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Inquiry-Based Learning on the Cloud

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Handbook of Research on Cloud-Based STEM Education for Improved Learning Outcomes

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Chapter 19
Inquiry–Based Learning on the Cloud:

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ABSTRACT

Cloud Learning Environments (CLEs) have recently emerged as a novel approach to learning, putting learners in the spotlight and providing them with the cloud-based tools for building their own learning environments according to their specific learning needs and aspirations. Although CLEs bring significant benefits to educators and learners, there is still little evidence of CLEs being actively and effectively used in the teaching and learning process. This chapter addresses this issue by introducing a European initiative called weSPOT (Working Environment with Social, Personal and Open Technologies for Inquiry-based Learning) for supporting and enhancing inquiry-based learning in STEM education via a cloud-based inquiry toolkit. The chapter presents evidence of using this toolkit within a case study that investigates how a secondary education community of students / co-learners selects information sources on the web and identifies factors associated with the reliability of information sources during their collaborative inquiry (co-inquiry) project in online environments.

INTRODUCTION

Learning Management Systems have dominated e-learning for several years. They have been widely used by academic institutions for delivering their distance learning programmes, as well as for supporting their students outside the classroom. They have also been established in the business sector as the mainstream platform for delivering training services to employees. A Learning Management System (LMS) is an online software application offering facilities for student registration, enrolment into courses, delivery of learning materials to participants, student assessment and progress monitoring. Popular examples of LMS used by the academic as well as the business world include Blackboard[1], Moodle[2], and CLIX[3].

However, the advent of Web 2.0 has altered the landscape in e-learning. Learners nowadays have access to a variety of learning tools and services

on the web. These tools and services are usually provided by different vendors and in many cases are open and free. Repositories like Wikipedia[4], YouTube[5], SlideShare[6] and iTunes U[7] offer access to a wide range of learning materials for free. Augmenting and configuring the diverse and distributed Web 2.0 tools and services in order to address the needs and preferences of individual learners are a significant challenge for modern online learning environments.

The transition from the traditional e-learning approach of LMS to Web 2.0 e-learning solutions bears significant benefits for learners. It puts emphasis to their needs and preferences, providing them with a wider choice of learning resources to choose from. The European project ROLE (Responsive Open Learning Environments)[8] has explored this transition within a variety of learning contexts and test-beds (Kroop, Mikroyannidis, & Wolpers, 2015). One of the these test-beds has been provided by the Open University[9] and concerns the transition from formal learning, where courses are exclusively prepared and delivered by educators, towards informal learning, where the learner is in control of the whole learning process. This transition is being implemented within the Open University test-bed as a transition from the LMS towards the Personal Learning Environment (Mikroyannidis & Connolly, 2015).

The Personal Learning Environment (PLE) is a facility for an individual to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences. The PLE follows a learner-centric approach, allowing the use of lightweight services and tools that belong to and are controlled by individual learners. Rather than integrating different services into a centralised system, the PLE provides the learner with a variety of services and hands over control to her to select and use these services the way she deems fit (Chatti, Jarke, & Frosch-Wilke, 2007; Mikroyannidis, Kroop, & Wolpers, 2015).

The Cloud Learning Environment (CLE) extends the PLE by considering the cloud as a large autonomous system not owned by any educational organisation. In this system, the users of cloud-based services are academics or learners, who share the same privileges, including control, choice, and sharing of content on these services. This approach has the potential to enable and facilitate both formal and informal learning for the learner. It also promotes the openness, sharing and reusability of learning resources on the web (Malik, 2009).

The CLE is enabled by the technological infrastructure of Web 2.0, employing popular and established technologies such as HTTP, XML, and SOAP. This makes it an ideal platform for the easy sharing of online resources, thus benefiting not only learners, but also those who design, produce, and publish creative digital works for educational purposes. This is a critical requirement for achieving a sustainable knowledge community, as not only consumers but also active producers are essential (Hu & Chen, 2010).

The web services employed by the CLE have made a significant impact on the design and delivery of e-learning resources (Vossen & Westerkemp, 2003). Unlike the traditional approach to courseware delivery followed by the LMS, where the focus is on the aggregation of learning objects, the CLE supports composition. Courseware units can be represented by cloud services and invoked within a workflow model (Anane, Bordbar, Fanyu, & Hendley, 2005). The composition and invocation of these services offer greater flexibility in designing and delivering learning paths.

Inquiry-based Learning (IBL) brings together the PLE and CLE paradigms by enabling learners to take the role of an explorer and scientist as they try to solve issues they came across and that made them wonder, thus tapping into their personal feelings of curiosity (Bell, Urhahne, Schanze, & Ploetzner, 2010). IBL supports the meaningful contextualization of scientific concepts by relating them to personal experiences. It leads to structured knowledge about a domain and to more skills and competences about how to

carry out efficient and communicable research. Thus, learners learn to investigate, collaborate, be creative, use their personal characteristics and identity to have influence in different environments and at different levels (e.g. me, neighbourhood, society, and the world).

Co-learning (collaborative open learning) has been taking place in informal ways mainly among users who master technologies in the context of open platforms, resources and social networks (Okada, 2007, 2013). Advanced skills and competences are essential in order to take full advantage of both co-learning and co-inquiry. Nevertheless, technological skills need to be developed in an integrated way with scientific literacy skills and for that, easy-to-use technologies integrated to a collaborative online environment might be helpful in the different stages of co-inquiry.

Co-inquiry is a cooperative process of raising important questions with experts or specialists, integrating relevant information and generating acceptable lines of thought based on scientific assumptions and knowledge areas (Heron, 1996). This process requires and provides opportunities for developing essential skills in scientific inquiry: formulating scientific questions, defining methodologies, collecting data, implementing analysis, discussing result interpretations and communicating research results with scientific explanations for feedback, evaluation and dissemination.

Co-learning based on co-inquiry aims at the collaborative construction of knowledge, in which co-learners are able to expand their social networks, integrate open learning with collective research and co-author collaborative productions. It is enriched through the interactive participation for co-creation and peer review in a much more open, critical and innovative way. Co-learners as co-investigators play important roles, such as *entrepreneurs* aware of individual and collective objectives and strategies, *technical* users of technologies, *proactive* participants in open platforms, *interactive* peers, *reflective* reviewers, *scientific* participants and *innovative* practitioners.

Competences for co-learning and co-inquiry can be represented by the "C" model shown in Figure 1, which is grounded on four foundational concepts: digital literacy, communication-collaboration, critical-creative thinking and scientific literacy.

The "C" model includes seven groups of skills described below:

1. **PLAN:** Goals, time, priorities, challenges, pros/cons and self-management. Participants are able to identify common objectives and other requirements to achieve expected and unexpected outcomes during the process.
2. **USE:** Various tools - search engines, hypermedia, translators, notifications, upload/download, tags, RSS feeds and applications. Participants are able to use open platforms by searching, aggregating, generating and disseminating content.
3. **SHARE:** Questions, links, ideas, comments, annotations and open content. Participants are able to contribute to the platform including a diversity of files, messages and content on wiki pages.
4. **MANAGE:** Networks, support, organisation, feedback, interests, consensus, review and improvement. Participants are able to manage contacts and content for improving the collective discussion.
5. **ELABORATE:** Mapping, interpretations, analysis, synthesis, systematisation and self-assessment. Participants are able to reflect, co-produce and assess diverse types of collective representations.
6. **DEVELOP:** Scientific questions, literature review, methodology, procedure, analytic discussion, scientific production, peer-review and dissemination. Participants are able to improve their learning through a set of activities for scientific research.
7. **CREATE:** Theories, best practices, methodologies, policies, higher impact, and derived research. Participants are able to disseminate

Figure 1. "C Analysis Model"–Competences for co-learning and co-inquiry (Okada, 2014)
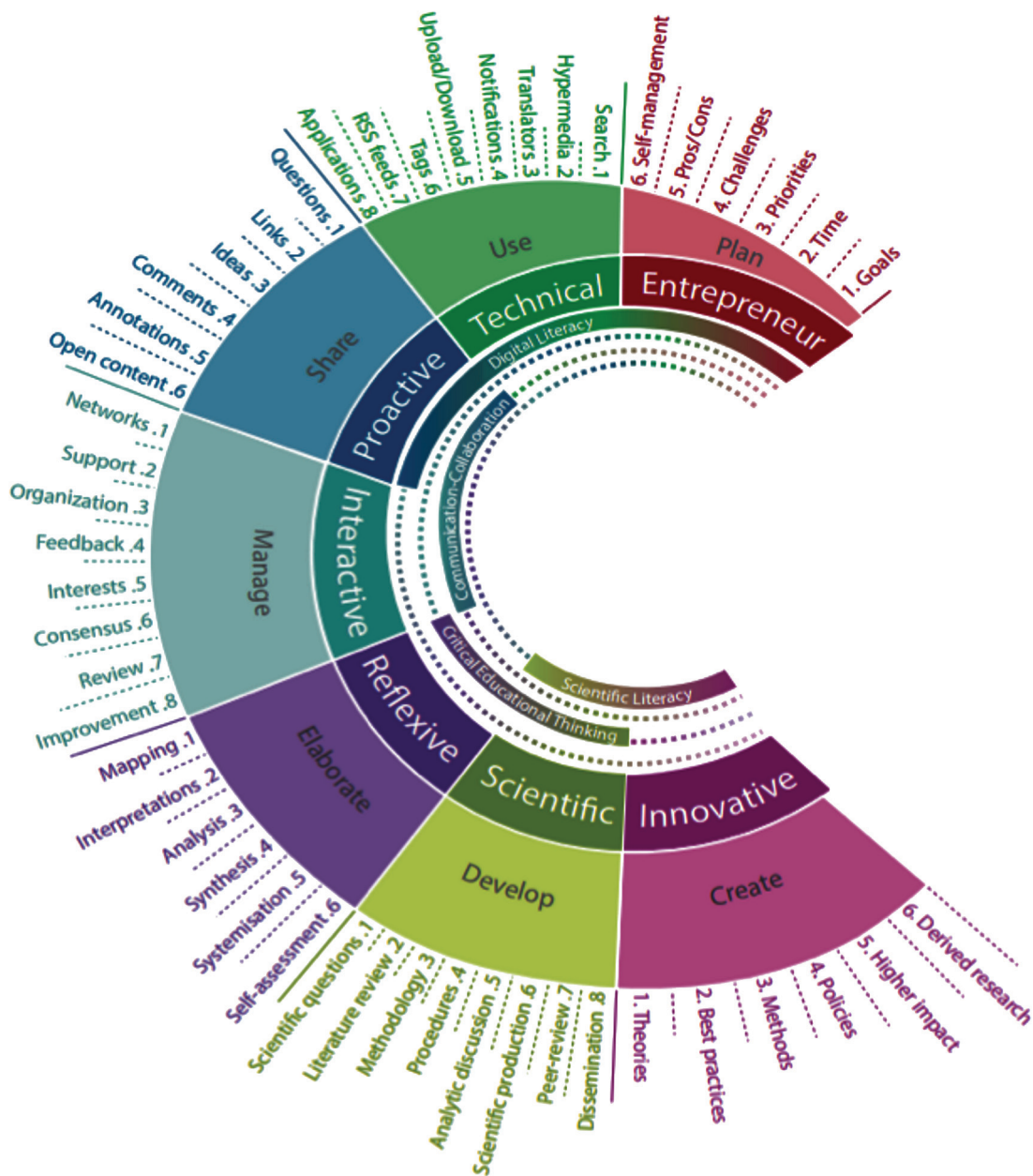
their co-authorships and exploit new work or studies through new publications and research opportunities.

weSPOT[10] (Working Environment with Social, Personal and Open Technologies for Inquiry-

based Learning) is a European project, aiming at propagating scientific inquiry as the approach for STEM education in combination with today's curricula and teaching practices (Mikroyannidis, et al., 2013). weSPOT aspires to lower the threshold for linking everyday life with science teaching

in schools by technology. weSPOT supports the meaningful contextualization of scientific concepts by relating them to personal curiosity, experiences and reasoning. In short, weSPOT employs a collaborative learner-centric approach in secondary and higher education that enables students as co-learners to:

- Personalise their IBL environment via a widget-based interface together with their peers.
- Build, share and enact inquiry workflows individually and/or collaboratively with other co-learners.

THE weSPOT PEDAGOGICAL APPROACH

As we have learned from the ROLE project, what is often missing from the PLE is not the abundance of tools and services, but the means for binding them together in a meaningful way (Mikroyannidis & Connolly, 2012). weSPOT attempts to address this issue by providing ways for the integration of data originating from different inquiry tools and services. Most importantly though, weSPOT enables the cognitive integration of inquiry tools by connecting them with the student's profile, as well as her social and curricular context. Individual and collaborative student actions taking place within different inquiry tools update the learning history and learning goals of the students, thus providing them and their tutors with a cohesive learning environment for monitoring their progress.

The Web 2.0 paradigm offers new opportunities for social learning by facilitating interactions with other learners and building a sense of connection that can foster trust and affirmation (Weller, 2009). Social learning, according to Hagel, Seely Brown, and Davison (2010), is dictated by recent shifts in education, which have altered the ways we catalyse learning and innovation. Key ingredients in this evolving landscape are the quality of interpersonal relationships, discourse, personal motivation, as well as tacit over explicit knowledge. Social media offer a variety of collaborative resources and facilities, which can complement and enrich the individual's personal learning space.

weSPOT provides students with the ability to build their own IBL environment, enriched with social and collaborative features. This IBL environment offers cloud-based tools for orchestrating inquiry workflows, including mobile apps, learning analytics support, and social collaboration in the context of scientific inquiry. These offerings allow students to filter inquiry resources and tools according to their own needs and preferences. Students are able to interact 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 offers them access to personalised bundles of inquiry resources augmented with social media, which they can manage and control from within their personal learning space.

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 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. Quite often, what students want is not necessarily what they need, since their grasp of the material and of themselves as learners, is incomplete (Shum & Ferguson, 2010).

In order to transform a Web 2.0 environment into a social learning environment, students need to be constantly challenged and taken out of their comfort zones. This raises the need of providing students with the affirmation and encouragement that will give them the confidence to proceed with their inquiries and investigations beyond their

existing knowledge. weSPOT addresses this issue through a gamification approach, by linking the inquiry activities and skills gained by learners with social media. In particular, this approach is defining a badge system that awards virtual badges to students upon reaching certain milestones in their inquiry workflows. This approach aims at enhancing the visibility and accrediting of personal inquiry efforts, as well as raising motivation, personal interest and curiosity on a mid-term effect.

THE weSPOT INQUIRY SPACE

The weSPOT inquiry space[11] (Mikroyannidis, 2014a, 2014b) is a personal and social IBL environment that reuses and extends the Elgg open-source social networking framework[12]. The weSPOT inquiry space has been built based on the following requirements:

- A widget-based interface enables the personalisation of the inquiry environment, allowing teachers and co-learners to build their inquiries out of mash-ups of inquiry components.
- Co-learners can connect with each other and form groups in order to build, share and perform inquiries collaboratively.

Inquiries in the weSPOT inquiry space follow the weSPOT inquiry model shown in Figure 2 (Protopsaltis, et al., 2014). The weSPOT inquiry model is based on six phases, placed within the context that represents the phases that researchers need to go through in order to conduct their research. These six phases are: problem, operationalization, data collection, data analysis, interpretation, and communication. Each phase also includes a number of activities to support teachers and co-learners in their inquiries through a suggestive "check list". Participants can start from the problem phase but also from any other phase depending on their lesson focus. Not all phases and sub-phases need to be completed for a successful inquiry. Teachers and co-learners can choose the

Figure 2. The weSPOT inquiry model
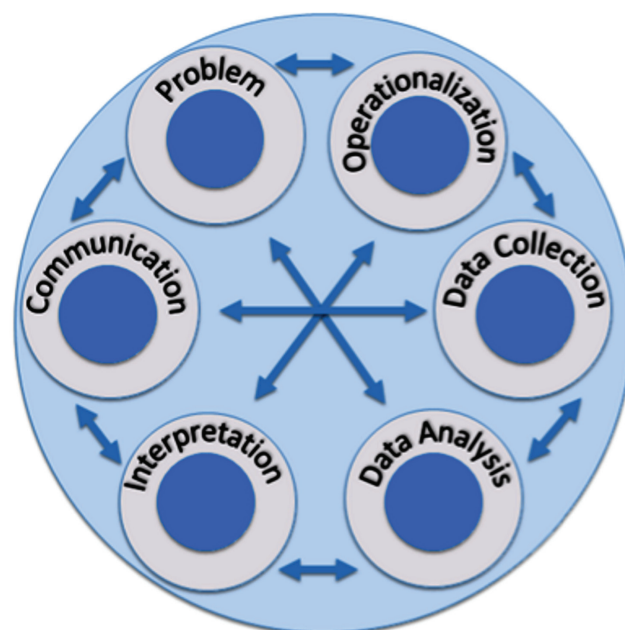
ones that fit their needs. A detailed description of the weSPOT IBL model can be found at the weSPOT teachers' online guide[13].

The weSPOT inquiry space enables its users (teachers and co-learners) to create mash-ups of their preferred inquiry components, assign them to different phases of an inquiry, share them with other users and use them collaboratively in order to carry out an inquiry. When creating a new inquiry, users are provided with a set of recommended inquiry components for each phase of the inquiry. They can then customise these sets of components by adding, removing and arranging inquiry components for each phase of the inquiry.

As shown in Figure 3, the weSPOT inquiry space offers a variety of inquiry components to teachers and co-learners, enabling them to create, edit and share hypotheses, questions, answers, notes, reflections, mind maps, etc. Some of these components communicate with the APIs of REST web services offered by external tools. Examples of such external tools are mobile apps that allow students to collect different types of data (photos, videos, measurements, etc.) with their smartphones and share them with other inquiry members via the weSPOT inquiry space. A learning analytics dashboard visualises all the activities taking place within an inquiry, enabling teachers to monitor the progress of their students and students to self-monitor their progress. Teachers also have the ability to create and award badges to the students that have reached certain milestones in an inquiry. These badges are displayed in the profiles of the students.

Figure 4 shows an example mash-up of inquiry components for a particular phase of an inquiry that explores the everyday uses of batteries. The phase is labelled "Discuss the findings" and corresponds

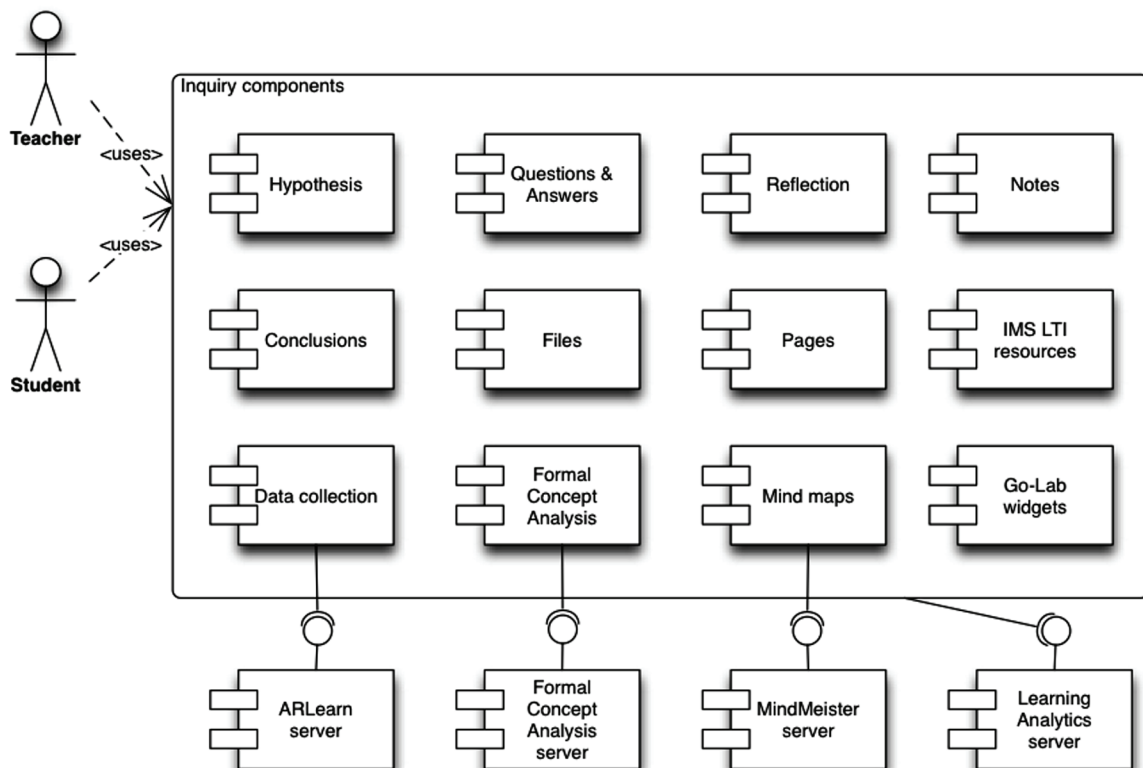*Figure 3. The component-based architecture of the weSPOT inquiry space*

Figure 4. A mash-up of inquiry components for discussing and interpreting the findings of an inquiry

to the "Interpretation / Discussion" phase of the weSPOT IBL model. In this phase, the members of the inquiry use collaboratively three inquiry components in order to discuss and interpret their findings. They use the "Discussion" component to exchange their views asynchronously in discussion forums. They also use the "Questions" component in order to provide answers to the key research questions of this inquiry and vote for the best answers. Finally, they create and share mind maps containing interpretations of their findings via the "Mind maps" component.

Users also have access to external resources and widgets and can use them in their mash-ups

together with the inquiry components offered by the weSPOT inquiry space. These resources and widgets originate from external LMSs, such as Moodle or Blackboard. For this purpose, we have implemented the IMS Learning Tools Interoperability (LTI) specification[14], thus allowing teachers to include in their inquiries either course components from LMSs, such as discussion forums or quizzes, or entire LMS courses.

Additionally, we have integrated an external widget repository offered by the European project Go-Lab[15].

Go-Lab is a European project aiming to encourage young people to engage in science topics, acquire scientific inquiry skills, and experience the culture of doing science by undertaking active guided experimentation. Targeting students from 10 to 18 years old, Go-Lab offers the opportunity to perform personalized scientific experiments with online labs in pedagogically structured and scaffold learning spaces that are extended with collaboration facilities. The Go-Lab widgets allow users to perform certain IBL activities, such as create graphs to visualise the data that they have collected and analyse them.

A CASE STUDY ON CO-LEARNING AND CO-INQUIRY

The purpose of this case study is to investigate the use of a cloud-based toolkit and an IBL methodology within STEM education in a secondary school. As a starting point, both educators and learners shared their research questions. Educators were interested in investigating how co-learners select information sources on the web and identified factors associated with the reliability of information sources during their collaborative inquiry (co-inquiry) project in online environments. Learners were focussed on analysing biodiversity on their school garden by identifying the influence of abiotic factors (Correa, Rabello, & Okada, 2014).

This research is based on qualitative content analysis implemented on the online platform weSPOT for inquiry-based learning projects. This study, conducted with 12 co-learners in a Brazilian public secondary school, investigated information literacy skills for co-learning and co-inquiry. Although students are responsive of the importance of using and comparing different sources of information they seem not to be aware of the reliability factors using the first results on search engines or popular websites such as Wikipedia which points to the necessity of developing learners' information literacy skills. Online environments and teacher's guidance are essential to support co-learners in developing competences which they will use throughout their life and in their work, particularly related to collaborative research and knowledge building.

In order to investigate how secondary co-learners search and select information sources on the web, educators divided it into two different phases, which comprised the use of different research instruments for data collection:

- A structured inquiry project using the weSPOT platform: online forum, questions, data collection;
- An online questionnaire containing 10 closed questions and 4 open questions.

In order to analyse school garden biodiversity, co-learners organised a discussion forum and mobile data collection for sharing pictures. The forum was used in association with ARLearn, an application integrated to weSPOT that enables co-learners to take pictures using their mobile phones during field trips, so that co-learners could capture images and then discuss them in the weSPOT forum as the images captured on their mobile phones were automatically sent to the weSPOT platform. Thus, co-learners took pictures of the school garden and then engaged in an online forum to answer two questions: (1)

How many living species are present in the picture you took? (2) Which abiotic factors influenced the presence of these living species in this garden?

Based on the first question in the forum, educators also asked co-learners the following questions: (1) "Supposing you did not know the meaning of species and/or abiotic factors, how would you search for information so that you could answer the previous questions?" and (2) "How would you confirm that the information you collected is reliable?" Based on these questions and the pictures taken with their mobile phones during the field trip to the school garden sent to weSPOT via the ARLearn app, six co-learners shared their concepts related to the theme and the information sources they would use in case they did not know the answers.

During the second phase of the research a questionnaire was adapted according to the "C" graphic of key competences for co-learning and co-inquiry focusing on students' digital literacy skills (Okada, 2014; Okada, Serra, Ribeiro, & Pinto, 2015). The online questionnaire was designed using Google Drive Forms and sent to co-learners by e-mail. Twelve co-learners submitted their answers.

The questionnaire comprised a total of 10 closed questions aimed at identifying co-learners' profiles and their digital literacy skills and 4 open questions aimed at investigating how co-learners select information sources and evaluate their reliability. The researchers conducted the analysis using the Compendium knowledge mapping tool[16].

Figure 5 shows the "Biodiversity in the school garden" inquiry as deployed in the weSPOT inquiry space. In this scenario, the inquiry components were selected by the science teacher based on 5 phases instead of 6. This means that the science teacher decided to eliminate the "communication" phase of the inquiry and include fewer activities for performing the inquiry during 3 weeks.

During the first week of the inquiry, co-learners were focused on the "problem" phase by reflecting on the 8 activities described in Table 1. For

this purpose, their science teacher selected the 6 inquiry components in the weSPOT inquiry space (see Table 1).

During the second week, co-learners were focused on the "operationalization", "data collection" and "data analysis" phases. They reflected on 10 activities using the inquiry components in the weSPOT inquiry space described in Table 2.

In the third week of the inquiry, co-learners were focused on the "interpretation" (results) phase and reflected on the 5 activities described in Table 3. For this purpose, their science teacher selected 1 inquiry component in the weSPOT inquiry space (see Table 3).

FINDINGS AND LESSONS LEARNED

Evidence from interviews and interactions in weSPOT categorised in the "C" model (Figure 1) shows that inquiry-based learning environments can be useful for supporting co-learners to manage next steps towards social and self-learning by personalised inquiry phases and learning analytics about their participation. In this case study, the participating co-learners were encouraged to share more ideas and suggestions through various weSPOT widgets and apps, including wiki pages, mind maps and mobile data collection apps. They also added votes and rates to colleagues' contributions and peer-review comments, including assessing reliability of information sources. Finally, they were able to retrieve and filter information through tags and RSS feeds.

Additionally, it was observed that teachers play an important role for:

- Sharing guidelines with co-learners to check reliability of information sources.
- Encouraging co-learners to check and assess references.
- Using advanced search engines and collaborating with an open repository.

Figure 5. A mash-up of inquiry components used in the inquiry "Biodiversity in the garden" (Correa, et al., 2014)

Table 1. Activities and inquiry components related to the 1ˢᵗ phase of the "Biodiversity in the school garden" inquiry

Phase 1: Problem			
Activity	**Inquiry Component**	**Refers to**	**Example**
Embedding	Notes	The current state of research and discoveries	Science teacher can introduce the concept of biodiversity globally and locally. Co-learners can share notes and examples in their school garden.
Existing knowledge	Mind map	What students know already about the topic	Co-learners can also represent familiar concepts in a mind map (e.g. species, organisms).
Language/ definitions	Questions	Terms and definitions for the field	Teacher can select new concepts for curious questions (e.g. biotic and abiotic factors).
Ethics	More Info	Ethical implications	Learners need permission to collect data of people and be aware of other issues (e.g. plant, animal).
Empirical meaning	Question Comments	Verifiable or provable issue	Co-learners can discuss how to check empirical evidence to support or reject their question.
Discussion/ Argumentation	Forum discussion	Arguments to support their decisions	Co-learners can discuss their reasoning to explain more elaborated and relevant questions.
Question	Question	Good scientific questions	Co-learners can review final questions with rates and votes.
Hypothesis	Hypothesis	Idea to be tested	Co-learners can predict possible ideas that address scientific questions (e.g. "Some biotic and abiotic factors might influence biodiversity in schools' gardens").

● Helping co-learners combine various sources of reliable information.

Figure 6 and Table 4 summarise relevant data from the co-learners' interactions and include data from the survey embedded in weSPOT based on the C analysis model for co-learning and co-inquiry. This image visualises key factors that might contribute to co-learners' developing their competences. Model C was also applied to identify competences and skills apart from scientific literacy. weSPOT offers a diagnostic instrument for analysing skills; however, Model C was selected in the study considering that the diagnostic instrument skills were not completely developed. Model C was also useful to plan the

following research activities and inquiry-based tasks to complete this project.

Based on the new functionalities, which will be available soon in the weSPOT toolkit during the next pilot studies, educators and researchers aim to encourage co-learners to analyse pros and cons, plan their social and self-learning path, use tags and RSS feeds, share open content, manage better organisation of their groups, feedback, reviews, elaborate interpretation, analysis, synthesis, including self-assessment, develop their scientific explanations with peer-reviews, and create new inquiry projects with high levels of autonomy for a collaborative guided inquiry. They will be able to apply the "C" graphic and diagnostic instrument shared in the weSPOT to visualise the areas, phases and skills that they want to develop in

Table 2. Activities and inquiry components related to the 2ⁿᵈ, 3ʳᵈ and 4ᵗʰ phases of the "Biodiversity in the school garden" inquiry

Phase 2: Operationalization			
Activity	**Inquiry component**	**Refers to**	**Example**
Indicators	Mind map	Aspects to be measured and how	Co-learners can use some sensors to measure temperature, humidity, wind, etc. and register in a map plan.
Predictions	Hypothesis/ comments	How one can demonstrate that a hypothesis is true	Co-learners then can specify how indicators and other factors can support their predictions with comments.
Resources	Mobile collection	Resources students will need to conduct their inquiry	Teachers and co-learners can establish the mobile data collection.
Methodology	Reflection	Method to conduct the inquiry, e.g. qualitative or quantitative, experiment or observation, etc.	If it is necessary they can establish a survey (using Google forms) and/or quiz.
Phase 3: Data Collection			
Activity	**Inquiry Component**	**Refers to**	**Example**
Tools	Mobile data collection and surveys	Tools for collecting data	Co-learners and educators can establish mobile collection components: photo, video, audio, text, numerical values and Google forms for surveys.
Information foraging	Mobile data collection	Validation of the information. Is it reliable and trustworthy?	Co-learners with teachers can establish criteria for rating and tagging data related to reliability and trustworthiness. However, mobile collection does not allow tagging data, including source, location and time.
Documentation	Mobile data collection	Systematic observation	Co-learners should be encouraged to include a systematic comments on data collected (images, videos, audio etc.). However, mobile collection does not allow users to include comments.
Phase 4: Data Analysis			
Qualitative analysis	Tagging interface	Qualitative analytical procedures	Co-learners should be encouraged to group data by analytical tags and reflect on new tags and groups. However, mobile collection does not allow grouping data.
Visualisation	Domain structure Excel graphs	How to represent data for visual analysis (e.g. graphs, clouds)	Co-learners should be encouraged to create graphics, schemes, clouds and new visualisation for data analysis. However, there is a few limited visual tools and data from inquiry components that are not integrated; that means students must copy and paste manually in Excel to create a graph.
Discussion/ Argumentation	LiteMap external tool	Argumentative reasoning	Co-learners should be encouraged to develop argumentation. However, there is not an argumentation tool integrated in the weSPOT inquiry space. An alternative is LiteMap but students must copy and paste information and evidence manually to create argumentation.

Table 3. Activities and inquiry components related to the 5th phase of the "Biodiversity in the school garden" inquiry

Phase 5: Interpretation (Results)			
Activity	**Inquiry Component**	**Refers to**	**Example**
Embedding	**Conclusion**	Obtained results in relation to existing theories	Co-learners should be encouraged to connect knowledge to explain their scientific explanation. However, for that, they must review mind maps, notes, reflections, references, question, hypothesis and other components and bring content manually to a conclusion wiki page.
Confirmation/ falsification	**Conclusion**	Confirm or reject the inquiry hypothesis	Co-learners should be encouraged to revise their hypothesis content and comments to include in their report with enough explanation. However, again they must bring (copy/paste) relevant content manually to a conclusion wiki page.
Relevance	**Conclusion**	The value and the meaning of the obtained results	Co-learners should be encouraged to review their own relevant data and results with explained annotation. However, another challenge is to visualise most relevant data and connections.
Discussion/ Argumentation	**Conclusion**	Evidence based argumentative reasoning	An alternative is LiteMap but students must copy and paste information and evidence manually to create argumentation.
Writing	**Conclusion**	Scientific report	Co-learners can be encouraged to export only relevant content of an inquiry project to prepare the final writing; however, the platform allows them only export full content without connections.

order to complete successfully their collaborative inquiry projects.

This study analysed an authentic scenario of a Brazilian public secondary school whose group of co-learners are frequently small due to non-attendance rates and drop-out rates, which are still high (Correa, et al., 2014). Participants had a few problems with internet connection as well as access to weSPOT, whose platform was in development. Some inquiry components were not completely developed; they could not test it, such as the learning analytics dashboard and the badges.

Both the participating educators and co-leaners were asked to indicate the key benefits of the weSPOT inquiry space. The responses of the educators are summarised as follows:

1. Flexibility to co-design the co-inquiry based on the interests and needs of the community of participants (teachers and co-learners).
2. Combining research questions that are co-related and using different functionalities to interact and provid feedback: e.g. rating, voting, and tagging.
3. Promoting collaboration in different stages, phases and components of a co-inquiry.

The key benefits of the weSPOT inquiry space for the co-learners were indicated as follows:

1. Easy-to-use components for planning a collaborative inquiry project.

Figure 6. "C" graphic about key competences for co-learning and co-inquiry
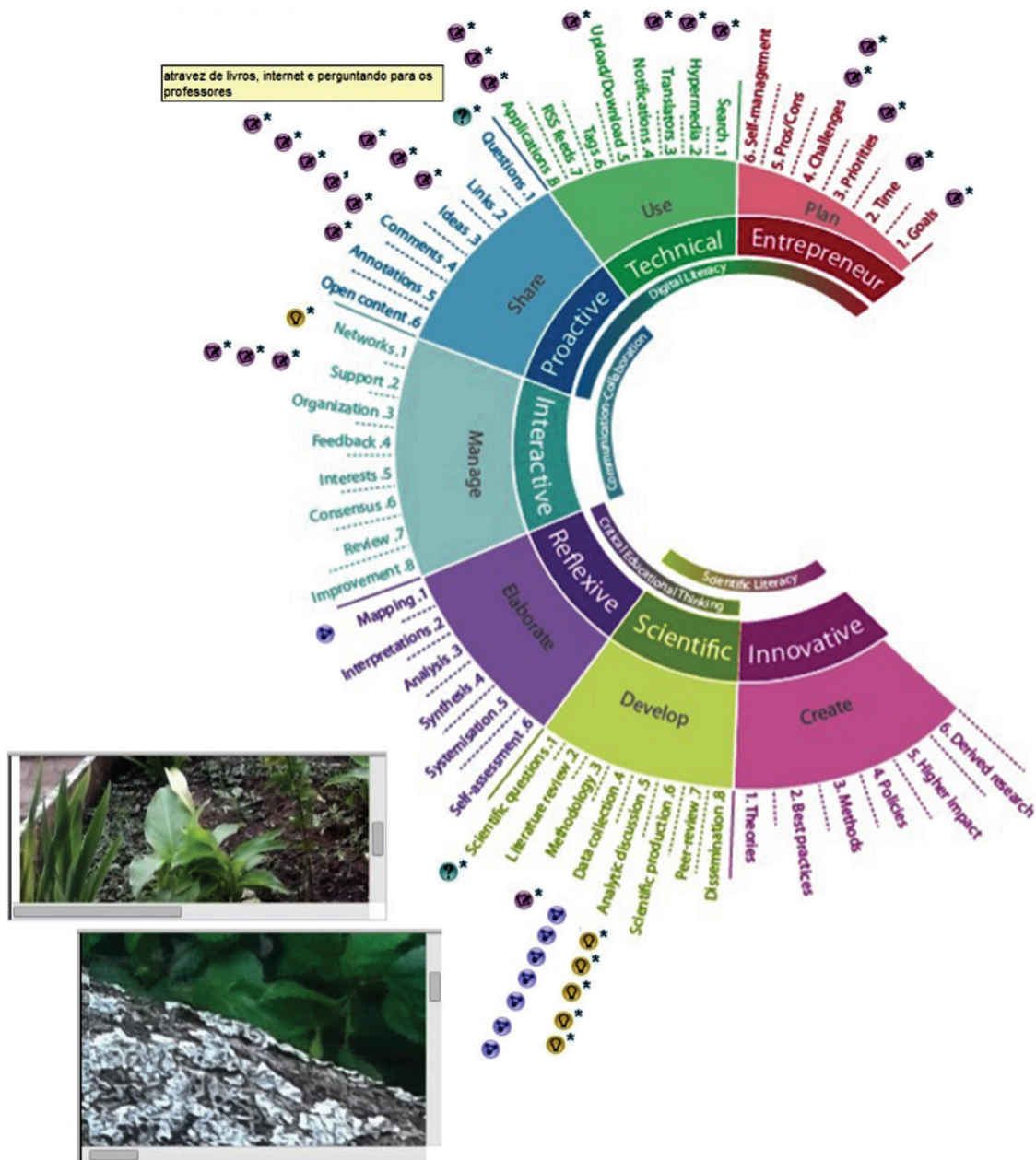
2. Structured environment with phases and components that can be accessed based on their needs.
3. Mobile interfaces are useful for sharing information and data anywhere and anytime.

Finally, both the educators and the co-learners identified the following key challenges of the weSPOT inquiry space:

1. Data analysis due to the lack of tools for annotating, tagging photos and group data.

Table 4. The weSPOT toolkit functionality used for co-learning and co-inquiry during the "Biodiversity in the school garden" inquiry

Categories	weSPOT Toolkit Functionality	Example
Goals	Inquiry [more Info]	To identify abiotic and biotic factors in the school garden with explanation of the concepts.
Time	Inquiry [more Info]	Activities were developed during science lessons.
Priorities	Rating	Students and teachers could use vote and rating to establish their priorities and visualise them using learning analytics dashboard.
Challenges	● Forum ● Email	● Problems described in the Forum: some photos taken did not appear in the system. ● Problems listed through email: internet access.
Search	Search in this inquiry	Students could search specific content to avoid duplication.
Hypermedia	Collaborative interfaces	Students could use most of the collaborative areas (forum, questions, notes, conclusion and mind maps) to add hypermedia.
Translators	Google Translator	Translator was useful to check description of interfaces which were in English and not available in Portuguese.
Up/Download	Attachments	Students could upload and download images that were not available in data (due to technical problems).
Applications	● Videoconference ● Compendium ● PowerPoint	● Science teacher, Participants and project coordinator organised a videoconference to discuss the project. ● Participants created this figure (Figure 6) in Compendium. ● Participants created a poster in PowerPoint to present results.
Questions	Question	What were abiotic and biotic factors in the school garden with explanation?
Ideas	● Answers to questions ● Notes ● Mind map	● Students could share their ideas, listing possible answers. ● Educators could include their ideas, including notes. ● All participants could contribute more ideas in MindMeister.
Comments	Most of the tools, e.g. forum, questions, hypotheses, notes, etc.	The only interface where students were not able to share comments was data collection, which made it difficult for them to analyse photos. They had to use another software tool.
Annotations	Notes	Students had difficulty sharing their notes; however, the educator researcher summarised annotations using notes.
Networks	Members	Members of this inquiry constituted a network of participants from a Brazilian school and educational technologists from the UK.
Support	● Forum discussion ● Notes ● Email	Technical support was provided by participants through three interfaces: forum, teachers' notes and email.
Mapping	Mind map	Participants could map key concepts of biodiversity that was summarised by the research educators.
Scientific Questions	Questions	All participants were focused on a particular question to be investigated with photo analysis and discussed based on extra references.
Methodology	Method	Photo analysis with qualitative discussion and surveys described in Method.
Data Collection	Photo, audio, video, text, files, emails	Participants had seven interfaces to share collected data, focusing particularly on photos and, when they had technical problems, they used email.
Analytic Discussion	Oral discussion, conclusion, poster, presentation, conference paper	Six examples present analytical discussion. Students were not able to complete their inquiry with a paper report, only through face to face discussion. Educators and researchers however were able to summarise conclusions with analysis and with various examples: poster, presentation and conference paper shared in the weSPOT toolkit.

2. Assessing the co-inquiry process and outcomes due to the variety of components and interactions.
3. Visualising significant contributions and integrating the phases for developing a research report.

Overall, the lessons learned from piloting the weSPOT toolkit within this secondary education case study can be extended to address a variety of learning contexts and distilled into the following set of best practices. These best practices reflect our proposals for effectively deploying and using cloud-based tools in order to support and promote IBL:

- **Multi-format introductory and guidance learning materials**: The need for suitable documentation of the new technologies has been recorded by the participants of this case study. Users are in need of guided learning materials that will help them understand the functionality and value of cloud-based tools.
- **Accessible and easy to use tools**: Best practice in this case indicates that a simple format of the cloud-based tools is required that enables learners to understand how to use them effectively and efficiently in order to perform scientific inquiries.
- **Tailored tools to meet the needs of specific subject audiences**: The need to be able to tailor the tools offered by the weSPOT toolkit to meet the needs of specific subject audiences was recorded in the case study. Best practice in this instance, therefore, allowed for cloud-based tools to be adjusted or even designed for learners studying particular subjects or, alternatively, educators investigating a wide range of topics.
- **Fostering a culture where the community is willing to engage in new innovative technologies**: In order to maximize the adoption of CLEs by the public, a suitable

culture towards new technologies needs to be fostered. Best practice in this case must enable the educator and trainer to adapt their approach so that a receptive culture is fostered among their learners.
- **Effective evaluation and feedback mechanisms**: Users of the cloud-based tools (learners and educators) should be given the opportunity to record and communicate their experiences from using these tools, in order to identify problems and suggest potential improvements. Effective evaluation and feedback mechanisms are thus required in order to facilitate the closer communication and collaboration between users and tool developers.

CONCLUSION

This chapter presented a cloud-based co-inquiry approach for STEM education. In particular, we introduced the weSPOT project, which is investigating IBL in secondary and higher education, in order to support STEM education via a cloud-based inquiry toolkit. The weSPOT toolkit enables co-learners to build their inquiry mash-ups with support from their teachers and use them collaboratively in order to perform scientific investigations together with their peers.

A case study involving real-life inquiry scenarios in secondary education has provided us with useful insight into the ways a cloud-based toolkit can support co-inquiry and co-learning. The findings and lessons learned from this case study will help us further improve our pedagogical approach and enhance our toolkit by addressing the key challenges brought forward by educators and co-learners.

As the weSPOT project is in progress, the pedagogical and technological work presented in this paper will be continued towards lowering the threshold for linking everyday life with science teaching and learning. The specific added value

in lowering this threshold will be investigated through a variety of pilots in real-life learning settings and different inquiry domains within secondary and higher education.

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KEY TERMS AND DEFINITIONS

Cloud Learning Environment (CLE): A cloud learning environment is a learning facility enabled by learning services on the cloud. The users of cloud learning services are academics or learners, who share the same privileges, including control, choice, and sharing of content on these services.

Co-Inquiry: Co-inquiry is a cooperative process of raising important questions with experts or specialists, integrating relevant information and generating acceptable lines of thought based on scientific assumptions and knowledge areas.

Co-Learning: Co-learning aims at the collaborative construction of knowledge, in which co-learners are able to expand their social networks, integrate open learning with collective research and co-author collaborative productions.

Inquiry-Based Learning (IBL): Inquiry-based Learning enables learners to take the role of an explorer and scientist as they try to solve issues they came across and that made them wonder, thus tapping into their personal feelings of curiosity.

Learning Management System (LMS): A learning management system is an online software application offering facilities for student registration, enrolment into courses, delivery of learning material to students, student assessment and progress monitoring.

Personal Learning Environment (PLE): A personal learning environment is a facility for an individual to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences.

ENDNOTES

1   http://www.blackboard.com
2   http://moodle.org
3   http://www.im-c.de/germany/en/solutions/learning-management/clix-learning-suite
4   http://www.wikipedia.org
5   http://www.youtube.com
6   http://www.slideshare.net
7   http://www.apple.com/education/itunes-u
8   http://www.role-project.eu
9   http://www.open.ac.uk
10   http://wespot-project.eu
11   http://inquiry.wespot.net
12   http://elgg.org
13   http://wespot.net/en/teachers
14   http://www.imsglobal.org/lti/index.html
15   http://www.go-lab-project.eu
16   http://compendium.open.ac.uk/institute