SCIENTIFIC LITERACY IN THE DIGITAL AGE: TOOLS, ENVIRONMENTS AND RESOURCES FOR CO-INQUIRY

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Abstract

This paper describes some European and International projects to promote Scientific Literacy in the digital age as well as technologies, environments and resources for co-inquiry. The aim of this research is also to describe computer applications, software tools and environments that were designed to support processes of collaborative inquiry learning to promote Scientific Literacy. These tools are analyzed by describing their interfaces and functionalities. The outcomes of this descriptive research points out some effects on student learning and competences developed known from the literature. This paper argues the importance of promoting scientific citizenship not only through schools and Universities (formal learning), but also non-credit online courses and community-based learning programmes (non-formal context), as well as daily life activities, educational open digital materials through social networks (informal scenario).

Keywords: Scientific literacy, tools, environments and resources, co-inquiry

Introduction – Scientific Literacy

Scientific literacy is considered as a key competence for social inclusion and well as active participation for a better world (European Union, 2013; UNESCO, 1993). The Royal Society's (1985:9) highlights scientific literacy as "*a major element in promoting national prosperity, in raising the quality of public and private decision making and in enriching the life of the individual*".

Due to the the rapid technological and scientific advances as well as the growing area of science communication, the meaning of scientific literacy has become more relevant for government bodies and non-governmental organizations. Currently, scientific literacy has been interpreted not only as the ability to read and comprehend science-related articles but also the capability to understand and apply scientific principles to everyday life.

In addition, according to the Literature about Responsible Research and Innovation (RRI), societal actors and innovative scientists should become mutually responsive to each other for developing a better understanding of scientific and ethical issues (including risks, benefits and barriers). This would therefore allow a proper embedding of scientific and technological advances in their society (Owen et al. 2012; Von Schomberg,2013). RRI deals with uncertain areas of knowledge is uncertain, where values and argument matter as much as facts. It is critical for each nation that its future citizens embrace the potential of science and technology. Scientific literacy as one of the key competences for 21st is considered essential to any citizen, who see it as the capacity to access, read and understand the global world with a scientific and/or technological dimension, in order to make a careful appraisal of it, and use that evaluation to make and inform everyday decisions.

Most of the initiatives in this area including international and national projects focus on promoting scientific skills through formal education. This paper, however, argues the importance of promoting scientific citizenship not only through schools and Universities (formal learning), but also non-credit online courses and community-based learning programmes (non-formal context), as well as daily life activities, educational open digital materials and social networks (informal scenario).

This paper describes some European and International projects to promote Scientific Literacy in the digital age as well as technologies, environments and resources for co-inquiry. The aim of this research is also to describe computer applications, software tools and environments that were designed to support processes of collaborative inquiry learning to promote Scientific Literacy. These tools are analyzed by describing their interfaces and functionalities. The outcomes of this descriptive research points out some effects on student learning and competences developed known from the literature.

The Importance of Collaborative Inquiry Learning

Several authors emphasize inquiry based learning as a meaningful approach for science learning, particularly develop Scientific Literacy competence. The traditional approaches for learning Science has focused on the memorization of scientific facts and information of phenomena. In order to develop a proper understanding and scientific skills new pedagogical strategies have been emerged which focus on supporting students to apply scientific concepts and methods as a scientists. Dewey (1910, 1938) argued that scientific knowledge is a process which develops as a product of inquiry, learning activities should encourage them to find inquiry-based solutions for authentic problems (Greeno, Collins, & Resnick, 1996; Henning, 2004).

Due to the rapid advances of digital technology for open education, the opportunity for citizens to develop their competences and skills are wider than ever before on both non-formal and informal contexts. Significant technological development has been perceived through new generation of open educational resources, open educational or professional networks, innovative massive open online courses as well as communities of practices. An significant number of initiatives related to science education based on inquiry and problem based approaches have been increased during this decade for promoting scientifically literate citizens, who are able to understand the value of science in their daily lives, evaluate public policy decisions as well as make informed questions and decisions about science at personal and global levels. Most of those initiatives developed by formal education aim to develop key competences and skills sumarised through the following three topics PISA (2015):

1. Explain phenomena scientifically: Recognise, offer and evaluate explanations for a range of natural and technological phenomena
2. Evaluate and design scientific enquiry: Describe and appraise scientific investigations and propose ways of addressing questions scientifically
3. Interpret data and evidence scientifically: Analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

Collaborative Inquiry Learning - technologies and virtual environments

During the last two decades, many software tools and virtual learning environments were developed for promoting inquiry based learning. Most of them, however, have not been updated since their projects were completed or their funding finished.

Period	Active?	Tool / Project	More information
1996 – 2012	yes	WISE = Web-based inquiry science environment	WISE, a free on-line science learning environment for students in grades 4-12 created by a large team from the University of California, Berkeley.
1998	No, last update 1998	GenScope learning environment	GenScope is a learning environment that uses the computer to provide an alternative to text-based science education. It provides teachers and learners with a new tool that enables students to investigate scientific and mathematical concepts through direct manipulation and experimentation.
2001 – 2010	No, last update 2010	The Progress Portfolio	The Progress Portfolio is software that helps students conduct long-term inquiry projects on computers (e.g. visualization projects, web-based inquiry projects, explorations with CD-ROMs, simulations, digital libraries, etc.). It allows students to document and reflect on their work using an integrated suite of screen capture, annotation, organization, and presentation tools. In addition, teachers can use the Progress Portfolio to guide students in their work through the design of prompts and templates that encourage students to think about key issues as they work. It is used by SIBLE: Supportive Inquiry-Based Learning Environment Project.
1995 – 2002	No, last update 2002	BGuILE = (Biology Guided Inquiry Learning Environment)	BGuILE, learning environments bring scientific inquiry into middle school science and high school biology classrooms. The environments consist of computer-based scenarios and associated classroom activities in which students conduct authentic scientific investigations.
2007 – 2010	No, last update 2010	nQuire	The nQuire software enables students guided by teachers to design and run science inquiries at school, at home, or outdoors on mobile devices. Teachers can choose from a set of ready made inquiries for their students, modifying them as they need, or creating their own new inquiries. They can also monitor their students' progress through inquiries, and give them access to new parts as they complete each stage.
2008 – 2011	SCY-lab is not available, but some tools are accessible	SCY – Science created by You	Science Created by You (SCY) is a project on learning in science and technology domains. SCY uses a pedagogical approach that centres on products, called “emerging learning objects” (ELOs), that are created by students. Students work individually and collaboratively in SCY-Lab (the general SCY learning environment) on “missions” that are guided by socio-scientific questions
2008	No, Website not accessible	Lets’ go	LETS GO frames its vision of “open inquiry” as the opportunity to catalyse and sustain global learning using mobile science collaborators that provide open software tools and resources, and online participation frameworks for learner project collaboration, mobile media and data capture, analysis, reflection and publishing.
2013 – 2015	Available Soon	weSPOT	The weSPOT project aims to propagate scientific inquiry as the approach for science learning and teaching in combination with today’s curricula and teaching practices. weSPOT is currently developing a “Working Environment with Social, Personal and Open Technologies” that supports users (from 12 to 25) to develop their inquiry based learning skills .
2014 - 2017	In development	ENGAGE	The ENGAGE project (Equipping the Next Generation for Active Engagement in Science) aims to help teachers develop the beliefs, knowledge and classroom practice for RRI (Responsible Research and Innovation) teaching. This requires adopting a more co-inquiry based methodology, which gives students opportunity for self-expression and responsibility for coming to informed decisions thorugh collaborative and open scientific research projects.

WISE - Web-based Inquiry Science Environment

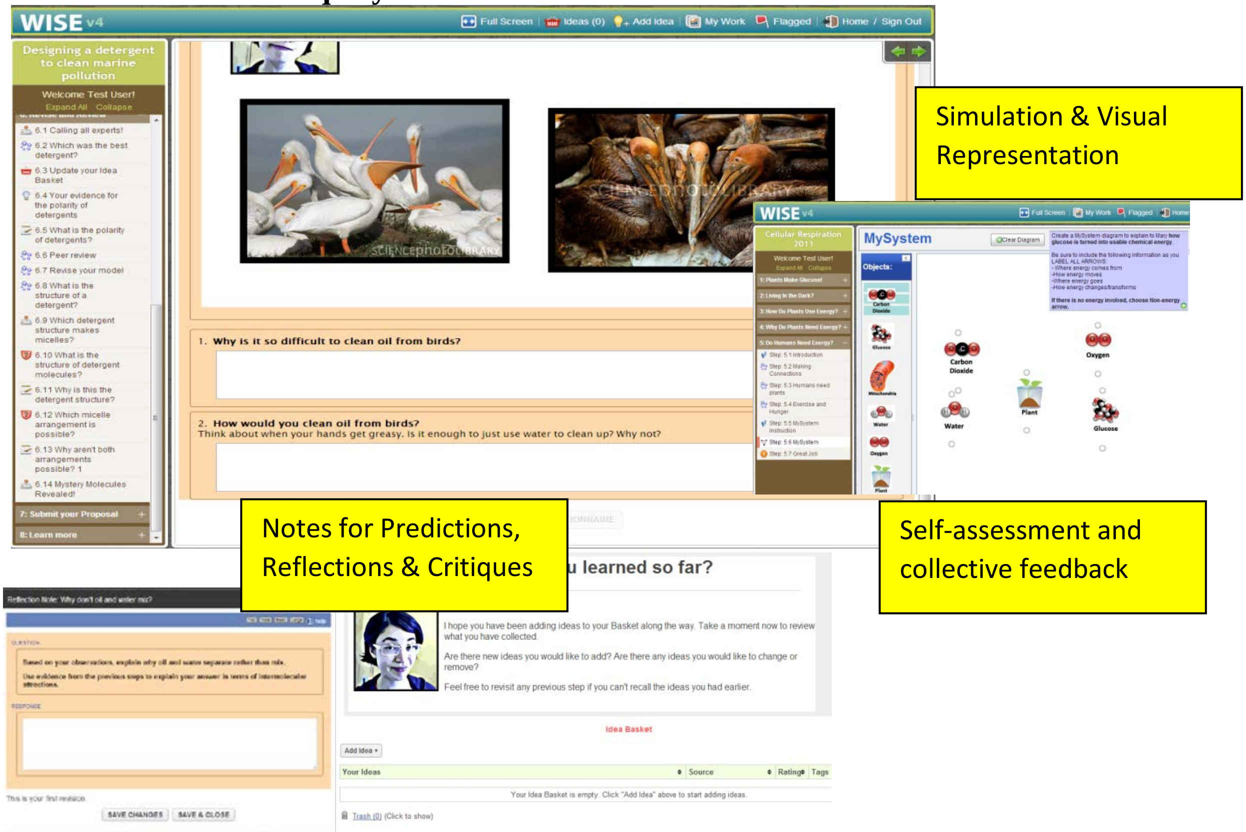

Figure 1 – WISE web-based Inquiry Science Environment - Colearn Community

WISE - **Web-based Inquiry Science Environment** was developed in 1997 by Berkeley University supported by the National Science Foundation. WISE is a virtual learning environment for designing, developing, and implementing science inquiry activities collaboratively. Its participants comprise a growing community of more than 15,000 science teachers, researchers, and curriculum designers, as well as more than 100,000 students around the world. Its main objectives are to investigate and provide:

1. Effective designs for inquiry activities and assessments.
2. Technology supports for students and teachers.
3. Authoring partnerships to create a library of inquiry projects.
4. Professional development programs to enable a wide audience of teachers to succeed with inquiry and technology.

What are its key features?

WISE (http://wise.berkeley.edu/) is entirely browser-based; it does not require the installation of any software. Users only need access to a computer with an Internet connection, with no required software other than the Web browser. It provides an easy-to-use interface for online discussions, visual graphical representations, reflective notes, interactive simulations and assessments. It also offers a library of inquiry projects with an increasing variety of science topics and range of student age groups.

WISE is Free and Open Source. It is available for anyone with a computer and internet connection. It is driven by a growing community of teachers, researchers, and software developers, who are continually expanding and improving the system. The WISE project library is also result of collaboration among teachers, researchers and experts. It focuses on bringing science inquiry into diverse learning settings: classrooms, museums, home-school environments.

How does it work?

Students can create and save their work on the central project server hosted by Berkeley University that enable their accounts be coordinated with teacher’s accounts. Users can access their work as well as the library of curriculum projects from any computer on the Internet. Teachers can choose from in the WISE Teacher's Portal, a set of materials including a detailed lesson plan with assessments grounded on to the AAAS National standards. Teachers can manage their student accounts, grade and monitor and student work as well as provide formative feedback during a inquiry based learning project.

Students can develop their inquiry projects through four steps:

1. Prediction, Observation, Explanation, and Reflection: Students register their predictions, include their observations with data collected, and integrate their evidence to describe explanations and changes to their predictions.
2. Critique and Feedback: Students define criteria to evaluate different claims in terms purpose and sources of evidence. Based on these criteria, they review the work of their peers by writing critical responses.
3. Science Narratives: Students then prepare coherent narratives based on the feedback received.
4. Challenge Questions: Students evaluate the quality of different scientific explanations and are redirected to relevant activities to improve their understanding.

What is its pedagogical approach for IBL?

WISE pedagogical approach is to emphase collaborative inquiry, engaging students to both self-monitoring and collaborative reflection. It also help teachers develop a sense of ownership, by providing opportunities for them to reuse, readapt or recreate new projects. Some pedagogical principals are:

1. Making Science Accessible

- Project builds on student ideas and scientific knowledge framework to model the inquiry process
- Students can connect project to personally relevant questions on topics of standards-based curricula

Making Thinking Visible

- Students explore and create personal representations to express their ideas
- Students can access and review multiple representations incorporated into assessments
- Activity promotes learning through representations as well as illustrates the process of inquiry

2. Learning From Others

- Students exchange ideas and learn from each other
- Peers have productive interactions to develop understanding
- Groups of learners develop shared criteria for scientific discourse
- Learners have the opportunity to share their findings after generating their own ideas

3. Promoting Autonomy and Lifelong Learning

- Project engages students in meaningful reflection as critics of diverse scientific information
- Project helps students understand and generalize the inquiry process to diverse science projects
- Project provides opportunities for learning and applying context-embedded content knowledge

SCY- Science created by you

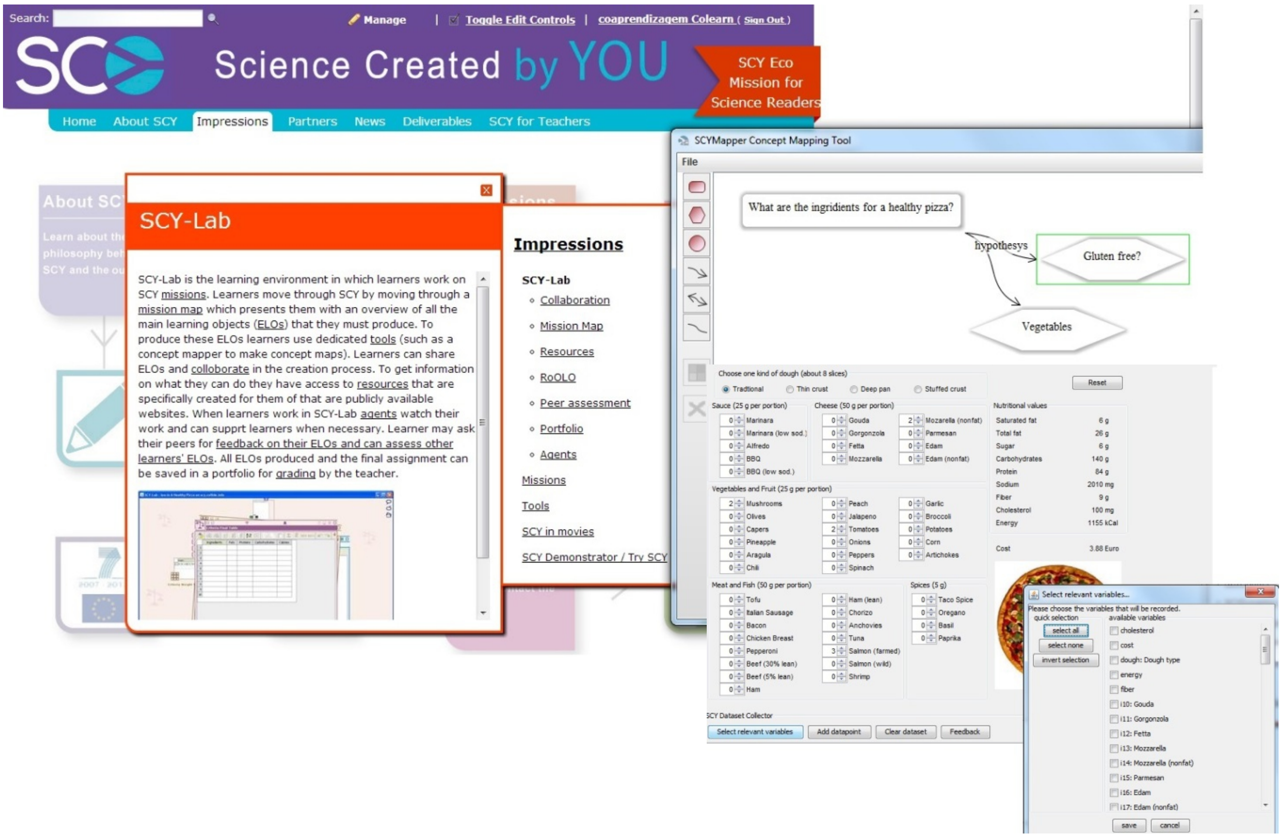

Figure 2 – SCY Science created by you - Colearn Community

What is SCY?

SCY - Science Created by You was developed by a consortium of 12 countries under coordination of Universiteit Twente, supported by the European Commission from March 2008 to February 2012. SCY is a system for students between 12-18 years developing their constructive and productive learning of science and technology. SCY offers some missions which requires a combination of knowledge from different content areas (eg, physics, mathematics, biology, as well as social sciences). Students perform several types of learning activities: experiment, game, share, explain, design, etc.

The configuration of SCY-Lab is adaptive to the actual learning situation and may provide advice to students on appropriate learning activities, resources, tools and scaffolds, or peer students who can support the learning process. In the course of the project, a total of four SCY missions were developed: "the design of a CO2-friendly house", "creating a healthy pizza", "determining water quality", and "forensic DNA".

What are its key features?

SCY (http://www.scy-net.eu/) is based on 'emerging learning objects' (ELOs) that are created by students individually or collaboratively in SCY-Lab, which is the general SCY learning environment on 'missions'.

The SCY approach is enabled by the innovative architecture of SCY-Lab that supports the creation, manipulation, and sharing of ELOs (models, data sets, designs, plans, etc.). The central unit in the SCY architecture is a broker that configures SCY-Lab to unfolding learning processes and activities. For this it uses information from pedagogical agents that exploit techniques of educational data mining to monitor information in the SCY repository that stores the ELOs as well as domain information, the log-files of student behaviour, and the recorded chats between students.

How does it work?

Users can find the detailed instructions for getting started in The teachers' manual, which is available at http://scy-net.eu/web/scycom/manual. The SCY-Lab and SCY-Portal, however, are not available http://scy-net.eu/web/scycom/full-scy-lab-and-missions.

The SCY-Lab digital learning environment provides the look and feel of a computer desktop. However the Using SCY-Lab, the student can navigate through a mission, open assignments, browse through previously made ELOs. For that, they can use these following tools to make new ELOs, communicate with fellow students and customize their workspace:

- SCY-Interview: helps learners to design a good interview.
- SCY-Feedback: is a peer assessment tool with which students can easily ask for and provide feedback on ELOs as they are being developed in a Mission.
- SCY-Data: enables students to process and visualize numerical data sets.
- SCY- Experimental Design: allows learners to write down experimental procedure as task trees.
- SCY-Lighter: is a Mozilla Firefox Add-on for collecting relevant information on the web and saving it into the SCY-Lab.
- SCY-Mapper: makes concept-maps representing ideas as nodes and the relationship between these ideas as links.
- SCY-ePortfolio: is used to build a mission portfolio to be assessed by the teacher.
- SCYAssessment : is a tool with which teachers assess submitted Portfolios (summative assessment).
- SCY-Text: is a simple text editor integrated into SCY-Lab.
- SCY-Uploader: enables students to import external files into SCY-Lab as ELOS (e.g. word documents).
- SCY-Dynamics: is a modelling tool that helps create and simulate graph-based models of complex problems and phenomena.
- SCY-Tagging: is a co-operative tagging tool used by students to tag ELOs in SCY-Lab.
- SCY-Chat: allows learners to communicate with each other in SCY-Lab and thereby collaborate on ELOs.
- SCY-Search: enables students to search the collection of ELOs to find relevant work by themselves or by other learners.
- SCY-Draw: Allow learners to create simple drawings, with elementary drawing capabilities: shapes, freehand drawings, importing images.
- SCY-Simulator: is a multi-purpose simulation tool that is able to show and run simulations.
- SCY-Datacollector: is a means for learners to collect numerical and multimedia data in the field with their mobile devices (based on the Android platform) and store the collections as ELOs. SCY-Formauthor is fully integrated into SCY-Lab and can be used to create forms for data collecting activities.
- Teacher tool: SCY-Authoring offers the teacher the ability to fine-tune a mission and obtain a real-time overview of activity in SCY-Lab.

What is its pedagogical approach for IBL?

SCY uses a flexible and adaptive pedagogical approach to learning based on "emerging learning objects" (ELOs) that are created by learners. the basic ideas behind constructionism focuses on learning by creating knowledge, this construction takes place when students are engaged in building objects SCY's ELOs such as models, concept maps, artefacts, data sets, hypotheses, tables, summaries, reports, plans and lists of learning goals.

In SCY-Lab (the SCY learning system) students work individually and collaboratively on "missions" which are guided by a general socio-scientific question (for example "how can we produce healthier milk?") and fulfilling the mission requires a combination of knowledge from different domains (e.g., physics and mathematics, or biology and engineering).

While on a SCY-mission, students perform several types of learning actions that can be characterised as productive (experiment, game, share, explain, design, etc.), students encounter multiple resources, they collaborate with varying coalitions of peers, and they use changing constellations of tools and scaffolds (e.g., to design a plan, to state a hypothesis etc.). The configuration of SCY-Lab is adaptive to the actual learning situation, advising students on appropriate learning actions, resources, tools and scaffolds, or peer learners that can support the learning process.

weSPOT – Working Environment with Social Personal and Open Technologies for inquiry-based learnin

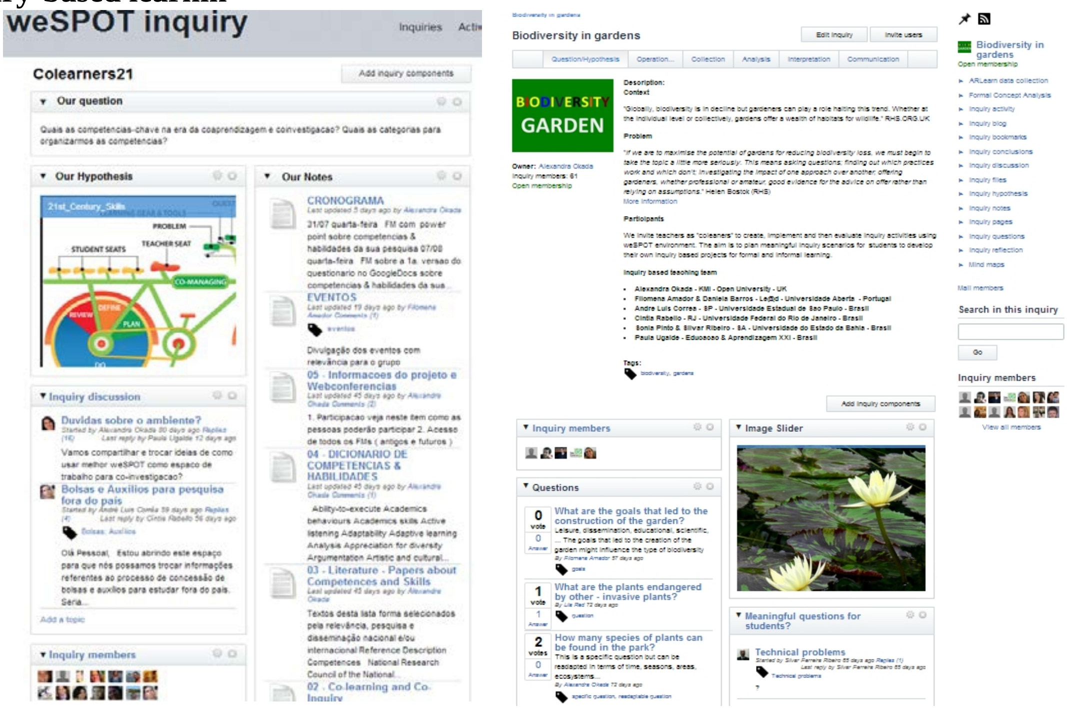

Figure 3 – weSPOT - Colearn Community – individual and collective examples

What is weSPOT?

The weSPOT project, supported by the European Commission from 2012-2015, aims to propagate scientific inquiry as the approach for science learning and teaching in combination with today's curricula and teaching practices.
In inquiry-based learning co-learners take the role of explorers and scientists and are motivated by their personal curiosity, guided by self-reflection, and develop knowledge personal and collaborative sense-making and reasoning.

What are its key features?

weSPOT will create a “Working Environment with Social, Personal and Open Technologies” that supports users (from 12 to 25) to develop their inquiry based learning skills by means of:

- a European reference model for inquiry skills and inquiry workflows,
- a diagnostic instrument for measuring inquiry skills,
- smart support tools for orchestrating inquiry workflows including mobile apps, learning analytics support, and social collaboration on scientific inquiry,
- social media integration and viral marketing of scientific inquiry linked to school legacy systems and an open badge system.

Eight primary test-beds in a European wide approach in 8 European member states

1. ***Food*****:** Examples of plastics contaminating food have been reported with most plastic types. Different countries might have different problems and solutions. Learners involved in this scenario will be acting as chemical engineers and food scientists.

2. ***Biodiversity*****:** Biodiversity is increasingly recognized as critical to human life. Species are more threatened than ever by human activities like urbanization, climate change, deforestation, agricultural expansion, overexploitation of marine ecosystems. To explore these issues, students will investigate different habitats and carry out fieldwork research. Their inquiry projects could be related to breeding program for endangered species, bird populations in a garden, bug populations in a flower bed, fauna in a pond-ecosystem, other food webs or succession.

3. ***Earthquake*****:** Students will download and format near real-time and historical earthquake data and seismogram displays from various sources (e.g. FORTH’s own seismological station, U.S. Geological Survey, Institute of Geodynamics - National Observatory of Athens). Students will create spreadsheets and graphs to explore earthquake magnitude, wave amplitude, energy release, frequency occurrence and location. In a more advanced scenario students could do GIS Mapping and Analysis using free GIS Software.

4. ***Sea*****:** High school students go on ½ year trip across the Atlantic Ocean, on their journey; they have normal class and run the clipper. In addition they explore their environment (water, air, physics on board, astronomy…) in personal projects.

5. ***Energy*****:** Using discussion students should identify disadvantages of the current building from the energy-efficiency point of view. They should try to predict (providing evidence) future energy problems. Forming teams, they will work on developing reasonable ideas for future energy-efficient buildings. Some guidelines to them: What type of new materials for new energy efficient building components with reduced embodied energy to use. What technologies will ensure a high quality indoor environment, keeping in mind Ecology.

6. ***School*****:** The student should provide research on expected changes in the future school. Possible directions:dropping and new courses; the future classroom – real or virtual;new ICTs in education; the role of the teacher; students relationships; new educational approaches; formal vs informal learning, the role of lifelong learning etc. Proposing innovative learning activities, preparing students for new jobs.

7. ***Innovation*****:** The students will reflect their learning environment (or other environments) to determine some of the most pertinent problems, obstacles, “things they do not like”, etc. With the help of a teacher those points will then be contemplated form the view point of what out of that could be changed and what (unfortunately) could not be changed.

8. ***Economy:*** In recent published Economic Complexity Atlas Slovenia is the tenth country with high Economic Complexity Index (ECI), and Bosnia is ranked on 8th place as country which has large ECI and small GDP (so it is expected that it will develop fast in next period). It would be interesting to research how these facts can be used for faster economic and social developments.

How does it work?

weSPOT aims for five main products: a) diagnostic instrument for inquiry skills b) inquiry reference model c) Inquiry workflow services for shared workflow definitions d) mobile clients for inquiry support e) collaboration clients and reflection clients inquiry analytics.

weSPOT will provide students with the ability to build their own inquiry-based learning environment, enriched with social and collaborative features. Smart support tools will be offered for orchestrating inquiry workflows, including mobile apps, learning analytics support, and social collaboration on scientific inquiry. These offerings will allow students to filter inquiry resources and tools according to their own needs and preferences. Students will be able interact to with their peers in order to reflect on their inquiry workflows, receive and provide feedback, mentor each other, thus forming meaningful social connections that will help and motivate them in their learning. From a learner's perspective, this approach will offer them access to personalized bundles of inquiry resources augmented with social media, which they will be able to manage and control from within their personal learning space. Inquiry workflows can be described by graphical representations, whose aim is to help users visualize and orchestrate their inquiry projects. These representations are a key to personal as well as social inquiry based learning. Learners can link diverse steps of their investigation and represent their scientific reasoning by integrating graphically their questions, hypothesis, concepts, arguments and data. Inquiry workflows play an important role as visual strategy and mediating tools in scientific reasoning.

It should be noted though, that there is a significant distinction between the user-centric approach of the Web 2.0 paradigm and the learner-centric approach of weSPOT. This is because a social learning environment is not a just a fun place to hang out with friends, but predominantly a place where learning takes place and it does not take place by chance but because specific pedagogies and learning principles are integrated in the environment.

What is its pedagogical approach for IBL?

The weSPOT's model aims to provide teachers and learners with the support and the technology tools, so as learners become able to find the optimal level of inquiry to match their needs and be facilitated in the transition from passive towards active learning.
weSPOT will employ a learner-centric approach in secondary and higher education that will enable students to:

- Personalize their inquiry-based learning environment.
- Build, share and enact inquiry workflows individually and/or collaboratively with their peers.

The project focuses on *inquiry-based learning* with a theoretically sound and technology supported personal inquiry approach, supporting four levels of inquiry based learning:

- ***confirmation***: students are provided with the question and procedure (method) as well as the results, which are known in advance
- ***structured***: the learning goal is to introduce students to the experience of conducting investigations or practicing a specific inquiry skill, such as collecting and analyzing data
- ***guided***: the question and procedure are still provided by the teacher. Students, however, generate an explanation supported by the evidence they have collected

• ***open***: students have the opportunity to act like scientists, deriving questions, designing and carrying out investigations as well as communicating their results

Conclusion

Some innovative approaches through digital technology have been emerged in formal education to support students learn about science by acting as collaborative open scientists. Based on virtual learning environments for non-formal or informal scenarios, new opportunities have also engaged learners, educators and researchers to interact through their social networks or communities of practices.

This paper discussed tools and environments to promote scientific citizenship, responsible environmental attitudes as well as digital and scientific culture appropriation. These new approaches based on co-inquiry might be an useful strategy for learning about how science is developed rather than focusing only on learning science facts.

Formal education has primarily the challenge of equipping citizens with science knowledge, skills and attitude for developing scientific literacy underlying important and most frequent issues. Different scenarios might enrich learners' motivation and understanding through software tools, mobile devices, and different.

Acknowledgement

The illustrations about the applications and software tools were created by COLEARN community.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) weSPOT project and ENGAGE project.

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