useful data (through the combination of shallow and deep analytics) for the assessment of the problem solving competence of the students involved in the task. We are discussing how parameters like the time on task (shallow analytics) could be combined with deeper analytics (students' proficiency level based on the complexity of the task) to provide insights to students learning process and on how it can be supported by the ENVISAGE system. The extended literature review findings were discussed also with a group of 20 stakeholders in the framework of a workshop that was organised for this purpose, followed by interviews and reviews of best practices with a series of online labs (presented in this document) that EA is already employing in the framework of the offered services (lessons, labs or PD activities). The outcomes were potential scenarios of use of the ENVISAGE service. We are proposing a characterization scheme for the virtual labs according to their complexity and the opportunities they are offering for supporting low, medium or higher level tasks. Based on the stakeholder analysis we are presenting a series of virtual labs that will be implemented as the prototype demonstrators in the initial phase of the project. It has to be noted that this document is the first version of the requirements and scenarios document and it will be enriched and revised in the framework of the project through the effective interaction between the project team as well as through a more extended interaction with the target groups.

Abbreviations and Acronyms

PD	Professional Development

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1 Introduction

1.1 ENVISAGE Concept

The overall concept of ENVISAGE is based on iterating the process of improving virtual labs through a pipeline that i) starts from the current version of a lab, ii) collects shallow analytics extracted from user behavioural data, iii) digs deeper into the obtained analytics using machine learning methods, iv) integrates the obtained information under the authoring tool, v) employs the authoring tool to build an improved version of the virtual lab and finally vi) iterates the above process. The approach of ENVISAGE is illustrated in Figure 1.1. First by monitoring the activity of the users and modeling their current behaviour through the use of shallow analytics (simple statistics on tracked data). Second by predicting in a reliable manner the future behaviour of the users through the use of deep analytics (outcome of the application of machine learning algorithms). Both of these approaches combined with state-of-the-art visualization methodologies will offer insights on what features are important and what functionalities users expect to find in a virtual lab. These insights will allow for a) optimizing the design and implementation of a virtual lab and b) enhancing the learning process in a virtual lab by offering personalized learning content.

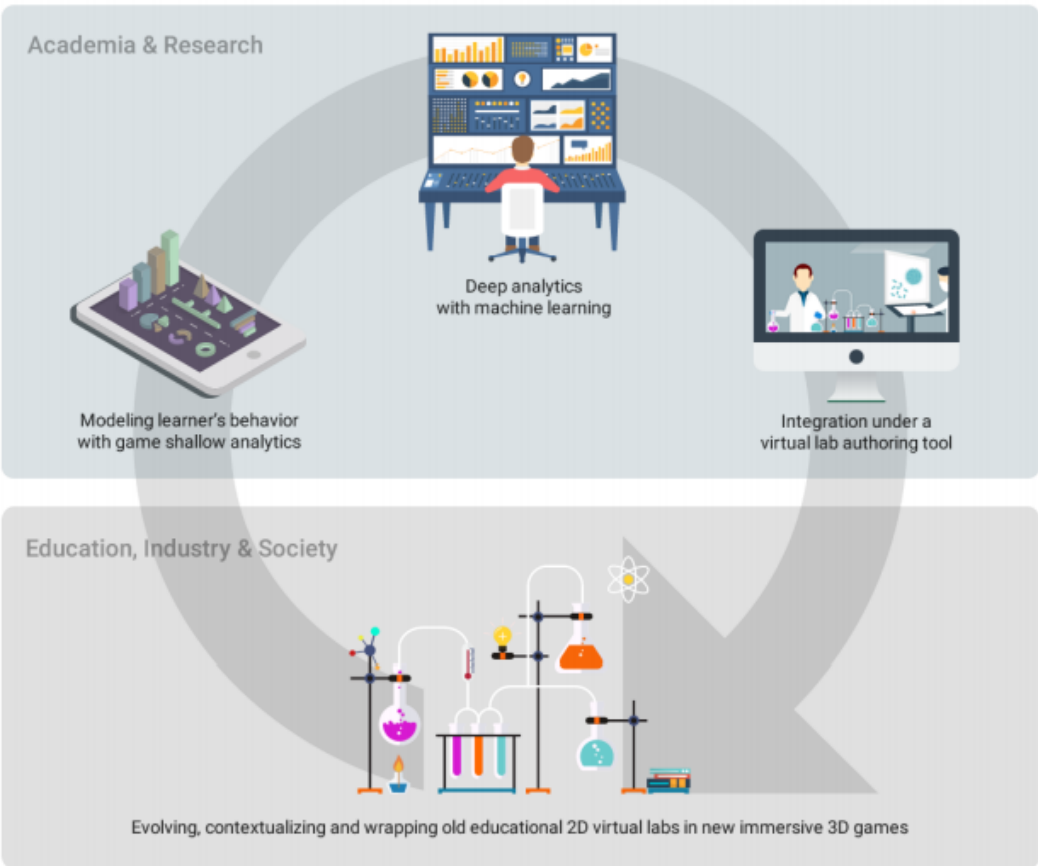

Figure 1.1: *The ENVISAGE virtual lab enrichment strategy through a four step approach.*

1.2 More efficient and effective learning, through mainstreaming new ways of learning with virtual labs and more efficient ways of assessing learning outcomes

The ENVISAGE service will facilitate the use of virtual labs in schools by promoting and applying the following methods:

● **Inquiry-based learning with virtual labs, which has already proven its effectiveness in school education.** Studies show that students learning with virtual labs gain more knowledge than students following expository instruction and more advanced knowledge than students who learn in a real lab. Provided within a structured learning environment (or even embedded in the experimentation process) and accompanied by inquiry learning apps, virtual labs give students the possibility to go through the whole inquiry process, starting with the formulation of research questions and hypotheses, via investigation and experimentation, ending with analysis of the experiment data, drawing conclusions, and discussing the results,

● **Learning by modelling, which supports students' understanding and reasoning about structures.** Using such applications students will be able to create and investigate models of scientific phenomena, uncovering interrelationships between and within those phenomena. This will contextualize students' learning activities and knowledge and help them draw parallels with and better understand the world.

Furthermore, ENVISAGE will develop a set of analytic modules assessing students' skills development, allowing to combine technical solutions with learning challenges (e.g. identification of misconceptions at an early stage of the experimentation process). These skills include, for example, thinking skills (e.g., problem solving, critical thinking and reflection) and social competencies (e.g., collaboration and communication). These skills will be acquired and applied by the students in the inquiry learning context. Moreover, innovative facilities for monitoring and assessment of the students' progress (using both shallow and deep analytics), will be available: 1) The teacher will be able to monitor students' work, having direct access to the experimentation space and, thus, the possibility to view student's progress and provide assistance, if needed. 2) Summaries of the students' activities and progress in the personalized experimentation spaces will be provided to the teacher at the end of the teaching session allowing monitoring of the work in the classroom and timely reaction in case of any questions or problems. 3) Advanced learning analytics functionalities will be available, allowing monitoring of the learning process and assessment of the learning outcomes. A feedback mechanism will allow to provide feedback on students' performance, related to specific learning activities. 4) Students will be able to view analytics of their own learning process and results and reflect on them and document conclusions using a self-reflection app.

The ENVISAGE innovation building methodology will include evaluation metrics and benchmarking activities, on the design and deployment of innovative Science learning practice and school organization change, by using the proposed virtual labs and resources, while it will be coupled with an evaluation framework, evaluating progress on learning achievements, based on the **PISA 2012 Framework for the assessment of the problem solving competence** of the students and teacher professional development and school organization change, which will accompany and support the running of the pilots. This approach will offer the basis for the validation of the introduction of ENVISAGE tools in European schools, so that piloting and field testing results can be collated and analyzed systematically and then disseminated widely, thus ensuring real impact and widespread uptake.

1.3 User groups and their perspectives

Virtual Labs Developers, Teachers Trainers, School Advisors: The design of a virtual lab is very important both for aesthetic, functional and educational reasons, while a "well-designed" lab can enhance the user experience. Clearly though, a good design is an absolutely subjective issue and different types of users might have different expectations from the same environment. The knowledge of the different expectations of each individual user or each segment of the users' community is very crucial for the decision making process regarding the design of several aspects of a lab. Importantly, ENVISAGE will provide designers with a means to break the "design-fail-guess-redesign" cycle and obtain a "design-test-redesign" cycle, which is more cost-effective, less risky and more mature strategy. This community includes mainly teacher trainers (heads of Science Teachers Professional Development Centres) and school advisors (Educators with very high qualifications and many years of experience who are coordinating networks of schools and supporting them through pedagogical guidance)

Teachers: Although teachers are often also the designers or even the developers of a virtual lab, we distinguish them because this is not always the case. From the perspective of a teacher, student behaviour metrics monitored in a constant basis provide insights directly into their knowledge cycle. Offering a semi-automatic way for compiling and understanding student behavioural data will reinforce attitude sensing and provide learning strategies with flexibility to adapt to the changing demands of students.

Learners Community: Students metrics allow for monitoring the student needs and address their concerns, locate trouble elements, and generally take better care of the learning process. The most commonly used ways to acquire community metrics are via online surveys, questionnaires, through mail, etc. Instead, ENVISAGE will enable continuous monitoring and high-level understanding of learner metrics providing schools with a means to reflect to the implemented approaches. This will ensure the provision of useful and interesting feedback to the students and determine the appropriate retention plans accordingly.

Teacher perspective: Certain types of user data have the potential to provide crucial information about the strong and weak points of learning environments or what causes a student to visit or revisit a virtual lab and inversely what causes students to churn out, and therefore can facilitate the improvement of several aspects of the lab, e.g., interface, through for instance an iterative testing approach, which compares different versions of a virtual lab. This can be further reinforced through the visualization of analytics results so that data are better comprehended. For instance, they could be taken into consideration in order to avoid certain design features that lead to undesirable situations, e.g., buttons that cause frustration to students. Examples of such types of data comprise for instance data conveying information about which parts of the lab are the most active and which are systematically ignored by the students. User data could also be used to help teacher recognize similar patterns in students' behaviour, categorize or segment students and treat them accordingly.

Student perspective: The main problem that arises in the context of optimizing virtual labs from a student perspective is to provide personalized goals to each individual student in a dynamic difficulty adjustment manner. These goals could be either short-term or long-term and must take into account measures like the previous level of difficulty, the required time to accomplish a task and the different attributes regarding the task. In this context, it is important to offer for instance goals that students should be able to reach without difficulty, but at the same moment, they should be on the edge of their possibilities so as to gradually improve their performance. In the same vein, it would be also useful to find students with similar characteristics and almost equal performance, and suggest optimal goals to the targeted student based on the early progress and results from the other similar users.

1.4 The scope of the current document

The current document aims to present the requirements of the different target groups, a series of proposals on the shallow and deep analytics and their added value in the learning process, a way to characterise virtual labs in order to be more easily accessible in the authoring environment and finally a series of virtual las that could be used as a pool for the first phase of the project. In Chapter 2 we are presenting an extended literature review on the use of the virtual labs, their potential to support students learning, a series of innovative assessment methods to identify students' competence proficiency, the current barriers that prevent the up-take of such tools in the current school settings. Chapter 3 is presenting the ENVISAGE proposed service (based on the literature review and the current state of the art in the field) focusing on the assessment of the problem solving skills of the students. The ENVISAGE virtual labs, integrated to full educational activities and lessons could provide useful data (through the combination of shallow and deep analytics) for the assessment of the problem solving competence of the students involved in the task. We are analysing the requirements of the different groups of stakeholders in terms of a) behavioural analytics and b) online authoring environments. We are discussing how parameters like the time on task (shallow analytics) could be combined with deeper analytics (students' proficiency level based on the complexity of the task) to provide insights to students learning process and on how it can be supported by the ENVISAGE system. The extended literature review findings were discussed with a group of 20 stakeholders in the framework of a workshop that was organised for this purpose (presented in Chapter 4), followed by interviews and reviews of best practices with a series of online labs (presented in this document) that EA is already employing in the framework of the offered services (lessons, labs or PD activities). The outcomes were potential scenarios of use of the ENVISAGE service. In Chapter 5 we are proposing a characterization scheme for the virtual labs according to their complexity and the opportunities they are offering for supporting low, medium or higher level tasks. Based on the stakeholder analysis we are presenting a series of virtual labs that will serve as a poll for the prototype demonstrators in the initial phase of the project. This is presented in Chapter 6. It has to be noted that this document is the first version of the requirements and scenarios document and it will be enriched and revised in the framework of the project through the effective interaction between the project team as well as through a more extended interaction with the target groups.

2 Current state of the art, contemporary approaches to science learning and innovative assessments

ENVISAGE focuses on engaging students in inquiry learning based on virtual labs in order to let them learn about science topics and to have them acquire scientific skills. In the current section we first describe what is currently known about inquiry learning with simulations and virtual labs, as well as their current implementation paradigms, and then we discuss how the ENVISAGE project will bring the current state of knowledge a step further.

2.1 Inquiry learning and TEL environments

Nowadays there is at large consensus that inquiry based approaches to learning science incorporating students' active investigation and experimentation are necessary to motivate students for science (e.g., Osborne & Dilon, 2008; Rocard, et al., 2007) and that, therefore, inquiry should be part of the curriculum also because inquiry skills have a value on their own (e.g., National Research Council, 2000; National Science Foundation, 2000; The National Academies, 2011). Inquiry is the process in which students are engaged in scientifically oriented questions, perform active experimentation, formulate explanations from evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations (National Research Council, 2000). There is also overwhelming scientific evidence that inquiry leads to better acquisition of domain (conceptual) knowledge (de Jong, 2006a). A metaanalysis reviewing 138 studies indicated a clear advantage for inquiry-based instructional practices over other forms of instruction in conceptual understanding that students gain from their learning experience (Minner, Levy, & Century, 2010). Contemporary, Technology Enhanced Learning (TEL), approaches to science learning provide students with ample opportunities for inquiry. TEL environments that offer simulations, games, data sets, and/or remote and virtual laboratories are significant in this respect. In these environments technological affordances are directly used for pedagogical purposes in that inquiry calls for non-linear, manipulable, and runnable content which technology is able to offer. Evidence is accumulating that TEL inquiry environments provide students with genuinely effective learning opportunities and large scale studies show that, on different outcome measures, TEL-based inquiry outperforms more direct approaches to instruction (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Deslauriers & Wieman, 2011; Eysink et al., 2009). These promising results, however, only hold when the inquiry process is structured and scaffolded. Scaffolds thus play a pivotal role in inquiry learning. Scaffolds come in many kinds. Examples are tools to create hypothesis, data analysis tools, and tools to save and monitor experiments. Currently a growing number of TEL inquiry environments have emerged that provide students with inquiry facilities together with integrated supportive structure and scaffolds. Examples of such learning environments are: Smithtown (Shute & Glaser, 1990); Belvedere (Suthers, Weiner, Connelly, & Paolucci, 1995); BGuILE (Reiser et al., 2001); BioWorld (Lajoie, Lavigne, Guerrera, & Munsie, 2001); Inquiry Island (White et al., 2002); GenScope (Hickey, Kindfield, Horwitz, & Christie, 2003; Hickey & Zuiker, 2003); SimQuest-based environments (de Jong et al., 1998); Co-Lab (van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005); WISE (Linn, Davis, & Bell, 2004); STOCHASMOS (Kyza, Constantinou, & Spanoudis, 2011); SCY (de Jong et al., 2010) and Go-Lab (de Jong et al., 2015). All these environments are based on simulations and/or virtual labs. For example, Go-Lab inquiry spaces follow the approach of inquiry learning as exemplified in the projects mentioned above and in doing this we focus on (combining) remote and virtual labs and integrate them with supportive structure and scaffolds.

In the next sections we zoom in on the virtues of virtual labs and its combination and will then discuss the role of scaffolds.

2.2 Virtual laboratories for inquiry learning

Do we need real, physical, laboratories for learning? The first question we should state is if online labs can replace real, physical, laboratories. Real laboratories are used in education for a multitude of reasons. Hofstein and Lunetta (2004), for example, described the values of real laboratory experiments for science education and mention understanding of scientific concepts and interest and motivation as main reasons for using laboratories. Balamuralithara and Woods (2009) list thirteen objectives for the use of physical laboratories which include awareness of safety procedures, and learning how to use humans' senses for observations. Also Feisel and Rosa (2005) present a list of objectives in real laboratories that include learning from failures and learning to work in teams. As an advantage for physical laboratories, some authors (e.g., Flick, 1993) emphasize a role for "physicality" acquiring conceptual knowledge since it would trigger additional brain activities and also would enhance student motivation. However, studies that explicitly focused on the use of physical manipulatives (e.g., Chambers, Carbonaro, & Murray, 2008) do not find these advantages and also in comparison with virtual manipulatives the assumed advantages of physicality could not be found (e.g., Corter, Esche, Chassapis, Ma, & Nickerson, 2011; Yuan, Lee, & Wang, 2010; Zacharia & Olympiou, 2011). Direct comparisons of the effects of physical and virtual laboratories on the acquisition of conceptual knowledge of the domain show that both approaches can be equally effective for learning but that in a number of cases virtual environments led to better results. Studies that found real and virtual laboratory experiments of equal effectiveness for acquiring conceptual knowledge are Wiesner and Lan (2004, chemical engineering), Klahr, Triona, and Williams (2007, physics (designing a car)), Winn, et al. (2006, oceanography), Zacharia and Constantinou (2008, phyiscs (heat and temperature)), Zacharia and Olympiou (2011, physic (heat and temperature)), and Corter, et al. (2011, mechanical engineering). Triona and Klahr (2003, phyiscs (springs)), who focused on the acquisition of inquiry skills, also found that simulated and real experiments were equally effective. Other work shows an advantage of virtual labs over real laboratories: Chang, Chen, Lin, and Sung (2008, optics) compared students who worked with a physical optics laboratory with students learning with simulations, Huppert, Lomask, and Lazarowitz Huppert (2002, microbiology), Finkelstein, et al. (2005, electrical circuits), and Bell and Trundle (2008, moon phases). Overall, we can conclude that the literature supports the idea that remote and virtual (online) labs can replace direct (or faceto-face) access to real physical laboratories.

2.3 The distinctive virtues of remote and virtual labs

The fact that physicality is not relevant for learning makes that remote laboratories can be used instead of real physical labs. Remotely-operated educational labs ("remote labs") provide students with the opportunity to collect data from a real physical laboratory setup, including real equipment, from remote locations. As an alternative there are virtual labs that simulate the real equipment. Remote and virtual labs both have specific advantages for learning. The first advantage of remote labs is that they do not mimic the real lab but students actually operate on real equipment. Remote labs thus give a more realistic view on scientific practice, including practical aspects such as occupied equipment etc. It, therefore, also give students a more realistic view on real lab work. Another advantage of remote labs is that measurement errors are present by nature, whereas in virtual environments measurement errors are often ignored. Competency in a domain includes knowledge that measurement errors (of different kinds) exist and how to deal with them (Toth, Morrow, & Ludvico, 2009). The reading of instruments in a virtual environment, for example, (with even a possibility to zoom in) is by nature easier than reading real instruments. Maisch, Ney, van Joolingen, and de Jong (2009) showed that knowledge about measurement errors that is acquired outside a laboratory context doesn't easily transfer to the students' actions in a physical laboratory which suggests that real laboratory experiences may be important. Learning, however, is not all about cognitive challenges and outcomes; also enthusiasm and engagement play a role. Compared to research on cognitive outcomes results on motivational aspects of online and real labs is scarce but there are indications that real and remote labs lead to higher student motivation than simulated labs. Corter and colleagues (Corter, et al., 2011; Corter et al., 2007), for example, who compared a real, remote and simulated lab on the same (mechanical engineering) topic found no differences in learning outcomes but found that student appreciated the remote and real labs more because of their realism. Kong, Yeung, and Wu (2009) also report that both teachers and students show high involvement in remote laboratories. Concerning the ease of experimentation the advantages go in the direction of virtual labs. In virtual laboratories students can experiment without any costs and can more easily and repeatedly experiment so that ideas can be quickly tested and evaluated. Another advantage for virtual laboratories is that reality can be adapted to serve the learning process. Reality can both be simplified by taking out details (and thus lowering fidelity) or be "augmented" by adding specific features to reality (such as adding vectors to moving objects). Lowering fidelity means that the requirements on students are less severe which may add learning (Alessi, 1988). Augmenting reality means that concepts that are not visible for students in the physical laboratory now become visible (such as the flow of electric current, see e.g., Jaakkola, Nurmi, & Lehtinen, 2010). In conclusion, remote and virtual labs both have their specific virtues to bring to the learning situation; each of them also focusing on partly overlapping but also different learning goals (Ma & Nickerson, 2006). Our next exploration is how to potentially combine remote and virtual labs.

2.4 The best of both worlds: Remote labs in combination with virtual experimentation facilities

Since remote labs are offered over electronically, remote labs already offer some of the advantages of virtual labs in the sense that remote labs can be extended by augmentations and cognitive scaffolds, thus gaining some of the evident advantages of virtual labs (see the next section). However, also in remote labs, experimentation is as time consuming as in real labs and, therefore, recent research started to develop and investigate combinations and sequences of the two. There are different possibilities here: blending (Olympiou & Zacharia, 2012; van Joolingen, et al., 2005) and alternating both modes for the same (Jaakkola & Nurmi, 2008) or different contents (e.g., Zacharia, Olympiou, & Papaevripidou, 2008).

Blending means that characteristics of virtual labs, such as augmentations, are added to remote labs (Yueh & Sheen, 2009). Most of the work, however has been on placing both versions in order and most of those studies showed that a virtual lab preceding a real (or in our case) remote lab is advantageous for learning. Example studies are Zacharia and Anderson (2003) mechanics, optics, and heat and temperature; Akpan and Andre (2000) on the dissection of a frog, Martínez-Jiménez, Pones-Pedrajas, Climent-Bellido, and Polo (2003), Zacharia (2007) on electrical circuits, Zacharia, et al. (2008) on heat and temperature, Jaakkola and Nurmi (2008) and Jaakkola, Nurmi, and Veermans (2011) on electrical circuits, and Dalgarno, Bishop, Adlong, and Bedgood Jr (2009) on a chemistry laboratory. From a more cognitive point of view there are indications that the combination works because students have to compare different types of representations. Jaakkola, et al. (2010) report a study in which they videotaped students who constructed electrical circuits only in simulated environments with students who first made this virtual construction and then made the same circuit in reality. These video data made clear that students in the combined condition profited from the fact that they had to compare two representations that sometimes differed and had to go into abstract reasoning to explain these differences. A similar finding was reported by Goldstone and Son (2005) who found that offering both abstract and concrete representations in a simulation helped the student understand the principle behind the simulation. In this study it appeared that students who moved from a concrete to an idealized simulation outperformed other students on immediate and transfer test. In ENVISAGE we will search for different ways to combine virtual labs and simulation facilities. In any case, both remote and virtual labs need scaffolds to function effectively.

2.5 The role of scaffolds in inquiry learning with online labs

Scaffolding refers to support (dedicated software tools) that helps students with tasks or parts of a task that they cannot complete on their own. Scaffolds aim at the different learning processes that constitute inquiry learning. For example, they can help students to create hypotheses (van Joolingen & de Jong, 1991), design experiments (Lin & Lehman, 1999), make predictions (Lewis, Stern, & Linn, 1993), formulate interpretations of the data (Edelson, Gordin, & Pea, 1999), reflect upon the learning process (Davis, 2000), plan and structure their work (van Joolingen, et al., 2005), and monitor what has been done (Hulshof, Wilhelm, Beishuizen, & van Rijn, 2005). We can also scaffold the complete process by having student work with an inquiry cycle (Manlove, Lazonder, & de Jong, 2007). Different types of structuring and scaffolds and their effects on knowledge acquisition have been overviewed in several studies (Bell, Urhahne, Schanze, & Ploetzner, 2010; Chang, et al., 2008; de Jong, 2006b, 2010a, 2010b; de Jong & van Joolingen, 1998; Fund, 2007; Linn, et al., 2004; Quintana et al., 2004; Sandoval & Bell, 2004; Zhang, Chen, Sun, & Reid, 2004). In any case meta-analyses (Alfieri, et al., 2011) show that inquiry learning is only productive when the inquiry process is structured and scaffolded.

2.6 Collaboration in lab work

In addition to being an excellent context for learning activities, lab work also forms a unique setting to develop soft skills such as autonomy and collaboration (Corter, et al., 2011; Feisel & Rosa, 2005). In modern labs work is always done in teams and the ability to work with others is a requirement for skilful lab work (Dunbar, 1999). One of the intended outcomes of learning with ENVISAGE virtual labs is that students acquire those skills. Looking at this issue from the other side, collaboration also helps to raise students' conceptual knowledge and inquiry skills in an inquiry learning situation. There is a growing awareness that knowledge construction processes are influenced by the social setting in which they take place. Collaboration is widely used and recognized as a way to enhance student learning (Lou, 2004; Lou, Abrami, & d'Apollonia, 2001). The positive effects of collaboration can be explained by the fact that engagement in a collaborative learning task provides students with the opportunity to talk about their own understandings and ideas. Inquiry learning tasks allow students to express and explore their own strategies and conceptions. During inquiry learning, students must make many decisions (e.g., which hypothesis to test, what variables to change), in a collaborative inquiry learning setting, students are invited to share these plans and ideas with their partner(s). This means that when students work collaboratively, they need to externalize their ideas; they must provide arguments and explanations so that their partner is able to understand and evaluate their ideas and plans (Teasley, 1997). Externalizing thoughts and ideas is believed to increase students' awareness of flaws and inconsistencies in their own reasoning or theories and to stimulate students to revisit their initial ideas. A study by Okada and Simon (1997) compared the inquiry learning behaviour of individual students and dyads in a molecular biology learning environment. They found that dyads considered more alternative hypotheses and carried out more useful experiments than individuals. The generation of an alternative hypothesis was often triggered by a question or a remark from the learning partner. In a recent studies Kolloffel, de Jong, and Eysink (2011) confirmed the effectiveness of collaboration in inquiry learning settings. Specific scaffolds might assist the collaboration process. For example, Gijlers and de Jong (2009) introduced a tool that visualized students' conflicting ideas and prompted students to think about conflicting ideas. In ENVISAGE, in order to minimize the change in classroom scenarios, while maximizing the advantages of lab activities, the collaborative learning part is considered as a face-to-face activity limited to classmates.

2.7 Innovative assessments

Virtual labs and the associated digital tools are rich sources of information (logfiles and student products such as concept maps, hypotheses etc.) for monitoring students' progress. Summaries of students' progress can be captured in learning analytics apps for activities and learning products. These analyses can also be the basis for online and offline assessment and for feedback. Information on the student's progress can, however, also come from direct questions to students, as can be done for example by using a quiz app. Aside from teacher assessment there are now good indications that self- and peer assessment are also effective means for (formative) feedback. In self-assessment, which has connections to reflection, students receive an overview of their own learning achievements and rubrics to assess these. Very much related to self-assessment is peer assessment which if well organised is an effective way of learning for both the commenting and for the receiving student. Peer assessment is recently also used in the context of inquiry learning. Often self- and peer assessment are used in higher educational contexts, but it also works for younger students. The idea of the portfolio originated from a professional context as a showcase of personal achievements and is now also used in educational contexts as well in which a learning portfolio is an organized compilation of selected work samples, which show the process and results of a learning path, proving the quality and level of achievement of the targeted competences. This way, the portfolio may be seen as an information sharing mechanism, making it possible to evaluate learning as a process (formative assessment) but also the final results of it (summative assessment). ePortfolios are the electronic version of traditional portfolios, meaning that the work samples inside them will be of digital nature; coming from different sources and tools. At the same time, the ways and processes a learner follows to develop and organise the work samples in an ePortfolio require and promote new skills. The main benefits of ePortfolios can be summarized as follows: ePortfolio connects learning and assessment, use of an ePortfolio supports the assessment of both the learning process and product, in using an ePortfolio the emphasis is shifted to students' progress and their point of view, the use of an ePortfolio can support the development of various skills like writing, organizing, communicating, critical thinking etc., an ePortfolio stimulates the students to value what they know rather than focus on what they don't, an ePortfolio encourages students to take responsibility for their own learning. Many of these advantages also have a connection with 21st century skills.

2.8 Learning by modelling

The work in the framework of ENVISAGE focuses on supporting the inquiry process by providing virtual labs with embedded assessment tools (through the acquisition of shallow and deep analytics). As stated above, this will specifically help the students with insufficient or developing inquiry skills or lower prior knowledge. To engage students at the other side of the spectrum of expertise we can introduce learning by modelling which requires a next level of reasoning from students. Learning by modelling, refers to learners who create an executable model of a scientific phenomenon themselves. The potential of learning by modelling is increasingly recognized by science teachers and policymakers worldwide (Common Core State Standards Initiative, 2013). Modelling is seen as a core scientific practice and advocated as a valuable pedagogical approach to science learning (e.g., Louca & Zacharia, 2012). Learning by modelling, distinguishes itself from other approaches to science learning in that it enables students to engage in a range of very deep cognitive processes such as analysing, relational reasoning, synthesizing, and testing and debugging (Jackson, Stratford, Krajcik, & Soloway, 1996), which eventually leads to a profound understanding of the topic at hand (Hashem & Mioduser, 2011). The literature reports on various benefits of learning by modelling in science education. It enables students to develop a better understanding of the behaviour of systems in general (Hogan & Thomas, 2001), promotes the development of specific (scientific) reasoning skills and leads to more profound domain specific knowledge (Milrad, Spector, & Davidsen, 2003), During learning by modelling, students can explore how changes at the level of the local interactions of components in a system lead to different behaviours and patterns at another level, namely the function of the entire system, thus implicitly learning about complex systems and emergent behaviour. Studies comparing learning by modelling with other, more expository forms of instruction indicate that learning by modelling positively fosters this more advanced reasoning about structures (Hansen, Barnett, MaKinster, & Keating, 2004). In ENVISAGE we will explore the development of a modelling tool that will be integrated to the ENVISAGE Authoring Environment and which will be used to provide different levels of complexity while students are using the virtual lab. The modelling tool will be configurable by the teacher which enables to offer students partly completed models or models to correct, both techniques are known to support learning (Mulder, Bollen, de Jong, & Lazonder, 2016). In such a way teachers will be able to create classrooms profiles by categorising their students at different levels of competence proficiency.

2.9 Conclusions from the overview of the literature

The general conclusions from this literature overview are:

1. Inquiry based approaches are more effective for acquiring conceptual domain knowledge than traditional more directive forms of instruction,

2. For learning domain knowledge, real, physical, laboratories are not necessary and can better be replaced by remote or virtual (online) laboratories,

3. Virtual laboratories to a large extend have overlapping characteristics and advantages, but also a few specific virtues, such as ease of experimentation for virtual labs and motivations in remote labs. Recent studies have shown that combining remote and virtual labs might render most effective form of inquiry learning.

4. Inquiry learning in remote labs will only be effective is the inquiry process is structured and/or scaffolded.

5. Collaboration between peer students is an important learning asset that can be realized in working with online labs, but this collaboration is not necessarily carried out online as well.

In ENVISAGE we focus on providing students with experimentation facilities through (combinations of) virtual labs with embedded assessment tool. We also believe that next to being advantageous for acquiring cognitive knowledge and competences, these types of environments are also very suited to raise students' interest in science.

2.10 Existing online labs and the barriers that prevent their uptake

Nowadays, access to virtual laboratory facilities is provided in blended learning or distance learning frameworks for schools, universities of science and technology, as well as universities of applied sciences (Auer & Gravier, 2009; Gustavsson et al., 2009; Kong, et al., 2009; Tan & Gillet, 2005). The labs offered differ widely in domain, intention, interface, and learner support. The diversity of the accessible virtual labs is, of course, a great advantage, as teachers may exploit them in their lessons to cover many topics. This diversity, however, also partly form the foundation for a number of barriers that prevent teachers from adopting remote labs as learning resources.

These barriers are:

- Existing online labs usually have no structuring and scaffolding for the inquiry process (Cooper & Ferreira, 2009),

- Existing virtual labs differ in interface and usage possibilities which makes them less usable in the classroom,

- Another potential barrier to use online labs is that they are not geared towards a specific age group and therefore often do not fit.

- Existing online labs are not organized along domains (rather on topics) which makes that teachers cannot integrate more online labs over a longer period,

• For existing online labs it is often unclear where they fit into STEM curricula,

• Most STEM teachers are not aware of virtual lab technologies and hence do not grasp their benefits,

• Teachers are not sufficiently trained in using virtual labs: they rarely implement activities in class unless they feel confident with the process and can troubleshoot problems,

• There is no support for teachers from the virtual lab owners,

• There is no community of teachers who use online labs,

• There are no tools or support to easily customise, localized or repurpose online labs for alternative scenarios or different contexts

• ICT infrastructure in schools may not be sufficient for use of online labs, e.g., difficulty to book computer laboratory time, low bandwidth Internet access

• Existing virtual labs often require browser plug-ins that may not be up to date and can only be updated by system administrators in schools.

These barriers force teachers, if they use virtual labs, to only exploit them on an incidental base. In ENVISAGE we will focus on removing those barriers (in sequence of the bullets above):

by offering structure and analytics for experimentation with virtual labs,

by providing students with a standardized interface,

by making online labs adaptable to context (age, discipline, language),

by indicating where online labs (and the associated activities) fit into a curriculum,

by providing teachers with dedicated support facilities (e.g. dashboard for analytics),

by connecting teachers and lab-designers, and

by creating and strengthening online teacher communities

In the following section we will first sketch the technological state of the art concerning online labs and then we move to describing scenarios of how we expect ENVISAGE to function for students, teachers, and lab-designers. After that we will discuss the challenges we will meet and the steps we need to take beyond the current state-of-the-art to achieve our ENVISAGE objectives.

3 Demonstration of impact on the achievement levels in science

3.1 Problem Solving Competence Assessment Framework for ENVISAGE

ENVISAGE aims to support teachers to organize and sequence inquiry-oriented and technology-enhanced learning experiences for their students through an advanced authoring environment. One of the ways ENVISAGE attempted to approach this, is by giving an Instructional Design process for educators to assist them in planning their experimentation activities.

In this section we will set the context of the use of ENVISAGE service. First we define the five phases of the inquiry process. ENVISAGE is mainly intended to be used during experimentation. However, ENVISAGE does not perceive learning by an inquiry as following specific step-by-step experimentation instructions in a linear sequence of activities, but rather as experiencing events that blend and merge. It furthermore encourages the widespread view that inquiry is a flexible pedagogy that allows teachers to tailor their experiments to the aspired learning outcomes and appropriate conditions of various classroom contexts. These experimentations could vary according to the age of the students, profoundly structured, and more open-ended inquiries both have their place in science classes. Then we will explain how existing analytics from the different inquiry phases could be combined with the ENVISAGE analytics to offer an integrated assessment service for different stakeholders.

3.1.1 Inquiry Instructional Model

Inquiry instructional model combines five different activities:

- "**Orienting & Asking question**", in this inquiry, the student focuses on answering a question, on investigating a controversial dilemma, and solving problems. Teachers may introduce this interrogation to the classroom and support it with narratives, videos, or animations. So finally the students should ask questions, discuss the issues involved and take notes of their ideas.
- In "**Hypothesis Generation & Design**", students express hypotheses based on their prior experience, the notes they have made and the structure of the question, as assumed relations within measurable dependent and independent variables. It is difficult for students to make proper assumptions on their resources. This learning activity, therefore, necessitates appropriate support (de Jong & van Joolingen, 1998). Rules for generating hypotheses could serve this stage as resources.
- "**Planning & Investigation**", clearly formulated hypotheses facilitate planning the work process. Planning includes determining the order of activities and intermediate goals, which tools and data to use, a clear timeline, and how these activities are divided among the participants.
- "**Analysis & Interpretation**", collected data will be analyzed and interpreted. Data analysis and processing tools have to be used at this stage. Teachers should support the learners in the case of difficulties. Sometimes they do not know where to start with

searches in the data. Teachers may help students to process the data by helping them organize the data collected and interpret them by identifying key issues. When solving problems, solutions found by experts can also be examined, and compared with students' solutions for the same problem. For investigation of controversial cases, different perspectives on approaching the situation should be analyzed, and the value of various information sources should be evaluated. These processes may generate new questions for further inquiry.

- "**Conclusion & Evaluation**", arriving at findings in the process of investigation can mean achieving consensus about a solution to a problem, producing a common artifact, or synthesizing views to come to a mutual decision. The evaluation process can be facilitated by presenting conclusions to a broader audience, as this allows for replication and endorsement of the presented results.

These are the steps that need to be mastered during passing from a presented situation to an actual goal to develop problem-solving competency. Problem-solving competence is defined in PISA: *"Problem solving competency is an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately apparent. It includes the willingness to engage with such solutions to achieve one's potential as a constructive and reflective citizen.*" (OECD 2013, p. 123).

Since PISA 2012 and consequently ENVISAGE deep analytics service will concentrate especially on the cognitive methods needed to solve real world problems. These levels of proficiency are divided into a high, moderate, and low level. Students proficient at high-level can develop complete, coherent mental models of different situations, and find an answer through target exploration and a methodical execution of multi-step plans. Based on PISA results, the estimated difficulty of this level is that an average of about 10% of the students should be able to answer it correctly. At the moderate level students can control moderately complex devices, but not always efficiently, handle multiple conditions or inter-related features by controlling the variables. About 45% of the students should be able to answer the questions on a moderate level. Moreover, at the low-level students can only answer if a single, particular constraint has to be taken into account, only partially describe the behavior of a simple, everyday topic, and around 45% of the students should be able to answer on this level. In the next section we are describing the PISA Problem Solving Competence Framework.

3.1.2 Problem Solving Competence Framework

In order to demonstrate the impact of the use of deeper analytics we will focus on describing the achievement levels in science based on the **PISA 2012 Framework** developed for the assessment of problem solving competence. This will offer the reference for validating the introduction of innovation in schools so that piloting and field testing results can be collated and analyzed systematically and then disseminated widely, thus ensuring rapid impact and widespread uptake. Problem solving competence is a central objective within the educational programmes of many countries (PISA, 2012).

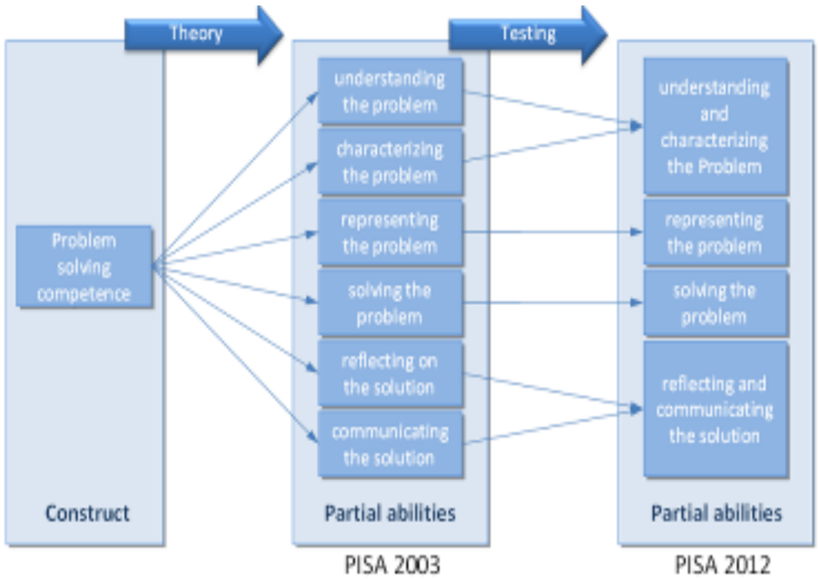

Figure 3.1: *The educational design of ENVISAGE will focus on the assessment of the problem solving competence following the PISA Framework. By developing inquiry experimentation scenarios (and the environment for their design and delivery) the consortium aims to measure the impact of the proposed intervention in comparison with the results of the PISA 2012.*

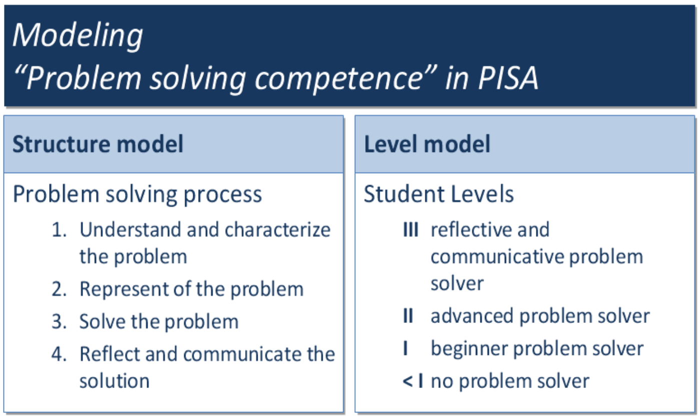

Figure 3.2: *The PISA 2012 assessment of problem solving competence is computer-based and interactivity of the student with the problem is a central component of the information gathered. The ENVISAGE consortium aims to integrate the specific approach in the ENVISAGE authoring environment to demonstrate the added value of the proposed intervention.*

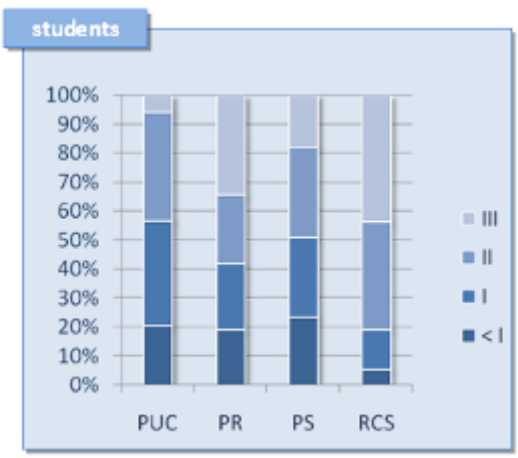

Figure 3.3: *Classroom profiles during the problem solving process: understanding and characterizing the problem (PUC), representing the problem (PR), solving the problem (PS), and reflecting and communicating the solution (RCS) (Koppelt and Tiemann, 2008). Such data from the ENVISAGE classrooms will be compared and analyzed to demonstrate the impact of the intervention, following a global and standardized approach.*

The acquisition of increased levels of problem solving competence provides a basis for future learning, for effective participation in society and for conducting personal activities. Students need to be able to apply what they have learned to new situations. The study of individual students' problem solving strengths provides a window on their capabilities to employ basic thinking and other general cognitive approaches to confronting challenges in life (Lesh & Zawojewski, 2007[i], Zawojewski et al, 2009[ii]).

The advances in software development tools and the use of networked computers have made possible greater efficiency and effectiveness of assessment, including the capability to administer dynamic and interactive problems, engage students' interest more fully and capture more information about the course of the problem-solving process. On this last point, computer delivery of assessment tasks makes it possible to record data about such things as the type, frequency, length and sequence of actions performed by students in responding to items. The organisation of the inquiry activities in the framework of the lab work (through the ENVISAGE Authoring Environment) is offering the opportunity to analyze the effects of such complex scenarios that fostering complex problem solving abilities.

The different steps that must be performed by the student (understanding and characterizing the problem, representing the problem, solving the problem, and reflecting and communicating the solution) are included in the educational design process and in this way the system will allow for the mapping of the changes in these partial abilities during the problem solving process (Tiemann et al. 2010, PISA, 2010). This innovative measurement procedure allows e.g. the analysis of solution paths or strengths and weaknesses on an individual level. This formative evaluation offers conclusions with regard to domain-specific characteristics of the curricular content. It could be answered whether a student has attained a certain competence level after a specific science activity. Additionally, students will work on tests of covariates computerized, too, so that the complete assessment will be carried out online. PISA 2012 outcomes will be used as the main reference for the evaluation approach of the ENVISAGE project.

3.2 Indicative Examples of Shallow and Deep Analytics for ENVISAGE Service

In this section we are presenting some indicative examples on shallow and deep analytics that could be provided from the ENVISAGE service to support students learning and achievement as well as the design of more effective educational experiences for the students. We will discuss the "Time on Task", the "Class Profile", and the "Competence Proficiency". The data which are used as examples are based on the work that has been done in the framework of the large scale policy support action Inspiring Science Education and involves more than 10,000 data sets from students who were assigned with specific inquiries and they had to follow the full inquiry cycle. The assessment method for the Class Profile and the Competence Proficiency are based on the PISA approach for assessing the problem solving competence as discussed above.

3.2.1 Time-on-Task

Time on task is very important parameter in educational research. It is also considered relevant variable, which is correlated to students' learning and achievement (Hattie et al., 2012). 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 (Berliner et al., 1991). In this case time on task refers to the time that is spent within the specific phase of the 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. The students show academic behaviour, they observe phenomena, draw conclusions, write reports or reflect on scientific questions. The time-on-task value indicates a change in their attitude and behaviour and is one of the most important factors influencing academic achievement (Marks 2000; Slavin 2003). Therefore, first insights in these constructs are possible by measuring the time of use of these resources.

As the main aim of the specific document is to provide examples on how the analytics could support the learning experience we are using as a reference data that were collected during the use of the Inspiring Science Education environment that offers the educators the facility to view the assessment results of their students, both individually and as a whole. Based on that, an analysis was done for several lesson implementations of different educational activities in various school environments in different European countries. The graph in Figure 3.4 is an example of the Inspiring Science Education statistics dashboard output for the average time spent per phase of a specific lesson. This data chart (presented as an example) was collected for the lesson: "Light: Reflection and Refraction". The chart gives a first overview of the average time spent by all students in all the 15 implementations (actual) for this lesson and compares it with the average time needed by all implementations in the participating countries (project-wide). A paired-samples t-test was conducted to compare the actual duration of the demonstrator and project-wide time. The t-test result showed that there is a significant difference in actual duration and the project-wide with $t = 0{,}017$ ($p < 0.05$).

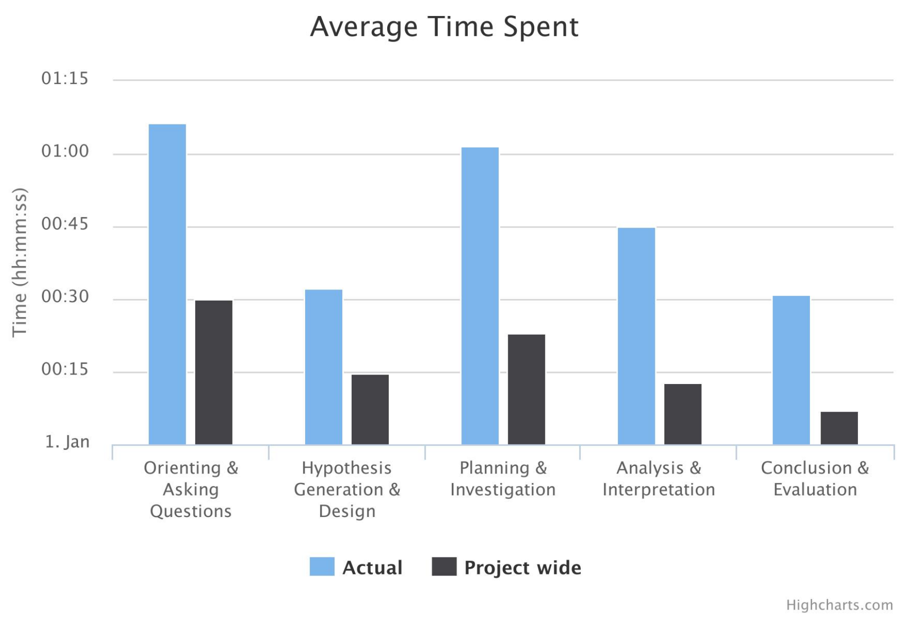

Figure 3.4: *The average time spent per phase in "Light: Reflection and Refraction" lesson compared to the overall average time per phase. The data indicate that this is a time consuming and (maybe) a rather complex task for students.*

A different way to use the specific information in the inquiry cycle is to perform comparisons between the expected (optimum) and the actual time devoted to each phase of the lesson.

Here we are using as an example the data collected from the use of the HYPATIA virtual lab (Described in Chapter 6). This is a quite complex lab that introduces students in particle physics. In all four out of the five phases of the inquiry process the students actually spent less time than the one assigned to them (Figure 3.5). Only phase 4 (Analysis and Interpretation) exhibits a slightly different behavior, even though the difference is within the accepted deviations. It is important to note that the most interactive phase of the lesson, and therefore the most demanding in terms of time, is phase 3 (Planning and Investigation). Ample time was given to the students in order to complete this phase and the results show that the time limits of the experimentation are reasonable and allow an easy implementation of the exercise in school, as far as the time limits are concerned. The overall time required for the completion of the complex activities of the HYPATIA virtual lab (understand the concepts, perform the experiment, analyze the results) is well under two hours, the time which is allocated to project work according to the Greek National Curriculum. The fact though is that such information can be very useful to the teachers in order to adopt their lessons accordingly so as to meet the optimum time that is usually provided by the developer/author of the educational activity.

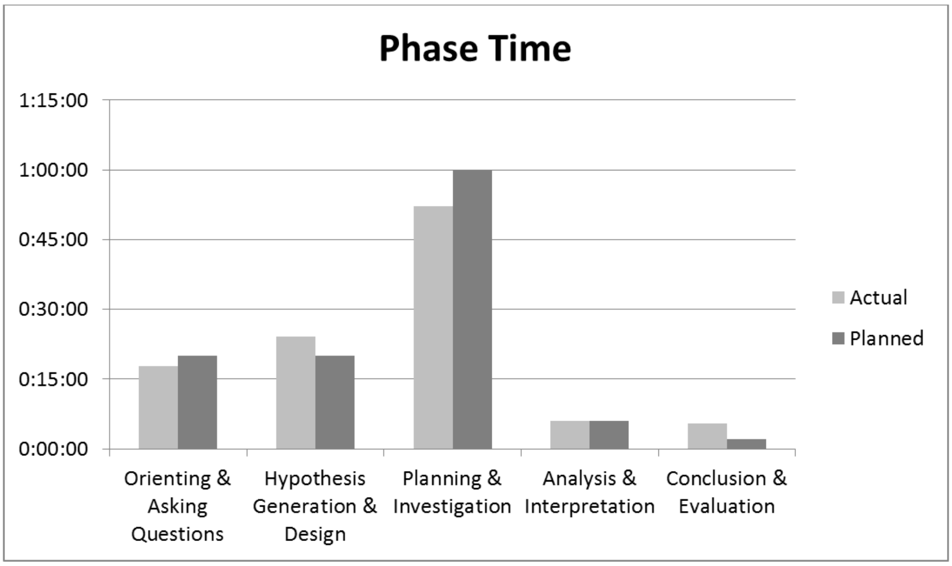

Figure 3.5: *The average time spent per phase in "Looking for Higgs Boson" lesson (with the use of the HYPATIA virtual lab in phase 3) compared to the planned/proposed time per phase. The data indicate that the implementations were made according to the proposed inquiry approach.*

3.2.2 Class Profile

In this section we are discussing the Class-Profile metric. Students are categorised in three categories according to PISA 2014 (see Figure 3.6). The Class-Profile is calculated by considering the lowest level task per phase for the completed task. Students (in the framework of the presented study have to solve two specific tasks that are connected with the specific partial ability). For example, if a student in the "Orienting & Asking question" phase completes successfully the two assigned tasks 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 the orienting & ask phase.

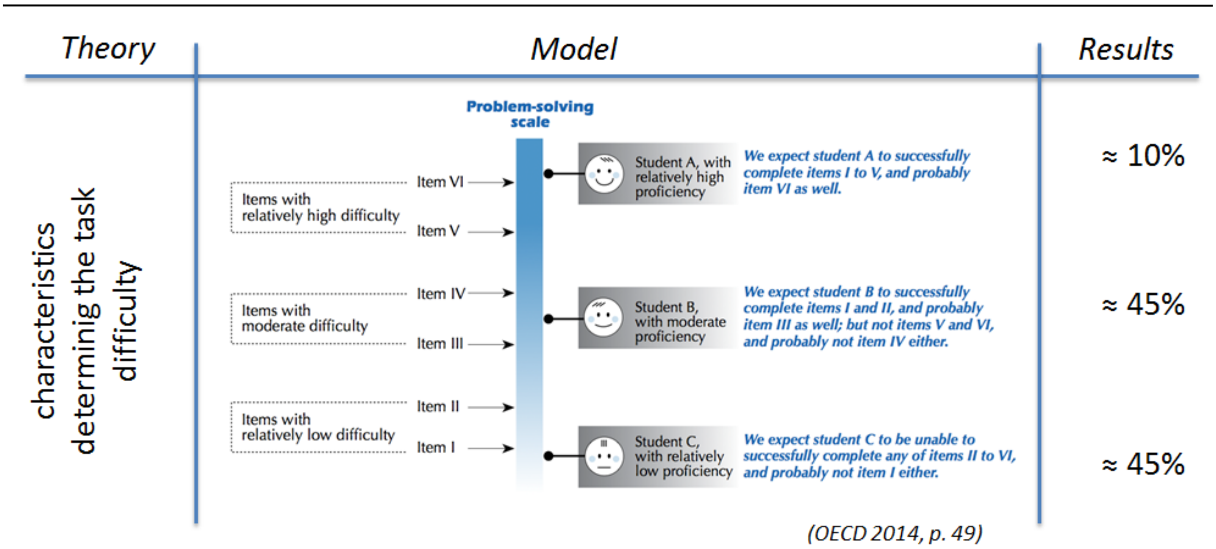

Figure 3.6: *Students categorisation according to PISA 2014 as far as their levels of proficiency in dealing with tasks of varying difficulty. On average OECD countries classrooms consist of 45% of students who show low proficiency, 45% with students with moderate proficiency and only 10% with students with high level of proficiency.*

Figure 3.7: The average values high, moderate and low performer per phase of all students, for all implementations realised in the framework of Inspiring Science Education pilots.

Moreover, if the student's answers were high and moderate respectively, 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. Further on the final percentages per class were calculated and presented in the dashboard as diagram shown in Figure 3.7 for all the inquiry phases and for all lessons in all countries (about 11,000 students' data sets from about 600 lesson implementations).

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. In the specific case the graph demonstrates that (for the specific sample) 25% students scored at the high level while the number of students scored at low level follow the empirical norm. 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.

3.2.3 Levels of Proficiency

The levels of proficiency could offer an opportunity to teachers for direct comparisons with country average or even OECD average scores. 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 results here are referring again to the same sample (11,000 students) and they are presented as the percentage of the total number of replies.

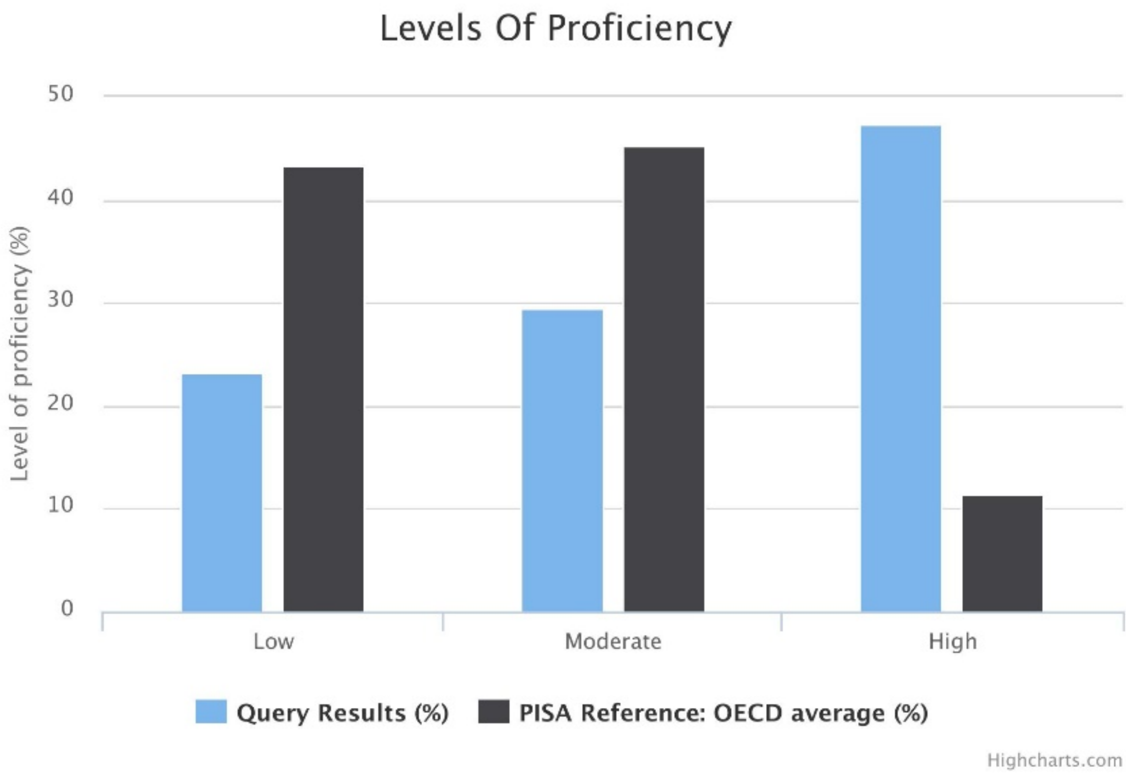

Figure 3.8: *The frequency of high, moderate and low levels of proficiency (%).*

The level of each task is added for every problem-solving question in the four phases 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 presented in Figure 3.8 compared with OECD average. The results are either compared with the average of all replies in the Inspiring Science Education study, or with the PISA standard. The findings demonstrate that the use of the system has helped students to outperform OECD average.

4 Requirements Elicitation – Stakeholders Workshops

During the first month of the project implementation two requirements elicitation events were organised. The first was a stakeholders' workshop involving 20 people. The second was an interactive session/discussion between the EA team and experts from IRCAM in France. IRCAM is an internationally recognized research center dedicated to creating new technologies for music. The institute offers a unique experimental environment where composers strive to enlarge their musical experience through the concepts expressed in new technologies. The main outcomes of the interactive session in IRCAM is presented in session 4.4.3.

The main outcomes of the workshop were two potential scenarios of use of the ENVISAGE system. During the development of the scenarios the expected functionalities of the system were discussed while the added value of the deep analytics that the system will provide was explored. EA has a wide network of teachers' trainers, school advisors and teachers with high skills who are coordinating a series of large scale activities EA team is designing. These people have been involved the last years in three large scale initiatives Open Discovery Space, Inspiring Science Education and Go-Lab. EA team took the advantage of the organization of the EDEN OPEN CLASSROOM Conference 2016 which was held in EA on the 4th, 5th and 6th of November 2016, and organized a day long intervention with 20 people.

The methodology followed in this event is based in years-long research outcomes on group dynamics and brainstorming and is customized to fit the needs of each specific goal that the event tries to solve but its backbone is comprised of a set of brainstorming and team-building techniques that contribute to its overall success and unique nature. In this chapter we will present the workshop methodology, describing the overall architecture of the process and the two main scenarios of use that emerged from the group work and the discussions.

4.1 Methodology

In this section we are describing the methodology used in the ENVISAGE workshop. It can be used as a reference for similar activities at the next stages of the project. It consists of four specific stages through which the participants work, to come one step closer at a time, to their goal that is set forth in the beginning of the event. Setting a goal for the workshop is of paramount importance as this is the guiding beacon for all the work carried out during the event. Having a goal (or more than one) in mind, the rest of the phases that such a workshop deploys, are the following:

- **Harvest Requirements**: During this phase, the participants draw upon the experience of professionals and invited experts by interviewing them in relation to the goal(s) of the workshop. Their purpose is to take notes related to the success stories being narrated in front of them and the experiences of the invited guests so that they can use them in the next phases of the event. In the framework of our workshop numerous examples of existing virtual labs were presented. We have used as reference the Go-Lab project and the Inspiring Science Education initiative virtual labs and tools. In this framework we had the opportunity to work with a group of experienced users of both systems.
- **Imagine**: During this stage, the participants share their ideas with one another on a common space so that each group member can see what the other participants took out

of the interviews with the experts during the initial phase. After the sharing process, meaning that the first “idea seeds” are planted, the participants revisit their notes, adding new ideas on them, or elaborating more on the ones that inspire them. After building on the ideas generated, the participants formulate concrete ideas that can then be developed further. For this phase to be considered completed, each group of participants has to have one or two ideas that will be then “cultivated” and modeled into a coherent story. In the framework of our workshop we have introduced the idea of the use of analytics during the experimentation phase. As discussed before during the use of the virtual labs (in most of the cases) teachers have no information on students’ real tasks. The idea discussed here focused on the usefulness of such an approach. For example how the data from the real use of the lab can be combined with the analytics offered by the Inspiring Science Education system? How a system like ENVISAGE could add value to the existing data? Here the participants are starting developing their ideas for potential future scenarios of use.

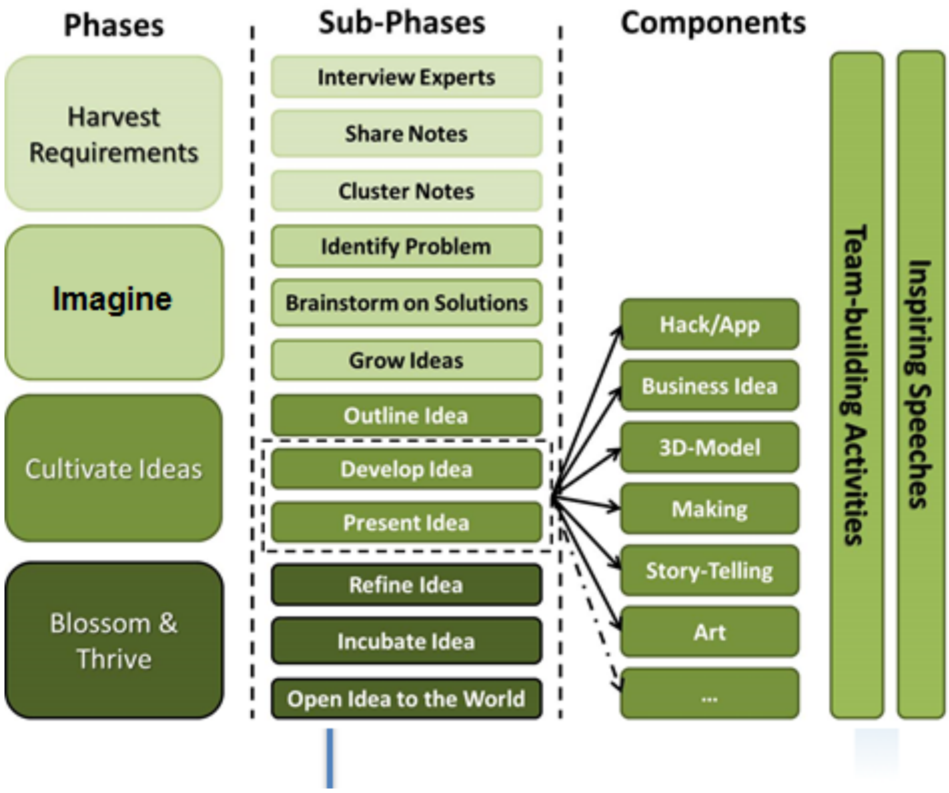

Figure 4.1**:** *The creative engagement process during the workshop*

- **Cultivate Ideas**: During this phase, the participants have a really specific idea that they want to develop (i.e. cultivate) further. Starting from this idea, they describe it as clearly as possible, identifying a title and a description and then they model it into a coherent story. Once all the stories are prepared, each group presents their project/idea to the rest. In the framework of our meeting the use of a system like ENVISAGE was discussed in the framework of current reforms in Greek Educational system, mainly in the field of STEM. Currently in Greece the curricula and the educational materials are going under significant changes in order for a multidisciplinary approach to be adopted. Additionally experimentation and lab work are taking a higher place in the educational reform agenda. Participants were impressed by the timing of the ENVISAGE service and they were very motivated to propose scenarios of use. Two main ideas came forth from the participants work. One is focusing on the use in the framework of the national exam for lower high school and one is focusing on a more informal activity, namely the EUSO contest (http://euso.eu/).

- **Blossom & Thrive**: During the last phase of the workshop, the participants have to prove that their ideas are sustainable and that there is a concrete plan of following them through to real-life implementation. Looking at their scenarios again, they are now called to come up with a tentative schedule that will guide their deployment in real-life situations. To make the scenario more realistic, each group has to also identify and describe a value proposition behind their idea, identifying their target audience and market that would be willing to finance their effort. The fact that the groups of participants included teachers, schools' advisors and science teachers' trainers helped us to define all the necessary characteristics for the scenarios discussed above.

Figure 4.2: *Presentations, Discussions and Lab work were included in the workshop programme.*

The outcome of the workshop were two scenarios of use of the ENVISAGE system. These scenarios are discussed in more detail in section 4.4.

4.2 Tools used

A set of tools were used to support participants in the development of the ENVISAGE Scenarios of Use. In the following paragraphs, these tools are briefly described.

4.2.1 Interview

One of the most important parts for the success of the workshop is the interview part where the participants "harvest" experiences and stories in order to collect input for their scenarios. In this part, organizers (and invited speakers) are introduced in the groups, so that the participants can discuss with them. Although this seems simple, it is a process that requires lots of planning and preparation on the side of the interviewee as well, as he/she has to be coached related to the goals set forth, so that he/she can provide the most relevant information when asked by the participants. Continuous monitoring of the process is also needed so that no participant dominates the group by being the one asking all the questions but also to make sure that the interviewee does not go in great lengths on his/her personal views instead of answering the questions quickly and accurately. In the framework of our workshop Prof. Christine Kourkoumelis from University of Athens and CERN (one of the developers of the HYPATIA virtual lab) was interviewed from the workshop organisers and the participants in order for the level of the tasks allocated to students during the use of the HYPATIA lab to be explored. The aim was to identify steps of the process where analytics would be useful in order to decide for the next steps of the experiment.

4.2.2 Inspiring Talks

Apart from the interviews conducted, each one of the phases described above, hosts one or more inspiring talks from invited speakers that get a maximum of ten minutes to present their work/interests related to the respective phase of the event. For example in our case Prof. Kourkoumelis presented to the participants the use of the HYPATIA virtual lab, its functionalities, the tasks and the challenges that could be assigned to the students and the integration of the lab in the inquiry cycle. This helped the participants relate to the process of generating new ideas that are then elaborated and refined into something concrete that can be moved into the modeling phase of "Cultivating Ideas".

4.2.3 Brainstorming Techniques

Once the participants have collected all the information needed through the interview, time has come to share their views on what was discussed. During this part it's essential to use brainstorming techniques. More specifically, in the Framework of the ENVISAGE workshop, every participant had continuous access to web materials and writing materials so that all ideas and thoughts were recorded. Some of the rules that were introduced are the following:

- **Focus on quantity**: This rule is a means that the greater the number of ideas generated, the greater the chance of producing a radical and effective solution.
- **Withhold criticism**: In brainstorming, criticism of ideas generated should be put 'on hold'. Instead, participants should focus on extending or adding to ideas, reserving criticism for a later 'critical stage' of the process. By suspending judgment, participants will feel free to generate unusual ideas.
- **Welcome unusual ideas**: To get a good and long list of ideas, unusual ideas are welcomed. They can be generated by looking from new perspectives and suspending assumptions. These new ways of thinking may provide better solutions.
- **Combine and improve ideas**: Good ideas may be combined to form a single better good idea, as suggested by the slogan "1+1=3". It is believed to stimulate the building of ideas by a process of association.

4.2.4 Team Building Activities

The workshop brought together a really diverse mix of participants with different experiences and from different areas of Greece. These people are working together in the framework of policy support actions and other innovative activities for schools. This characteristic can shorten the time that a participant needs to adapt to the group he/she is assigned to. Most of the time, people were happy to open up and express their ideas. In any case additional exercises and games that can make them feel more open were also implemented. In this part, well-known and widely used team building exercises are used.

4.3 Workshop Participants

The workshop participants were science teachers, science teachers' trainers and school advisors from different location of Greece. Participants have formed two main groups. In the first science teachers and science teachers' trainers were involved. In the second group science teachers and school advisors were involved. Their details are presented on Table 1.

Table 1: *The names and the experience of the workshop participants.*

Name	Prefecture	Theme
Αργύρη Παναγιώτα	Attica	Teacher in Physics
Ρόζη Αικατερίνη-Μαρία	Attica	Teacher in Physics
Πέτρου Ρούλα	Attica	Special Education
Κοντογιάννης Ανδρέας	Attica	Teacher in Mathematics
Μανουσάκη Κλεοπάτρα	East Peloponnese	Science Teachers Trainer (EKFE Argos)
Χιωτέλης Γιάννης	West Peloponnese	Teacher in Physics –Biology
Παλούμπα Ελένη	South Peloponnese	Science Teachers Trainer (EKFE Sparta)
Μίχας Γιάννης	Evia Island	Science Teachers Trainer (EKFE Evia)
Μακρής Νίκος	Thessalia	Teacher in Geology
Νεράντζης Νικόλαος	Thessaloniki	Teacher in Physics
Βουκλουτζή Ελένη	Macedonia	Teacher in Biology
Σούλη Αλεξάνδρα	Epirus	School Advisor – Geology
Χαλιώτη Κατερίνα	Cephalonia Island	School Advisor – Physics
Θ. Πιερράτος	Macedonia	Teachers Trainer (EKFE Thessalonikis)
Γαργανουράκης Βασίλης	Crete	Teachers Trainer (EKFE Hrakleion)
Κοτσακώστα Μαρία	Thessaloniki	School Advisor
Νίκου Σταύρος	Thessaloniki	School Advisor
Ασημίνα Κοντογεωργίου	Thessalia	School Advisor

4.4 Exploitation Opportunities

4.4.1 EUSO Contest Scenario

EUSO European Union Science Olympiad

The European Union Science Olympiad (EUSO) is a multidisciplinary, integrated science, practical-based, team competition for EU high school science students who are sixteen years of age or younger on

December 31st prior to the competition. Young EU students get an opportunity to display their scientific capabilities, develop their talents and promote their career as scientists. The Mentors get an opportunity to compare the syllabi and educational trends in science education within the EU member states with a view to improve science education at national levels. EU member states are invited to send a delegation of three teams with three science student in each team (nine students in total). They are accompanied by not more than one Mentor for each discipline (Biology, Chemistry and Physics) who is also a member and the Scientific Jury. Thousands of students are participating every year to the contest at local and national level while about 300 students are participating to the European finals.

Figure 4.3: *The 14th EUSO was held in Estonia (Tartu) from 7th to 14th May, 2016.*

The students' teams are selected per school and they participate to the local and national competitions. Students are assigned with specific challenges both theoretical tasks as well as lab work. In the framework of the lab work they have to use specific experimental devices and to set-up experiments to measure different parameters. Usually the lab equipment available in school labs is not sufficient to support students' preparation. For this reason, students have to visit the local science teachers training center which is very well equipped. In such a case teachers/mentors and science teachers' trainers are working together to support the students' teams. Still students have to devote significant time to move from their school to the training center. This prevents many students from being involved in the contest.

According to the ENVISAGE workshop participants (teachers and science teachers' trainers) a system like ENVISAGE can support the up-take of a contest like EUSO. Mentors could design a series of experiments by using the ENVISAGE authoring tool and to make it available for their students. Students will be able to work with the virtual experiments even to their home and they will have the opportunity to develop significant skills and knowledge in the subject. Additionally, mentors will be able to monitor students work and performance and will provide support to specific areas.

The system could be also used from the students to design their own experiments. Mentors will create a series of tools and instruments in the virtual space and students will be asked to create an experimental facility with the specific tools, simulating the real experience during the contest.

Overall the group of participants (science teachers and science teachers' trainers) who proposed the specific scenario were convinced that such a system could have significant impact on supporting students and mentors who want to be prepared effectively for both the national and the international EUSO contest.

4.4.2 Final Exam Scenario

The second scenario is aligned with the current reform in science education at lower high school level. The last years the New Greek Science Curriculum has been implemented in all Greek high schools. The new curriculum aims to contribute to the current agenda about curriculum reform in Europe which focuses on improving science education as a way of child development for a sustainable society. More specifically, the new science curriculum aims to develop scientific skills, understandings and competences both inside educational institutions and in all societal "informal" settings where learning, culture and social interactions occur (i.e., museums, science centers, environmental parks). The science curriculum tries to become a balanced open and/or closed curriculum, on comparing the best practices of the high scored countries in PISA, and giving emphasis on the relationship between formal and informal science education, on the connection of science education to society and everyday life, on effective hands on activities we really need, and, finally, on the school science textbooks and their role to develop responsible citizenship (Rocard, 2007). More specifically the main priorities for the science education at high school level are:

- A reversal of school science-teaching pedagogy, from mainly deductive to inquiry-based (inductive) methods and the adoption of key competences (Mathematical reasoning, Familiarization with Science and Technology and Learning to learn competences), provides the means to increase interest in science.
- Improvements in science education should be brought about through the new forms of pedagogy: the introduction and gradual adoption of the inquiry-based and collaborative learning approaches in schools and the development of teachers' networks should actively be promoted and supported.
- Renewed school's science-teaching pedagogy based on the Inquiry Based Science Education will be led by a broader "user-led" innovation, or "learner generated" content and knowledge, thus providing increased opportunities for cooperation between actors in the formal and informal arenas.
- Specific attention should be given to raising the participation of girls in key school science subject, and to increasing their self-confidence in science.
- Teachers are key players in the renewal of science education. Among other methods, being part of a network allows them to improve the quality of their teaching and supports their motivation.

According to the views of the participants (mainly the school advisors) the current reform efforts are rather limited as far as the adoption of the inquiry process (and more specifically the experimentation) is concerned. The fact is that teachers are following traditional instruction approaches. It has to be noted that although there are numerous calls for the introduction of inquiry in school practice the final exam system remains unchanged. According to the participants views the current reform effort could be supported by from the introduction of innovative assessment methods that could be integrated in the final exam for all students. In such a case the current status will change and teachers will have to introduce the experimentation in the class work.

The workshop participants believe that a system like the proposed one can offer a great opportunity to overcome the current barriers. The teams who have the responsibility for the final exams at national level can integrate virtual experimentation in the process by adopting an ENVISAGE-like approach. The exam committee could design the students' tasks and deploy such an innovative approach in the final exam. They could also create a database with virtual labs to be used so both teachers and students to have the chance to get experience in working in tasks related to the specific infrastructure.

4.4.3 A musical instrument lab for deep science learning

In this section we are describing a quite advanced scenario that is the outcome of an interactive workshop/discussion that took place in IRCAM, France on the 8th and 9th of November. The main idea is the development of an advanced 3D virtual workbench allowing students to experiment in exploring acoustic simulations by developing their own musical instruments and test them while they are studying the underlying laws of physics and their mathematical representations. In the following we are describing the different stages (three) of the proposed scenario. Each stage offers different possibilities to explore the shallow and deep analytics that could be offered to the learners and their teachers during the process. In each stage an instrument will be designed with the final goal of playing a concert. The design process will trigger inquiry to the actual geometrical characteristics of the instrument, to the relation with the physics of the produced musical sound, as well as the underlying mathematical equations and the produced sound. The three iterations differ, however, in their level of deeper concepts to be taught as they refer to higher school classes.

In Stage 1, targeted to students up to 14 years, students will discover the properties of their designed instruments. Starting point for the scientific approach is to write down the physics equations related to the sound phenomenon such as the frequency of a wave and the sounding body producing it. The student describes the geometrical shape of the sounding body and the physics of the medium that will disturb the molecules related to the sounding body. Beatrice continues to "shape up" the sound by altering the equations he/she wrote down. A fundamental virtual instrument of his/her own is born. He/She explores the potentials of putting more notes influencing the frequency. This means that his/her preliminary design needs to be altered. Now the starting point in order to refine his/her instrument will be the design. Using the workbench, he/she manipulates the virtual tubes with his/her pen altering lengths or putting more complex surfaces. He/She calibrates frequency properties using his/her voice. He/She experiments using an actuator with his/her hands in order to vibrate the virtual sounding body.

Following the deployment in real settings (Stage 2, 14-16 years) the virtual instrument is saved and available for further customization as the teacher requests from all pupils to make virtual instruments that play specific notes or parts of a song and contain specific spectral properties (timbre, harmonics). The student goes back to refine his/her instrument. He/She receives guidance from her Music teacher about the nature of the sound and the notes he/she is supposed to play in the musical score the whole class is preparing. He/She asks his/her Math and Physics teachers to help him/her alter his/her design in order to do so. His/Her teacher answers his/her questions by giving him/her ways for experimenting with the appropriate parameters. He/She finally writes down his/her notes in MIDI format and places his/her virtual instrument in the ENVISAGE platform that plays along the MIDI file prepared by the class. The instrument is going to be 3D-printed in order to play along with real instruments.

As the project reaches its final stage an advanced case of interaction between virtual, real, and physical 3d printed instruments, inspire the high school students to gradually familiarize with the 3D printing technology, its applications and potential. Students are now engaged in a challenging collaborative project in which they have to study, analyse, design and build musical objects, using the 3D printer of their school. To accomplish this they acquire solid knowledge and understanding by inquiry and practice in a variety of curriculum subjects of physics, mathematics, geometry, informatics, engineering/technology and also music and history of music and arts. For example, they need to identify and understand the function of the main elements of the instrument. To accomplish this, they use free 3D visualization tools of engineering drawings and simulation software. They practice their knowledge on mathematics and geometry related subjects to derive main geometrical parameters and relationships. In order to fully understand how a wind instrument works and produces sound they further develop concept and content knowledge of physics curriculum topics like, waves, pressure, equilibrium, laminar air motion, laws of ideal gases through experimentation and inquiry-based simulation resources. Furthermore, students are learning to use computer-aided-design software to design themselves the components of the instrument (using the ENVISAGE authoring tool) which they will then build with the 3D printer. Free, open-source software is chosen for this purpose that offers an integrated user interface for coding, rendering and visualizing in 2D and 3D.

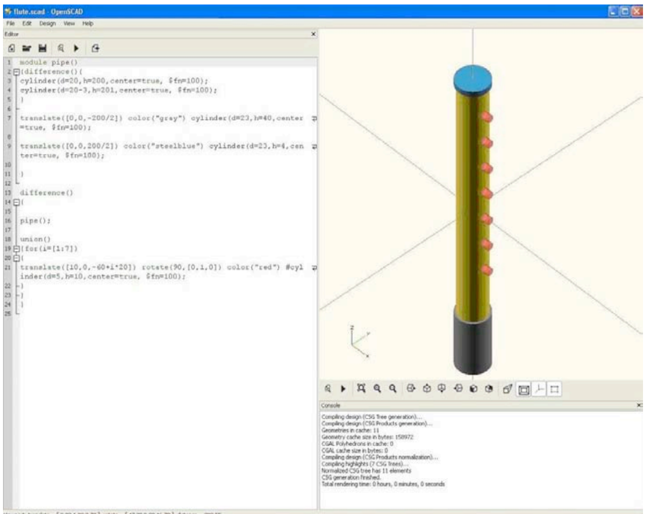

Figure 4.4: *Students use open-source software for computer-aided-design. To the left is the code they write to design the parts of the instrument, to the right is the direct 3D visualization of the designed object, which can then 3D-print*

In this way students practice and further develop their knowledge on informatics related curriculum topics, like code development with variables, functions, libraries, conditional and iteration statements etc. As students are split to work in groups they have to learn to share source code, specifications and design parameters and cross-check each other's work. In the next phase students' 3D-print and assemble all components. They then can play, test and tune their creation like a real musical instrument. They may need to do improvements, alterations to their design, 3D-print again certain parts until they reach the final goal. At the last phase of the course students work on making a comprehensive presentation of the project and their experience in order to share it with the school community and the general public. During the whole duration of the course and their work they improve their social and verbal skills (collaboration, communication, presentation, project planning and management), develop key competencies (creative learning, innovative thinking, problem solving, multi-disciplinary thinking) and digital literature. They perform tasks like real scientists, researchers- musicians and engineers do for their everyday job, and learn and develop similar work practices and attitudes.

This scenario is quite advanced and maybe at some level goes beyond the expectations for the ENVISAGE project. As ENVISAGE aims to explore the potential of deep analytics in supporting students learning and practices we believe that such scenarios could be used as a reference towards future developments and services for schools. This scenario offers unique opportunities for exploring deep science learning that is characterised not only by the students' cognitive outcomes but also by the development of their skills to solve complex problems as well as by their attitudes towards scientific concepts that govern every day phenomena.

5 A Characterization Scheme for ENVISAGE Virtual Labs

In the framework of the work done in Go-Lab project EA has developed a template, which aimed to collect the basic information required from each virtual lab from the initial pool of virtual labs that were integrated to the Go-Lab portal (http://golabz.eu). The development of the template was based on the specific characteristics of the Go-Lab approach. In the framework of the Go-Lab approach the identification of virtual labs that support the implementation of the inquiry cycle or essential features of inquiry learning was of major importance. It has to be noted the effective implementation of inquiry is a crucial parameter for assessing the development of the problem solving competence. As ENVISAGE is focusing on data acquisition of deep analytics (e.g. evidence towards assessing the problem solving competence of the students) we are proposing to follow the same characterisation scheme in the framework of this project. This will allow for the consortium to a) use and enrich numerous virtual labs from the Go-Lab repository and to b) design a series of very specific experiments which will offer the opportunity to the project team to demonstrate the potential of the embedded students' assessment project in a well-defined scenario (process, tools and objectives).

Additionally, the provision of guidance for students learning during their work with the virtual lab was explored in detail as the Go-Lab Repository was aiming to provide guidance (including scaffolds) and support tools (like tools for making tables, drawing pads, estimating errors or tool for making graphical representations) as an additional service. Finally, specific technical characteristics of the online labs had to be described in order for the technical team of the project to be able to organize their integration to the system.

The proposed template for ENVISAGE includes three main parts: The first one includes General Information about the online lab, the second part asks for the description of the pedagogical characteristics of each lab as well as the identification of the different phases of the inquiry cycle that the online lab proposes, and finally the technical part that asks for the technical parameters of each virtual lab. The template is presented in Table 2**Error! Reference source not found.**.

Table 2. *The ENVISAGE template for the characterization of the virtual labs.*

General Information	
Lab Title	
Lab Category	*Please select one of the following:* • Remote lab • Virtual lab(s) • Data-set/Analysis Tool
Lab Owner	
Lab URL	
User Interface Language(s)	
Primary aims of the lab	*For example:* • Demonstrate how scientists work • Help explain the scientific process

Current number of lab users	
Demographic information of users (if available)	
Average time of use (per experiment/session)	
Brief description of the lab	*Please provide a description of the lab's content*

Pedagogical Information	
Subject domain(s)	• Chemistry • Biology • Physics • Earth Sciences and Environment • Technology • Engineering • Mathematics • Other (*please specify*)
Grade Level	• Primary Education (10-12 years old) • Lower Secondary Education (12-15 years old) • Upper Secondary Education (15-18 years old) • Higher Education Bachelor • Higher Education Master
Engaging in scientific reasoning	*Please describe how the use of the lab can support students in manipulating, testing, exploring, predicting, questioning, observing, analyzing and making sense of the natural and physical world.*
Inquiry Cycle Phase *Please describe how the lab promotes the inquiry process.*	*Which inquiry phases are supported by the lab?* Orientation Questioning Hypothesis Experiment planning Observing Analysing Conclusion Evaluation Reflection
Use of guidance tools and scaffolds	*Please describe if the lab provides scaffolds in other words, are students given specific tools for one or more of the processes in the inquiry cycle.*
Teacher ICT competency level	*Please explain the ICT skills teachers need for effective use of the lab.*
Level of difficulty	*Please choose one of the following levels:* • Easy, Simple to Use (No teacher

Pedagogical Information	
	guidance is needed) • Medium (Teacher Guidance is needed at some stages of the process) • Advanced (Teacher has to support students during the whole process)
Level of interaction	*Please choose one of the following levels:* • Low (Users may only change very few parameters or can only follow one line of action) • Medium (Users may choose over a number of parameters to manipulate) • High (All parameters of the experiment should be defined by the use)
Context of use	*Please describe the context of use (e.g., to be used in the computer lab, in the framework of the school programme, in the framework of specific events, e.g.,, CERN Masterclasses).*
Supporting students with learning difficulties and special needs	*Please describe if the lab (and the supportive materials) could be used by students with special needs.*
User manual	
Additional supportive materials (e.g.,, usage scenarios)	
Description of a use case	*Please describe a common use case.*

Technical Information	
Web client (link to client app(s)	
APIs (server)	• *Do you provide APIs for other clients (operation and monitoring, …)* • *Full technical specs (inputs, outputs, data, video channels, parameters …)*
Alternative clients	• *If it is a remote labs, provide the link to its simulation (if it exists)* • *If it is a simulation, provide the link to the actual remote lab (if it exists)*
Compatibility	• *Platforms (Windows, MacOS, Linux, iOS, Android etc.)* • *Special plugin(s) with version (flash, java, etc.)* • *Browser(s) with version (Explorer > xx, Firefox, Google Chrome etc.)*
Registration needed	• *If Yes, give details:* • *If it is the case we will need a lot of information to enable interoperability*

Technical Information	
Does the lab require to book time/schedule beforehand?	
Conditions of use	• *Free, bartering, paying?* • *First in first served or access through booking? Do you grant ENVISAGE the right to make these conditions of use public?* • *Is the lab already referenced in an educational repository? (If yes, which?) Are there usage restrictions because of this? Can this repository be harvested? How?*
Additional software/hardware needed?	
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	*If so, is this available and in which format? Is this experimental data searchable?*
Does the lab track user interactions?	*If Yes, provide some details*

6 Virtual Labs to be used in the ENVISAGE scenarios

In this section we will list a number of virtual labs based on the aforementioned template. This list of labs will serve as the pool from which a restricted number of labs will be selected for the purpose of ENVISAGE. These labs will be examined by both technical and educational partners and the most promising will be selected for further development.

6.1 Speed of light (Virtual Lab involving Medium Level Problem Solving Tasks)

General Information	
Lab name	Speed of Light Experiment
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi, Greece
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/SpeedOfLight/SpeedOfLight_v3.0.html
User Interface Language(s)	English
Primary aims of the lab	The “Speed of Light Experiment” lab aims to demonstrate to students in an engaging and interactive way how the speed of light was measured using mechanical means by H.Fizeau in 1849
Current number of lab users	-
Demographic information of users (if available)	No individual user data is available
Average time of use (per experiment/session)	Approximately one hour is typical
Brief description of the lab	The “Speed of Light Experiment” lab demonstrates to students in an interactive way how the speed of light was measured with high precision using mechanical means. Students can perform experimentation with different setup parameters in order to understand how the speed of an object like a bullet, a ball or a particle can be measured through mechanical means, and in particular by using the cogs of a spinning wheel. In this way they understand and simulate how the speed of light was measured by mechanical means by H.Fizeau in 1849

Pedagogical Information	
Subject domain(s)	Physics
Grade Level	Students of Upper Secondary Education (15-18 years old)
Engaging in scientific reasoning	The lab is designed so that the user can setup specific parameters and see animated in 3d the effect they have in the system under study. This

Pedagogical Information	
	mimic the process of experimentation and exploration used by researchers or scientists during their work on designing, simulating and testing an experimental setup or apparatus. The user is given instructions on how to setup the different parameters of the lab (i.e. number of cogs, revolutions per minute and distance) and identify which combinations can use in order to determine the speed of a passing object like a bullet, a ball or a particle. The students can work in groups in order to exchange their results and findings, to reflect on the process they followed, to present arguments on their thinking, reasoning and strategy on how to reach or find a solution. In this way they simulate in practice what researchers and scientists do to discover and establish new knowledge, explain phenomena etc.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Low to medium. Teacher guidance, explanation and support is needed to clarify the stages of the process
Level of interaction	Medium
Context of use	Can be used by group of students or by individual students and teachers
Supporting students with learning difficulties and special needs	No special support is provided
User manual	Guidance and instructions are included in the weblink of the lab
Additional supportive materials (e.g. usage scenarios)	It is up to the teacher to provide an appropriate lesson plan or learning scenario that incorporates

Pedagogical Information	
	this lab
Description of a use case	Students can perform experimentation with different setup parameters in order to understand how the speed of and object like a bullet, a ball or a particle can be measured through mechanical means. In particular using the cogs of a spinning wheel. In this way they understand and simulate how the speed of light was measured by mechanical means by H.Fizeau

Technical Information	
Web client (link to client app(s)	**http://www.3dtrainingdesign.co.uk/GoLab/SpeedOfLight/SpeedOfLight_v3.0.html**
APIs (server)	N/A
Alternative clients	N/A
Compatibility	Runs on all platforms with up-to-date browsers
Registration needed	*No*
Does the lab require to book time/schedule beforehand?	*No*
Conditions of use	• Free • *Do you grant ENVISAGE the right to make these conditions of use public?* Yes • *Is the lab already referenced in an educational repository? Go-Lab*
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	The lab itself does not store user data
Does the lab track user interactions?	No

6.2 Building Atomic Orbitals (Virtual Lab involving Medium Level Problem Solving Tasks)

General Information	
Lab name	Building Atomic Orbitals
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/Molecules/Molecule-ORBITALS/Molecule-ORBITALS-v1.2.html
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students how atomic orbitals are build. – Demonstrate how scientists work – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	Atomic orbitals are mathematical functions that describe the properties of electrons in atoms. Using this lab, you will learn how to build atomic orbitals according to the general principals involved and you will also be able to visualize their shapes.

Pedagogical Information	
Subject domain(s)	Chemistry› Analytical chemistry› Atomic structure Chemistry› Analytical chemistry› Atoms – generally Physics› Energy Physics› Fields
Grade Level	16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific inquiries related to the building of atomic orbitals.
Inquiry Cycle Phase	Orientation Conceptualisation

Pedagogical Information	
	Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium
Level of interaction	Medium
Context of use	To be used in computer lab or remotely from home or as part of an event.
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	no
Description of a use case	Used by students as self-directed individual inquiry in an organic chemistry class. Used in order to apply and test understanding of concepts covered in class.

Technical Information	
Web client (link to client app(s)	http://composer.golabz.eu/embed/apps/524310e1-7af8-45ff-b5ad-7c391e7bf24e/app.xml
APIs (server)	NA
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla, Google Chrome
Registration needed	*no*

Technical Information	
Does the lab require to book time/schedule beforehand?	*no*
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? Yes, Go-Lab* ***http://www.golabz.eu/lab/building-inorganic-molecules***
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no
Does the lab track user interactions?	no

6.3 Building Inorganic Molecules (Virtual Lab involving Low Level Problem Solving Tasks)

General Information	
Lab name	Building Inorganic Molecules
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi
Lab URL	**http://www.3dtrainingdesign.co.uk/GoLab/Molecules/Molecule-IONIC_COVELANT_BONDING/Molecule-IONIC_COVELANT_BONDING-v1.0.html**
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students how to build inorganic molecules. – Demonstrate how scientists work – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	This lab will help you learn how to build inorganic molecules. You will also be able to investigate the nature of the bonds between

	the atoms and how are electrons placed.

Pedagogical Information	
Subject domain(s)	Chemistry› Analytical chemistry› Bonding – generally Chemistry› Analytical chemistry› Covalent bonds Chemistry› Analytical chemistry› Electrons – generally Chemistry› Analytical chemistry› Ionic bonds Chemistry› Analytical chemistry› Molecules – generally Chemistry› Analytical chemistry› Role of electrons in reactions Chemistry› Chemical reactions Chemistry› Inorganic chemistry
Grade Level	12-14, 14-16, 16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific inquiries related to the structure of inorganic molecules.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium
Level of interaction	*High*
Context of use	To be used in computer lab or remotely from home or as part of an event.

Pedagogical Information	
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	no
Description of a use case	Used by students as self-directed individual inquiry in an inorganic chemistry class. Used as an opportunity to apply and test understanding of concepts and methods covered in class.

Technical Information	
Web client (link to client app(s)	http://composer.golabz.eu/embed/apps/e678ba89-908f-480a-bc1a-6dc0e82ce3f6/app.xml
APIs (server)	NA
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla, Google Chrome
Registration needed	*no*
Does the lab require to book time/schedule beforehand?	*no*
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? Yes, Go-Lab* ***http://www.golabz.eu/lab/building-inorganic-molecules***
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no
Does the lab track user interactions?	no

6.4 Foucault's Pendulum (Virtual Lab involving Medium Level Problem Solving Tasks)

General Information	
Lab name	Foucault Pendulum
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/FoucaultPendulum20150123/TW_Applet.html
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students how Foucault proved the Earth's rotation. – Demonstrate how scientists work – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	Foucault's Pendulum allows students to perform the famous experiment that was the first substantial proof of Earth's rotation. Alongside, the use of the lab allows the students to get acquainted with the main principles of pendulums as well as the basic concepts in geography like latitude, longitude and the motion of Earth.

Pedagogical Information	
Subject domain(s)	Physics› Energy› Energy transfer and storage Physics› Energy› Kinetic energy Physics› Energy› Potential energy Physics› Fields› Magnetic field Physics› Forces and motion› Acceleration Physics› Forces and motion› Circular motion Physics› Forces and motion› Foucault pendulum Physics› Forces and motion› Gravitational force and gravity Physics› Forces and motion› Oscillations

Pedagogical Information	
	Physics› Forces and motion› Pendulum Physics› Forces and motion› Period Physics› Forces and motion› Rotation Physics› History of science and technology› Scientists and inventors
Grade Level	10-12, 12-14, 14-16, 16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific inquiries investigating the motion of a pendulum in different parts of the globe.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium
Level of interaction	*Medium*
Context of use	To be used in computer lab or remotely from home or as part of an event.
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	no
Description of a use case	Used by students as self-directed individual inquiry in geography, physics or astronomy class. Used as an opportunity to apply and test understanding of Earth’s rotation.

Technical Information	
Web client (link to client app(s)	http://shindig2.epfl.ch/gadget/go-lab/lab/foucault-pendulum/fp.xml
APIs (server)	NA
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla Java is required It will not run natively on MAC OS or Linux. The DirectX configuration of the host Windows OS should have the following enabled: DirectDraw Acceleration Direct 3D Acceleration AGP Texture Acceleration Most PCs built and deployed in the last 4 to 5 years, with Windows XP SP2 or newer, should be suitable.
Registration needed	*no*
Does the lab require to book time/schedule beforehand?	*no*
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? Yes, Go-Lab http://www.golabz.eu/lab/foucault-pendulum*
Additional software/hardware needed?	Java is required
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no
Does the lab track user interactions?	no

6.5 Wind Energy Simulation (Virtual Lab involving Medium Level Problem Solving Tasks)

General Information	
Lab name	Wind Energy Simulation
Lab category	Virtual Lab

Lab Owner	Ellinogermaniki Agogi
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/GoLab-WindEnergy/GoLab-WindEnergy.v1.0.html
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students how wind energy mills are working in order to produce energy. Demonstrate how scientists work – Understand how random changes - in wind speed and power requirement of the town - affect the use of this natural energy resource. – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	This lab allows the user to take control of a wind farm to provide electrical energy for a small town.

Pedagogical Information	
Subject domain(s)	Engineering› Mechanical Engineering› Energy use Environmental education› Energy Geography and earth science› Earth science› Meteorology Mathematics Physics› Energy
Grade Level	12-14,14-16,16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific inquiries to test the production of energy through wind mills.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis

Pedagogical Information	
	Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium
Level of interaction	*High*
Context of use	To be used in computer lab or remotely from home or as part of an event.
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	no
Description of a use case	Used by students as self-directed individual inquiry in an environmental studies class. Used as an opportunity to explore the problem at hand or apply and test understanding of concepts related to renewable energy and green energy.

Technical Information	
Web client (link to client app(s)	http://composer.golabz.eu/embed/apps/17ae04b8-8da6-4a0f-bc64-8d19bd17976b/app.xml
APIs (server)	NA
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla, Google Chrome
Registration needed	*no*
Does the lab require to book time/schedule beforehand?	*no*

Technical Information	
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? No*
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no
Does the lab track user interactions?	no

6.6 Organic Molecule Builder (Virtual Lab involving Low Level Problem Solving Tasks)

General Information	
Lab name	Organic Molecule Builder
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/Molecules/Molecule-COMPOUND_BONDING-v4/Molecule-v4.0.html
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students how organic molecules are build. – Demonstrate how scientists work – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	Using the Molecule Builder the user explores the properties and nature of 20 different molecules or compounds. This resource is spread across 4 linked sections: 1. Select a molecule and associate it with a homologous series

	2. Associate the homologous series with a functional group 3. Chose a structure map for your molecule 4. Build the molecule from various elements

Pedagogical Information	
Subject domain(s)	Chemistry› Organic chemistry› Carbon Chemistry› Organic chemistry› Hydrocarbons
Grade Level	12-14,14-16,16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific inquiries related to the structure of organic molecules.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium
Level of interaction	*High*
Context of use	To be used in computer lab or remotely from home or as part of an event.
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	no
Description of a use case	Used by students as self-directed individual inquiry in organic chemistry class. Used as an opportunity to apply and test understanding of

Pedagogical Information	
	concepts covered in organic chemistry class.

Technical Information	
Web client (link to client app(s)	http://composer.golabz.eu/embed/apps/f580d0e1-05e1-44ee-b15c-2b7fa6182c55/app.xml
APIs (server)	NA
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla, Google Chrome
Registration needed	*no*
Does the lab require to book time/schedule beforehand?	*no*
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? No*
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no
Does the lab track user interactions?	no

6.7 Naming Organic Molecules (Virtual Lab involving Low Level Problem Solving Tasks)

General Information	
Lab name	Naming Organic Molecules
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/Molecules/Molecule-

	NAMING-v4/MoleculeNaming-v4.0.html
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students how organic molecules are named. – Demonstrate how scientists work – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	Using the Molecule Naming Lab the user can select from a list of 19 molecules and are asked to name it.

Pedagogical Information	
Subject domain(s)	Chemistry› Organic chemistry› Carbon Chemistry› Organic chemistry› Hydrocarbons
Grade Level	12-14,14-16,16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific inquiries connected to the naming of organic molecules.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium

Pedagogical Information	
Level of interaction	*High*
Context of use	To be used in computer lab or remotely from home or as part of an event.
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	no
Description of a use case	Used by students as self-directed individual inquiry in organic chemistry class. Used as an opportunity to apply and test understanding of concepts connected to organic molecules.

Technical Information	
Web client (link to client app(s)	http://composer.golabz.eu/embed/apps/4c76b1a2-fee6-4c78-b409-023f5a66f13e/app.xml
APIs (server)	NA
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla, Google Chrome
Registration needed	*no*
Does the lab require to book time/schedule beforehand?	*no*
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? No*
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no

Technical Information	
Does the lab track user interactions?	no

6.8 Double Slit experiment (Virtual Lab involving Medium Level Problem Solving Tasks)

General Information	
Lab name	Double Slit experiment
Lab category	Virtual Lab
Lab Owner	Ellinogermaniki Agogi
Lab URL	http://www.3dtrainingdesign.co.uk/GoLab/DoubleSlit/DoubleSlitBeta03.html
User Interface Language(s)	English
Primary aims of the lab	– To introduce to students the double slit experiment. – Demonstrate how scientists work – Help explain the scientific process – Support students in manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.
Current number of lab users	NA
Demographic information of users (if available)	NA
Average time of use (per experiment/session)	1 didactical hour
Brief description of the lab	With this lab, the user can perform the famous double-slit experiment. In quantum mechanics it is an experiment that shows how light has both a wave nature or characteristic and a particle nature or characteristic, and that you cannot get rid of either one. So light is said to have a dual wave-particle nature. The same is true of electrons and other quantum particles.

Pedagogical Information	
Subject domain(s)	Physics› High Energy Physics› Free electron lasers Physics› Light› Properties of light - generally Physics› Waves› Diffraction
Grade Level	16-18
Engaging in scientific reasoning	Through virtual engagement in simulated 3D

Pedagogical Information	
	environments and scenarios, students will be placed in the role of scientist and challenged to carry our scientific experiments to study the dual nature of light.
Inquiry Cycle Phase	Orientation Conceptualisation Questioning Hypothesis Experimentation Analysis Conclusion Discussion - Reflection
Use of guidance tools and scaffolds	No specific guidance tools and scaffolds are provided. Guidance and instructions are included in the weblink of the lab
Teacher ICT competency level	No special ICT skill level is required
Level of difficulty	Medium
Level of interaction	*Medium*
Context of use	To be used in computer lab or remotely from home or as part of an event.
Supporting students with learning difficulties and special needs	no
User manual	no
Additional supportive materials (e.g. usage scenarios)	yes
Description of a use case	Used by students as self-directed individual inquiry in a physics class. Used as an opportunity to apply and test understanding of the wave-particle duality.

Technical Information	
Web client (link to client app(s)	NA
APIs (server)	NA

Technical Information	
Alternative clients	NA
Compatibility	Browsers: Explorer, Mozilla, Google Chrome
Registration needed	*no*
Does the lab require to book time/schedule beforehand?	*no*
Conditions of use	• *Free* • *Do you grant ENVISAGE the right to make these conditions of use public? Yes* • *Is the lab already referenced in an educational repository? No*
Additional software/hardware needed?	No
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	no
Does the lab track user interactions?	no

6.9 HYPATIA (Virtual Lab involving High Level Problem Solving Tasks)

General Information	
Lab name	HY.P.A.T.I.A.
Lab category	Virtual Lab/Analysis Tool
Lab Owner	University of Athens, department of Physics / Institute of Accelerating Systems and Applications (IASA) Christine Kourkoumelis hkourkou@phys.uoa.gr
Lab URL	http://hypatia.iasa.gr
User Interface Language(s)	Greek, English
Primary aims of the lab	HYPATIA aims to show students how real high energy physic research is done. It provides the students with real data and an environment that closely resembles what actual researchers use, to give them the opportunity to conduct their own analysis and "discover" new particles.

Current number of lab users	300/month
Demographic information of users (if available)	Users from all over the world, but mostly from Europe. Data provided by Google analytics. No individual user data is available.
Average time of use (per experiment/session)	Depending on the experiment. One hour is typical.
Brief description of the lab	HYPATIA is an event analysis tool for data collected by the ATLAS experiment of the LHC at CERN. Its goal is to allow high school and university students to visualize the complexity of the hadron - hadron interactions through the graphical representation of ATLAS event data and interact with them in order to study different aspects of the fundamental building blocks of nature.

Pedagogical Information	
Subject domain(s)	Particle Physics
Grade Level	• Upper Secondary Education (15-18 years old) • Higher Education Bachelor
Engaging in scientific reasoning	HYPATIA is designed so that the user can view real events as they are detected by the ATLAS experiment at CERN. The scenarios involving HYPATIA mimic the process used by actual researchers during their work on event analysis. Thus, the user can analyse real data using real methods and get a taste of what it feels like to be a particle physics researcher. The user is given instructions on how to identify the various kinds of events that he will have to go through. Then every user (or pair) has to apply those criteria to the available events (which are different for every group of students) and identify then on his own. Then he has to study the histograms and reach a conclusion based on his analysis.
Inquiry Cycle Phase	Orientation Questioning Hypothesis Analysing Conclusion Evaluation
Use of guidance tools and scaffolds	No guidance tools and scaffolds provided. Guidance and assignments are however incorporated in the webpage along with the applet.
Teacher ICT competency level	*No special ICT skill level required*
Level of difficulty	Medium (Teacher Guidance is needed at some stages of the process)

Pedagogical Information	
Level of interaction	High
Context of use	Flexible. Can be used by individual student or teacher as well as in an organized Masterclass
Supporting students with learning difficulties and special needs	No specific provisions
User manual	http://hypatia.iasa.gr/en/HYPATIA_Instructions_eng.pdf
Additional supportive materials (e.g.,, usage scenarios)	Help page http://hypatia.iasa.gr/en/help.html
Description of a use case	Students can examine real Z boson decays and calculate their mass through the use of the built-in invariant mass table. They can do the same with simulated Higgs boson decays. Then they create histograms that give them the invariant mass and width of the particle.

Technical Information	
Web client (link to client app(s)	http://hypatia.iasa.gr
APIs (server)	N/A
Alternative clients	N/A
Compatibility	Runs on all Platforms but requires java (java plug-in installed in the browser)
Registration needed	*No*
Does the lab require to book time/schedule beforehand?	*No*
Conditions of use	• Free • *Do you grant ENVISAGE the right to make these conditions of use public?* Yes • *Is the lab already referenced in an educational repository?* Yes *http://portal.discoverthecosmos.eu*
Additional software/hardware needed?	*No*
Does the lab store experimental data (measurements performed by users, images collected, etc.)?	The user can export the results of his experiment as images (histograms) of text (invariant masses). The

Technical Information	
	lab itself does not store user data.
Does the lab track user interactions?	*No*

7 Conclusions

In this phase of the project (first two months) we have defined the stakeholders involved in a learning situation involving virtual, online learning environments such as virtual labs, focusing on the teachers and learners but also considering other relevant groups in the design/development and learning process (teacher trainers and school advisors). We have analysed the requirements of the different groups of stakeholders in terms of a) behavioural analytics and b) online authoring environments. The stakeholder analysis was based on a workshop with 20 participants, followed by interviews and reviews of best practices with a series of online labs (presented in this document) that EA is already employing in the framework of the offered services (lessons, labs or PD activities). Based on the stakeholder we have presented a series of educational scenarios that will serve as a pool for the prototype demonstrators. These scenarios are organised at three levels, referring to the complexity level of the tasks that are assigned to the students while using the online labs. These scenarios will feed into WP5 for specifying the virtual labs to be designed and developed using the authoring environment (WP4) and will provide the test bed for evaluating the effectiveness of the developed technologies in WP2-4 to address the stakeholder requirements.

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