WESPOT: INQUIRY BASED LEARNING MEETS LEARNING ANALYTICS

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Abstract: *weSPOT 1is a new project supported by the European Commission launching on 1st of October 2012. weSPOT aims at propagating scientific inquiry as the approach for science learning and teaching in combination with today's curricula and teaching practices. It lowers 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. weSPOT addresses several challenges in the area of science learning and technology support for building personal conceptual knowledge. The project focuses on inquiry-based learning with a theoretically sound and technology supported personal inquiry approach. In inquiry based-learning learners take the role of an explorer and scientist and are motivated by their personal curiosity, guided by self-reflection, and develop knowledge personal and collaborative sense-making and reasoning. weSPOT will work on a meta-inquiry level in that it will (a) define a reference model for inquiry-based learning skills, (b) create a diagnostic instrument for measuring inquiry skills, and (c) implement a working environment that allows the easy linking of inquiry activities with school curricula and legacy systems.*

Keywords: *Mobile Learning, Inquiry-based Learning, Learning Analytics*

1. INTRODUCTION

In the last ten years students have gained multiple ways to learn with digital and mobile media. Especially social and mobile media gained high popularity and are foreseen to be the most important media channels for the target group of learner between 12-25 years old today. Nevertheless the teaching approaches in primary, secondary, and higher education are still largely the same as 100 years ago. The integration and connection between informal and formal methods of learning and instruction often have failed either due to media literacy problems, the problem of recognizing informal learning activities in the curricular context or other. On the other hand inquiry-based learning has been widely recognized in science learning as a successful and promising approach as for example in the report of the European Commission “Science Education Now: A renewed pedagogy for the Future of Europe” (European Commission, 2007). Increasingly the overall aim of Science Education in the digital age through inquiry based learning is to make all students scientific literate, able to apply science knowledge to improve their own lives, deal with an increasingly complex technological world and make science-related decisions as responsible citizens (AAAS -the American Association for the Advancement of Science, 1989). Scientific inquiry in empirical sciences -the main focus of weSpot -answers the question of how phenomena are related: **why** things do happen. It is about cause-consequence relations, which can principally be tested in experiments. It is not about believes but about empirical evidence. Inquiry based learning is learning, which starts from a project idea follows the rules of scientific inquiry. It leads finally to structure knowledge about a domain and to more skills and competences about how to carry out research which is efficient and which can be communicated. Inquiry skills and competences are needed to carry out scientific research. To give some examples: It starts from clearly formulated research questions with clearly defined terms, it goes to structured observation under defined conditions and end with methodological competences which allow to process the collected data. Many more competences and skills are necessary to carry out meaningful inquiry. The weSPOT project aims for a fundamental change in science learning support, based on an inquiry based-learning approach. By lowering the barriers for personal inquiry, enabling of reflection, creating visibility of informal learning achievements weSPOT foresees a bottom up change in science education that is acceptable to all stakeholders, scalable, and sustainable. The starting points for weSPOT are three main assumptions:

- ***Curiosity is created by everyday experiences,*** there is an urgent need to link informal everyday learning activities to the place where scientific concepts are developed, reflected and taught today: the classroom. Curiosity can only be leveraged by continuous support of student awareness, reflection, and linking to classroom collaboration.
- ***Personal experiences and insights are the key for understanding scientific concepts***: therefore the project aims at supporting learning in developing self-directed inquiry skills and support learners in their journey from confirmation inquiry to open and personal inquiry projects driven by curiosity.
- ***Progress in science is strictly linked to consistent and critical reasoning and systematic observation and experimentation in empirical settings***. There is a general lack of skills and competences on how to do scientific inquiry: this shortcoming must be quantified and precisely described in terms of underlying skills and the educational interventions needed to develop these. As we experience in university and school teaching, these inquiry competences are remarkably underdeveloped in students’ concepts.

weSPOT will create a “**W**orking **E**nvironment with **S**ocial, **P**ersonal and **O**pen **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.

weSPOT is going to design, implement, and evaluate a working environment that supports all levels of inquiry (Tafoya et al, 1980) and motivating and fostering the transition from classical confirmation inquiry to open inquiry. First successful experiments for such an approach have recently been developed in international contexts (Wong et .al, 2011). Based on the competences in the life cycle of inquiry model, the project will develop technology for inquiry support on the four different levels (confirmation, structured, guided, open), along the entire inquiry life cycle, and therefore enable educators as well as learners to perform pertinent inquiry projects and to develop towards self-directed open inquiry.

The project will develop an open source service framework for inquiry workflows, for mobile data collection and experience sampling, for experience based learning and personal inquiry. Additionally it will develop learning analytics tools for collaborative and personal reflection and a badge system for linking formal and informal learning activities via social media.

The weSPOT diagnostic instrument for inquiry skills and competences will be used a) to establish a European baseline of the current level of inquiry skills in the target group and b) to demonstrate the potential of the weSPOTtechnology for STEM-learning in general.

The effects of the weSPOT smart inquiry process support tool on inquiry, reflection, and self-directed learning competences will be evaluated in 8 European test-beds in the target group of students between 12-25 years of age, in mobile experimental settings, with the help of the weSPOT assessment tool. weSPOT will utilize the inquiry support technology in the hands of students in the age range of 12-25 today to activate curiosity and reasoning in authentic everyday situations, driven by self-created inquiries for constructing personal conceptual knowledge, understanding, and experiences on scientific and technological subjects.

2. INQUIRY-BASED LEARNING REFERENCE MODEL AND DIAGNOSTIC INSTRUMENT

weSPOT will develop a reference model for inquiry skills as well as a diagnostic instrument to measure the individual performance on the defined inquiry skills. The reference model and diagnostic instrument are based on the five inquiry skills areas described by the US National Research Council (2000):
engaging by scientifically oriented questions
giving priority to evidence in responding to questions
formulating explanations from evidence
connecting explanations to scientific knowledge
communicating and justifying scientific explanations to others

Furthermore Tafoya (1980) suggested four kinds of inquiry-based learning based on different levels of student autonomy (Table 1). The first level is the ***confirmation inquiry*** in which students are provided with the question and procedure (method) as well as the results, which are known in advance. The second level is ***structured inquiry***, where the learning goal is to introduce students to the experience of conducting investigations or practicing a specific inquiry skill, such as collecting and analysing data. The third level is the ***guided inquiry***, where the question and procedure are still provided by the teacher. Students, however, generate an explanation supported by the evidence they have collected. The teacher provides students with only the research question, and students design the procedure (method) to test their question and the resulting explanations with guidance or mentoring support. The fourth and highest level of inquiry is ***open inquiry***, where students have the opportunity to act like scientists, deriving questions, designing and carrying out investigations as well as communicating their results. This level requires experienced scientific reasoning and domain competences from students.

The weSPOT inquiry reference model will provide detailed indicators and measurement methods for these inquiry skills and test them in international test-beds and different subject domains including food safety, breeding of endangered species, investigation of earthquakes, class under sails exploring sealife, ecological transport, energy efficient buildings, product innovation, global warming, and economic complexity.

Main responsibility for:			
Level of inquiry	Problem	Procedure	Solution
Level 4 Open inquiry	Student	Student	Student
Level 3 Guided inquiry	(teacher)	Student	Student
Level 2 Structured inquiry	(teacher)	(teacher)	Student
Level 1 Confirmation/ verification	(teacher)	(teacher)	(teacher)

Table 1. Level of inquiry according to (Tafoya et al, 1980)

weSPOT builds on the works in the SCY[2] (Science created by YOU) project as for example the defined Learning activities and SCY Lab components will be on of the starting points for the inquiry skill taxonomy. The SCY project defined a list of 53 learning activities of which some are directly related to the inquiry activities referred to in the weSPOT taxonomy.

Developing the assessment tools and diagnostic components in weSPOT includes four main steps:
1 Develop inquiry skills taxonomy and competence definitions as also the related assessment procedures.
2 Develop a questionnaire for test items and validating these with a number of participants to have a valid questionnaire that can be given to teachers as an online tool.
3 Develop behavioral indicators and actions and map them onto tracking information defined in the inquiry tools.
4 Develop a visualization of the assessed data for supporting teachers and learners in the self-directed learning, i.e. what is my activity/logging data on the relevant activities to become a good inquiry learner.

As described above, the weSPOT project will not only develop a smart and adaptive inquiry support and guidance environment, but also a diagnostic instrument which is able to measure the students' skills and competences related to a meaningful inquiry process. This diagnostic instrument has a threefold objective: First, to provide feedback to the student about his/her own progress in scientific reasoning, second, to provide feedback to the teacher or other learning guide, to be informed about additional support or input needed in different stages of the inquiry process, and third, for the weSPOT project, to provide on one hand a base line for the respective skills and competences present without weSPOT and, on the other hand, the improvement achieved when using the weSPOT approach.

[2] SCY, Science created by YOU, Project number IST-212814

This diagnostic instrument will look at the entire inquiry life cycle which may start with the formulation of a research question and may end with the valorization of the results and it will cover the four different complexities of inquiry, from confirmation inquiry to open, self directed inquiry (see inquiry levels above). The aspiration of the weSPOT diagnostic tool is, to be as non-invasive for the student inquiry as possible. This means that the student should not be disturbed in the inquiry or research activities. It is aimed to assess the learner´s state (competences / skills, level of understanding, motivation, problem-solving) by tracking mechanisms, which collect the relevant data on the fly. To reach this ambitious goal, it is necessary to observe and to interpret continuously the learner's interactions with the virtual inquiry environment. (Of course, the student has to be informed about the nature of data collection and about the objectives linked with). Some few questions may be necessary for indicators, which cannot be approached by intelligent data mining. The basis for the diagnostic tool will be a very specific ontology which covers the different aspects of research oriented inquiry.

The diagnostic tool will be rather process oriented, than result oriented since the emphasis in weSPOT is on the inquiry process and not only on the results, since the concrete results depend on many surrounding variables like availability of data, or technical influences or random variables which can not be fixed in a given environment. The process of development of the weSPOT diagnostic tool can be described as follows: Starting point is the above mentioned inquiry ontology, which contains the related concepts. From this ontology, the relevant and measurable concepts for every phase of the inquiry cycle have to be selected which represent a specific skill or competence of inquiry. These concepts have to be transformed into behavioral indicators of students' behavior, which can be collected with non-invasive tools during inquiry activities and which than will be processed to an individual profile. This profile will provide rather qualitative feedback for the use of the student, the teacher, and the weSPOT project. There are two theoretical frameworks, which will be used in the weSPOT diagnostic tool and procedure:

One framework for assessing the learner´s competence state in a non-invasive way is the microadaptivity approach (see for example Kickmeier-Rust et al., 2008; Albert et al., 2007). The microadaptivity approach was developed within the EC-funded projects ELEKTRA (6th framework) and 80Days (7th framework) in the context of game-based learning. The microadaptivity approach is a set-theoretic framework which builds upon concepts from research on problem solving (see for example Pretz, Naples & Sternberg, 2003). The problem states are defined by a set of objects and their properties. In this context, objects are conceptualized quite broadly, it is an entity which can be manipulated by the learner. A manipulation of such an object, i.e. the change of a property of at least one of the relevant objects, is called an action. Such actions reflect the learners' interactions with the learning environment. In this sense, actions are used as observable indicators within the microadaptivity approach. The observable indicators have to be interpreted in terms of underlying skills and competences. An alternative approach for identifying observable indicators is to built on existing theories and frameworks focusing on specific skills of the identified "Inquiry skill areas". For example, for the "Priority to evidence" skill area as one important skill to be considered is the ability to gather valuable pieces of information from different sources. An already established framework for such a process is the theory of information foraging (Pirolli & Card, 1999). Pirolli and Card describe a set of "success-indicators" which are used to differentiate between successful and unsuccessful information foragers (i.e. young researchers in the context of weSPOT), for example the rate of gain of valuable information per time. Similar indicators have to be developed to measure the relevant inquiry skills and competences.

3. LEARNING ANALYTICS FOR REFLECTION AND INQUIRY SUPPORT

There is a growing movement to more open learning environments. For instance, Personal Learning Environments replace monolithic Learning Management Systems with user configurable sets of widgets as described in Chatti (2010) or the FP7 ROLE-project. Learning infrastructures provide generic services for learning, for instance through registries[3], or open educational resource infrastructures (Duval, 2010). However, how learners and teachers interact with these widgets, services, and resources or with each other often remains unclear, both for the users involved, as well as for system components -which makes it difficult to personalize the interactions.

At the same time, there is a growing movement of quantified self in medicine (Purpura, 2011), sports, many other fields and, indeed, learning (Duval, 2011). The basic idea in many of these initiatives is to enable users to track their activities, in order to enable self-analysis, often by visualizing traces of the activities. More specifically for weSPOT, the field of 'learning analytics' focuses on tracking learning activities too promote self-awareness and reflection through algorithmic analysis (in educational data mining (Pechenizkiy, 2011)) and information visualization. Ongoing research focuses on the design, development and evaluation of a suite of tools for tracking learning activities and visualizing them as learning dashboards over the full gamma from mobile devices (including augmented reality eyewear) over tablet and laptop to desktop computers, up to tabletops and large public displays. In a participatory design approach, these developments and evaluations take place in projects with "real life" test-beds. Mobile clients provide exciting affordances for automatic tracking of learning activities – for instance, students can track time spent, proximity, etc. or 'check in' for a lecture in a foursquare[4] type of way. On laptop and desktop environments, trackers have been developed for learning activities (leveraging existing tools like

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wakoopa[5], rescuetime[6] or the rabbit Eclipse plugin[7]). The data can be made available in visualizations that rely on OpenSocial widgets (Santos, 2012), so that learners and teachers can compose their own dashboard. Standalone applications provide rich statistics in the form of line charts, parallel coordinates and bar charts, as well as recommendations for relevant documents. Finally, what we call learnscapes for tabletops and large public displays can make very rich information spaces available with associated filtering, navigation and visualization. This kind of research typically follows a user centered rapid prototyping approach, where we first rely on paper prototypes to gather initial feedback on early ideas and then develop gradually more functional digital prototypes in rapid iteration cycles. We then deploy more advanced implementations in realistic test beds with tens to hundreds of learners.

The main issues that will be targeted in the support of Learning Analytics of weSPOT are:

- *What are relevant learner actions?* Maybe some mouse clicks or physical interactions are not related to the learning activity (for instance: quick email or chat interrupt, or leaving the room to get a coffee), but then again, maybe they are and it is often difficult to figure out what activity is relevant at which point in time.
- *How can we capture learner actions?* We often rely on trackers for laptop or desktop interactions, social media for learner interactions (through twitter hash tags or blog comments, for instance) and on physical sensors for mobile devices. However, capturing all relevant actions in an open environment in a scalable way is challenging. What are low-threshold approaches to collect information in inquiry projects.
- *How can we evaluate the usability, usefulness and learning impact* of dashboards and contextual reflection support? Whereas usability is relatively easy to evaluate (and we have done many such evaluations of our tools), usefulness, for instance in the form of learning impact, is much harder to evaluate, as this requires longer-term and larger-scale evaluations.
- *How can we enable goal setting* and connect it with the visualizations, so as to close the feedback loop and enable learners and teachers to react to what they observe and then track the effect of their reactions? We are experimenting with playful gamification approaches, that present their own challenges, for instance around trivialization and control. weSPOT links the personal learning analytics approaches to social media and an open badge system.
- *How can we leverage attention metadata for recommending and mining?* We model learner actions as 'attention metadata'. The focus of learning dashboards is on visualizing these data for self-awareness and reflection. Alternative approaches to achieve the same goal include *'educational data mining'* to identify relevant patterns and *educational recommenders* that can suggest resources, activities and people.
- How can we exploit novel opportunities in mobile devices for supporting *communication and collaboration* between learners and with teachers, which is especially relevant in a Computer Supported Collaborative Learning (CSCL) setting, the more so as these devices can capture context information. This is a central question also linked to the mobile support of inquiry in weSPOT.
- *How can we design physical spaces that promote learning* rather than hinder it, especially in the case of tabletops and large public displays, where the impact of the physical environment on the user experience is sometimes higher and, vice versa, the devices have a higher impact on the physical setting (Harris, 2010).
- *What kind of data and service infrastructure can best support the applications we envision?* Of particular relevance here is a linked open data approach that can integrate well with the Web infrastructure (Bizer, 2009) and that can support an open analytics infrastructure (Siemens, 2011).
- *How can we enhance and exploit facilities for seamless transition* from mobile over tablet and laptop to desktop, tabletop and large public displays. Issues here include coherence, synchronization, screen sharing, device shifting, complementarity and simultaneity (see http://precious-forever.com/).

[5] http://wakoopa.com/ [6] https://www.rescuetime.com/ [7] http://code.google.com/p/rabbit-eclipse/

5. CONCLUSION

weSPOT aims at approaching several challenges using mobile technology, an inquiry-based learning approach and technologies for learning analytics.

The project will develop all components as open source software and share the outcomes of the project with scientific and TEL community. All project developments will be evaluated in international test-beds and pilots in several domains. This paper can also be seen as a first step for sharing this effort in the TEL community and a call for cooperation. As the project aims not only to work with open source technologies but also link the developments to several existing Learning Management Systems (LMS) potential partners are invited to contact project partners for further cooperation.

LITERATURE

Albert, D., Hockemeyer, C., Kickmeier-Rust, M. D., Peirce, N., & Conlan, O. (2007). Microadaptivity within complex learning situations – a personalized approach based on competence structures and problem spaces. *Poster presented at International Conference on Computers in Education* (ICCE 2007).

Bizer, C. (2009). The Emerging Web of Linked Data, *IEEE Intelligent Systems*, *24*(5), 87-92.

Chatti, M. A., Agustiawan, M. R., Jarke, M., & Specht, M. (2010). Toward a Personal Learning Environment Framework. *International Journal of Virtual and Personal Learning Environments*, *1*(4), 66-85.

Duval, E. (2011). Attention please! Learning analytics for visualization and recommendation. *Proceedings of LAK11*: 1st International Conference on Learning Analytics and Knowledge (p. 9-17). ACM. doi:http://doi.acm.org/10.1145/2090116.2090118

Duval, E. & Wiley, D. (2010). Guest Editorial: Open Educational Resources, *IEEE Trans. on Learning Technologies*, *3*(2), 83-84.

European Commission (2007). *Science Education NOW: A renewed Pedagogy for the Future of Europe.* Luxembourg: Office for Official Publications of the European Commission, pp. 577–616.

Harris, S. (2010). *The Place of Virtual , Pedagogic and Physical Space in the 21st Century Classroom*, http://www.scil.com.au/documents/stephen-harris_virtual-pedagogical-physical-space.pdf

National Research Council (2000). *Inquiry and the National Science Education Standards.* Washington, DC: National Academy Press.

Kickmeier-Rust, M. D., Marte, B., Linek, S. B., Lalonde, T., & Albert, D. (2008). Learning with computer games: Micro level feedback and interventions. In M. E. Auer (Ed.), *Proceedings of the International Conference on Interactive Computer Aided Learning* (ICL), September 24-27, 2008, Villach, Austria. Kassel: Kassel University Press.

Pechenizkiy. M. & Calders, T. (Eds). *Proceedings of EDM11*: 4th International Conference on Educational Data Mining.

Pirolli, P. & Card, S. K. (1999). Information Foraging. *Psychological Review*, *106*, 643-675.

Purpura, S., Schwanda, V., Williams, K., Stubler, W., & Sengers, P. (2011). Fit4life: the design of a persuasive technology promoting healthy behavior and ideal weight. in *Proceedings of the 2011 annual conference on Human factors in computing systems*, 2011, 423-432.

Pretz, J. E., Naples, A. J. & Sternberg,R. J. (2003). Recognizing, Defining, and Representing Problems. In: J. E. Davidson and R. J. Steinberg (Eds.), *The psychology of Problem Solving* (pp. 3-31). Cambridge: University Press.

Proposal for a Regulation of the European Parliament and Council establishing Horizon 2020 -the Framework Programme for Research and Innovation (2014-20) http://ec.europa.eu/research/horizon2020/pdf/proposals/proposal_for_a_regulation_of_the_european_parliament_and_of_the_council_establishing_horizon_2020_-_the_framework_programme_for_research_and_innovation_(2014-2020).pdf#view=fit&pagemode=none

Santos Odriozola, J.S., Goveaerts, S., Verbert, K. & Duval, E. (2012, accepted). Goal-oriented visualizations of activity tool tracking. A case study with engineering students," in *Proceedings of LAK12*.

Siemens et al. (2011). Open Learning Analytics: an integrated & modularized platform Proposal to design, implement and evaluate an open platform to integrate heterogeneous learning analytics techniques, http://solaresearch.org/OpenLearningAnalytics.pdf.

Tafoya, E., Sunal, D., Knecht, P. (1980). Assessing Inquiry Potential: A Tool For Curriculum Decision Makers, *School Science and Mathematics, 80*(1) 43-48.

Wong, L.-H., & Looi, C.-K. (in-press). Enculturing self-directed seamless learners: towards a facilitated seamless learning process framework mediated by mobile technology. *Proceedings of IEEE International Conference on Wireless, Mobile and Ubiquitous Technology in Education 2012*, Takamatsu, Japan.