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Supporting Inquiry-based Learning with Google Glass (GPIM)

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Abstract. Wearable technology is a new genre of technology that is appearing to enhance learning in context. This manuscript introduces a Google Glass application to support Inquiry-based Learning (IBL). Applying Google Glass to IBL, we aim to transform the learning process into a more seamless, personal and meaningful learning experience. Google Glass aids users from a first person perspective with hands-free interaction. This paper first introduces the educational background and the framework behind the application. Next, the Personal Inquiry Manager (PIM) of the weSPOT project is introduced. The design and functionalities of Glassware PIM (GPIM) are explained in detail. The paper concludes with open issues for future research, especially focused on evaluation and further developments.

Keywords: Inquiry-based Learning, curiosity, wearable, ubiquitous

1 Introduction

Given the role that science, technology, engineering, and math (STEM) have in stimulating innovation, development of new products and economic growth, it is important to tackle the shortcomings of STEM learning which have been pointed out in several studies [1]. Latest PISA results show huge differences between countries in terms of performance in science and mathematics. In the European countries a general decrease of abilities of mathematics skills has been identified [2]. Inquiry-based learning (IBL) is suggested as an approach to spark students' curiosity in general and specifically on science topics. IBL has been widely recognized in science learning as a successful and promising approach as mentioned for example in the report of the European Commission "Science Education Now: A renewed pedagogy for the Future of Europe" [3]. In the European project weSPOT[1] a consortium is currently establishing an infrastructure to support IBL with digital technologies. In this paper an implementation for Google Glass is introduced. Example workflows of IBL activities are provided and we argue why technology can be sometimes an obstacle rather than a support. We introduce the Personal Inquiry Manager (PIM), the Glassware PIM (GPIM) and provide a discussion on future developments and evaluation.

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2 Background

IBL is a pedagogic and teaching approach grounded in constructivism, advocating students to follow their own learning path to build and organize knowledge. On the one hand, it allow students to take the role of scientist as they investigate issues arising from their curiosity. On the other hand, this approach changes the role of teachers from the lecturer to a facilitator who analyzes and guides the learning process of students. Thus teachers become focused on organizing the learning process, fostering students' curiosity and supporting the cognitive development of the students [4]. Students develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world [5].

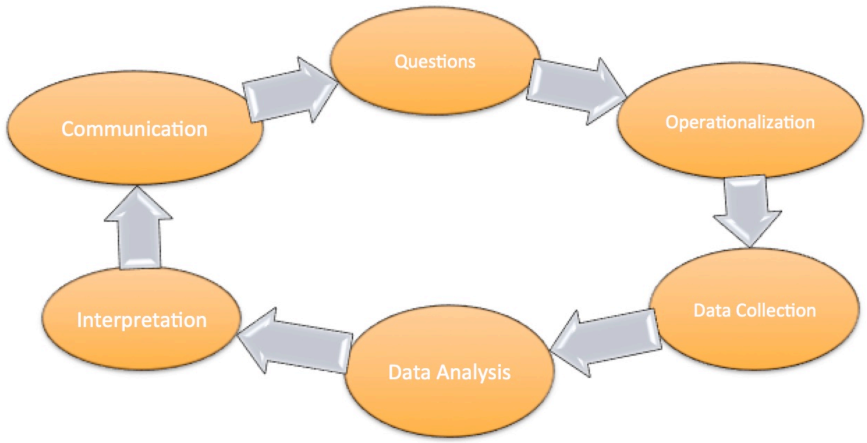

Fig. 1.. Inquiry-based Learning model from weSPOT.

weSPOT [6] is a European project which aims at fostering scientific inquiry as the approach for science learning and teaching, linking everyday life with science teaching in schools using technology. weSPOT uses IBL as a methodology to support personal curiosity, experiences and reasoning. It has the following three underlying objectives:

1. implement a working environment that allows the easy linking of inquiry activities with school curricula and legacy systems
2. create a diagnostic instrument for measuring inquiry skills
3. work out a reference model to foster IBL skills.

The IBL model of the weSPOT project consists of six phases [6] as shown in Figure 1.

The learning activities in each phase are linked to the skills that students develop when performing the learning activities. Amongst other skills, *reflection* is placed at the centre of each inquiry phase and considered as an integrated process of every inquiry activity. Reflection is vital in every moment of the inquiry, as students need to reflect upon the question, hypothesis, and even upon data collected, in order to proceed with the following steps in the inquiry. In addition, there is bidirectional communication between the different inquiry phases, meaning that IBL phases can be performed without any order restriction depending on students or teachers needs. The 6 phases in detail are the following:

1. Students very often start formulating questions or presenting ideas that make them curious. These questions can arise from a theoretical foundation or from direct natural observations where students experience a moment of curiosity (*wonder moment*).
2. Operationalization enables learners to define the concepts and ask themselves what they know already about the topic. But they also need to understand how to measure the empirical observations that will take place in the data collection process.
3. In the data collection phase, learners collect evidences by taking pictures, recording videos, audio recordings or notes. These observations will help sutdents to determine in the next phase if their assumptions where correct or not.
4. Data analysis involves treating, exploiting and inspecting the data collected. Once the data is cleaned, students check the results and they compare them with the assumptions they made in the firs phase. At this stage of the inquiry, learners can draw conclusions from the analysis.
5. Once the analysis is done, students do an interpretation of their conclusions, which will help them to describe the relevance of their inquiry. The outcomes must be related to previous research or modify current assumptions based in new evidences.
6. The last phase of the process is communication, where results, findings and conclusions are shared or published with colleagues or stakeholders who may use these results afterwards.

This model has lead to the design of the Personal Inquiry Manager (PIM), an application for Android and iOS that supports mobile access to inquiries out of the classroom. The PIM has been designed to enable data collection and instant messaging in context, but it also provides affordances to organize awarded badges and questions. Based on the pedagogical framework that weSPOT provides, the PIM was designed to facilitate more self-directed learning as it enables students to set up personal meaningful inquiries.

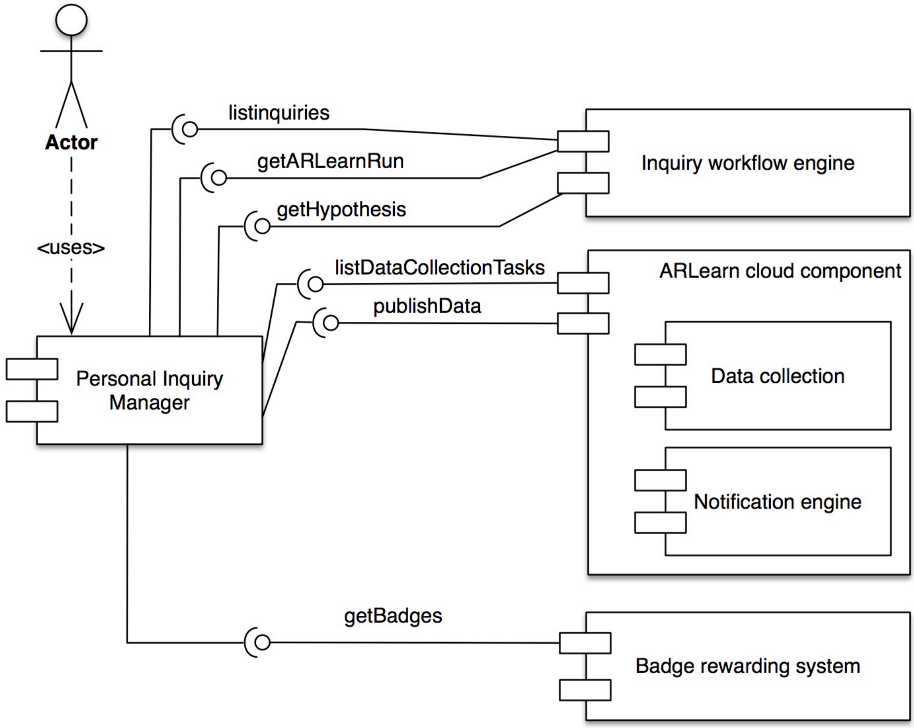

Fig. 2.. The weSPOT services used by the PIM.

Within the scope of this article, the weSPOT services used by the PIM with three other system components are relevant (see Figure 2): 1) the *Inquiry Workflow Engine*, the *ARLearn data collection service* [7] and the *Badge Rewarding system:*

1. The Inquiry Workflow Engine (IWE) is based an open source social networking, ELGG. It has been designed as the backend of weSPOT tool suite. It provides affordances to support all inquiry phases based on widgets and also inquiry components like the data collection task module, chat widget interface, etc. Besides the browser based front-end, the IWE offer a complete RESTful API to enable bidirectional interactions with clients like PIM or GPIM, which will be introduced later.
2. ARLearn is an open source tool suite for educators and students, to organize mobile serious games [7]. Like IWE, ARLearn features client/server architecture. The ARLearn data collection service exposes its functionality via a RESTful API in order to give access to third party applications developed for instance for android, iOS or Google Glass.
3. The Badge Rewarding system was developed on ELGG to assess students on the inquiry process. The system allows teachers to create, award and

list badges per student and inquiry and it offers its functionality via RESTful API.

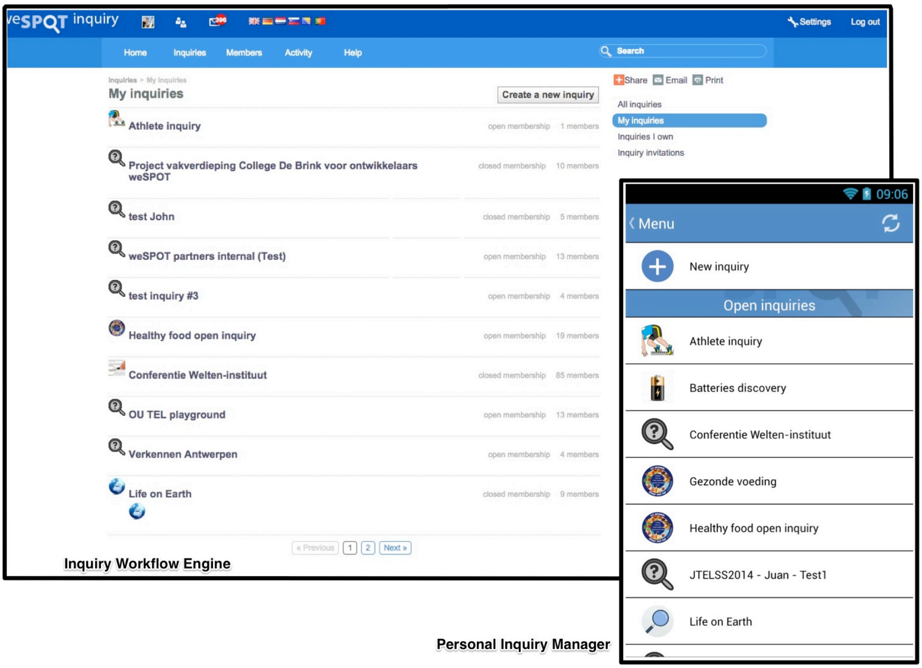

Fig. 3.. Inquiry Workflow Engine (left) and Personal Inquiry Manager (right).

The PIM is an application that complements the IWE with data collection functionality. It provides affordances to collect images, videos, audios or texts in context, which enables more meaningful and autonomous inquiries. The PIM has been downloaded and installed more than 150 times and is currently used in several weSPOT pilots. However, from these experiences we realized situations where having the smartphone on your hands block the students on the inquiry process. These situations arise when students need to take measurements or notes while they use their hands to manipulate or to operate other tools. Therefore we suggest a solution to enable data collection without having the technology in the way.

3 Extending PIM for Google Glass

Currently, tools like (PIM) are following the so-called Tricorder interaction pattern. The Tricorder is a mobile device from the Star Trek science-fiction television series (1966-1969) that features scanning an environment and that provides information about that environment. A key characteristic of this pattern is that the Tricorder is a handheld device that the user waves in the direction of interest. This leads to the suboptimal situation in which the mobile device is always in between the user and the real world. As an alternative to this approach HUD has been developed. A HUD projects information into the visual field of the user. The cockpit of a fighter-jet is probably the best know example of a HUD and was introduced in the 1950s. This manuscript presents a first version of the PIM build on wearable HUD, like Google Glass. With the availability of Google Glass, it is possible to translate applications that adhere to a typical Tricoder interaction patterns (i.e. PIM) into a HUD pattern (i.e. GPIM).

Google Glass is an optical head-mounted display (OHMD). It was developed by Google Inc. to offer an innovative kind of wearable device that allows its users hand-free interactions. In the scope of this article, we contribute to the IBL research community with the first application for Google Glass to support IBL. Therefore, we present a Google Glass native application (Glassware) to support IBL.

The Glassware Personal Inquiry Manager [14] (GPIM) is an extension of the PIM. It enables first view data collection processes where the technology is always ready without blocking the student experience. The PIM was meant to be more flexible as it supports different kinds of inquiries regarding their structure, the type guidance or the topic. For instance, guided inquiries where teachers through the tool give instructions to students or open inquiries, where students research their own wonder moments are well covered. In contrast, the GPIM offers a more concrete approach. In this case a personal and guided inquiry is always supported, because the linear process begins from students' curiosity, capturing a wonder moment, and always continues with the data collection phase. Although they were designed from different perspectives, they can be used together. For instance when a student is responsible for tasks like being the reporter of the activity. GPIM allows the student to do whatever is needed in the PIM, such as send a message or take measures, while the student is also recording a video to report about the activity. This becomes interesting in current research on IBL that is featuring roles to facilitate their engagement in the process, because different roles can be supported at the same time.

Since IBL is a collaborative development, the individual and personal contributions become important for the group, because it might provoke asymmetry of knowledge among students within the inquiry. Differences in how students see or understand an specific topic generate content and knowledge negotiations, which will help students to acquire higher levels of understanding in the subject matters. Thus, characteristics of wearable devices such as first view perspective, better support students explaining their points of view and to recall these moments as they have exactly had them.

As shown in Figure 4, through Google Glass users see a card on the right top corner of their field of view. Google Glass has a touchpad placed on the right side of the device. By swapping backward and forward the user is able to navigate between the cards of the application.

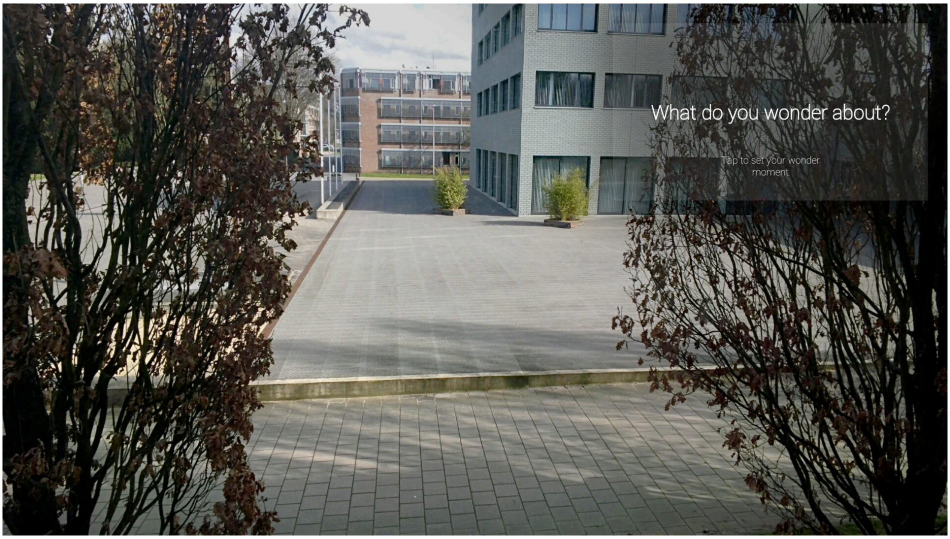

Fig. 4.. Field of vision with Google Glass.

3.1 Background

3.1.1 Requirements for personal mobile technologies in learning

Designing mobile technology to support activities in the field can be challenging, however Sharples [8] suggests some concrete requirements for this purpose. He highlighted the role of new technology as a supplement, offering students quick access to their information over long periods of time and relates near-unlimited information to the context. The following list identifies some key requirements [8] for mobile IBL:

1. Sharples defines *high portability* as a technology requirement for being available wherever the student needs to learn. This is an essential requirement in mobile IBL, where data collection becomes important in context.
2. *Unobtrusiveness* while supporting mobile IBL processes is relevant for science inquiries situations in the field. Especially when students need to collect data while they manipulate other tools at the same time.
3. The *individuality* requirement defined by Sharples, states that technology must be designed to adapt to learner's abilities and to support personal and more meaningful learning.
4. Technology must be provided *intuitively* for people without experience.

Insights based on Sharples' requirements make it possible to investigate whether GPIM address to these requirements.

3.1.2 Seamless learning

Wong et al. [9] presented a framework for seamless learning. They based their framework on an analysis of literature about MSL (mobile-assisted seamless learning). Out of the analysis, ten features that characterize the seamlessness of a design were identified. The following two fit into our approach:

1. *Encompass formal and informal learning*: technology has the affordances to create links between informal and formal learning by connecting curricula content with everyday life activity and experiences.
2. *Across time & location*: traditional learning takes place in specific settings and contexts. Using mobile and wearable technology information is no longer time and location dependent. That means students are able to learn anywhere at anytime.

As it was pointed out in [10] the HCI design process can be faced from different perspectives. In an earlier publication we have reported challenges connected to the HCI design patterns [11] for educational AR applications [12].

3.2 Implementation of GPIM

The GPIM has been designed as an extension of the PIM to better support data collection processes. As a wearable (and mobile) device it only supports phases that can be usually done in context, such as having a wonder moment or collect data. Thus none of the other phases of the IBL model have been included. As it was explained at the beginning of the chapter, GPIM starts from the collection of wonder moments. The first screen, on Figure 5, supports the capturing of wonder moments and it acts as a trigger that fits the user's mobile workflow. The user experiences a moment of curiosity and starts the application to capture it. To activate the GPIM the student will not need to interact physically with the device. Just in time and in an unobtrusive way students are able to use their voice to start a new inquiry by using "Ok Glass, new inquiry" command.

Fig. 5.. (1) Capture *wonder moment*, (2) hypothesis and (3) data collection.

During this initial phase, the user makes a statement about what he or she wonders about. For instance, a student realizes that some shadows are larger in the afternoon than in the morning. From teacher's perspective, the collection of these *wonder moments* can be a source of inspiration to develop new inquiries or activities. Following the example of the trees, a teacher can design a lesson about the rotation of the Earth around the Sun.

However, it is difficult for novice students to reach those *wonder moment* situations by themselves. Therefore they need examples or models to use as source of inspiration for training then to capture their *wonder moments*. As a solution, we suggest an inference method called backward chaining, to explore the potential benefits of working backwards from the goals [13]. In this case, the goals are either the data collected in early demo inquiries or the hypotheses made by teachers' beforehand. Thus, GPIM supports inquiry skills development through guided inquiries performed in first-view perspective.

Once the user has captured the *wonder moment*, he/she needs to come up with a hypothesis that they would like to refute within the inquiry process. Thus GPIM enables contextual reflection since students have to come up with a hypothesis in context. An example, following the earlier case a *wonder moment* could be: (1) 'is it possible to calculate the height of other objects that cannot be measured easily such as tress'. And then the consequent hypothesis: (2) 'students can compare two trees measuring their shadows'.

The next step is data collection. The goal is to collect evidence, which help students to refute or accept their hypothesis. The data collection process begins with displaying three options, which represents the three different types of data that can be collected from GPIM. The following figure presents how the options are listed to the user (Figure 6). After data has been captured, the data collection screen shows the number of items collected and also a new option is available in the menu (Figure 6).

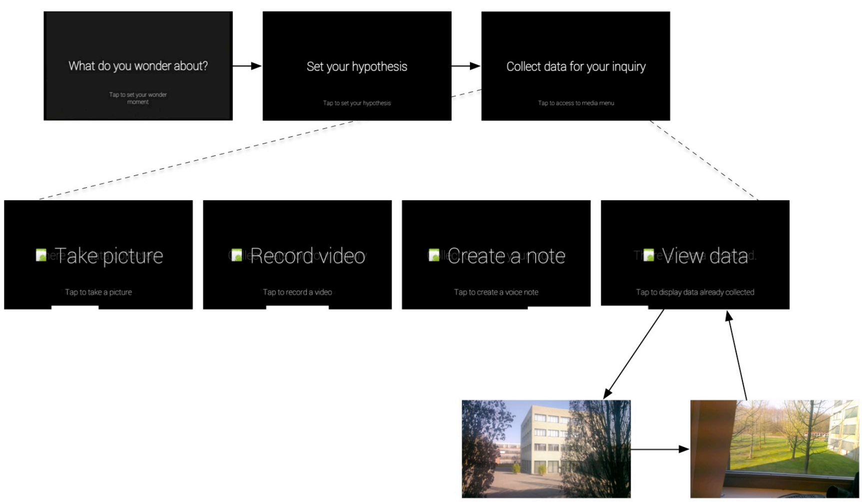

Fig. 6. Workflow of the GPIM.

GPIM provides affordances for teachers to orchestrate the inquiry process. Teachers are able to track students' progress because all the items collected by the students, contain time and location metadata. From a student's perspective GPIM enables communication between them and also with teachers because it synchronizes data from all devices. Therefore, students and teachers are able to see what others collected (Figure 6).

The GPIM synchronizes all individual contributions with the IWE when the user is online. However, the nature of an inquiry will lead to users stepping in and out of zones of wireless internet. When no internet is available, the GPIM will continue to work in an offline mode, enabling the users to continue capturing and viewing data. This makes the GPIM suitable for every context, including areas without internet connection. In addition, an inquiry can be an ongoing task. With the GPIM, inquiries spanning several days can be paused and resumed whenever the student wants.

4 Discussion and future work

The weSPOT project aims at fostering scientific inquiries linking everyday life with teaching, using technology and relating scientific concepts with curiosity, personal experiences and reasoning. The PIM was implemented for Android and iOS to support mobile IBL in context. However, the data collection process sometimes blocks the inquiry flow because there are specific situations that require students to interact or operate other tools along the inquiry process. Supporting data collection in these situations becomes a difficult task since students have to hold the smartphones in their hands. In this manuscript we present the GPIM as a solution. GPIM is a native Google Glass application to support IBL enabling hands-free interactions with the environment. Since the process is supported from a first person perspective, the application offers a more personal, meaningful and seamless experience to the students. The GPIM was designed following Sharples' requirements for the design of personal mobile (wearable) technologies to support learning. The *high portability* and *unobtrusiveness* mentioned by Sharples are present in GPIM due to the fact that it builds on a wearable device that students can bring wherever they go without blocking their learning experiences. The *individuality* requirement relates to the fact that technology should adapt to the learner's abilities. The GPIM supports individual and personal inquiries, in the sense that students performed inquiries based on their curiosity.

A limitation of our research is the difficulty to scale up the added value of Google Glass in education. Since we only own one device any kind of setup becomes artificial. However we have observed from experiences with students that the current interface of the GPIM has some usability issues. For example, the interaction with the menu is not easy for inexperienced users. Thus a new design has been included in the roadmap of the GPIM to fully enable voice interaction and simplify the navigation.

Although Google Glass has stopped its Google Glass Explorer program for users, the research community is already working on the next release. Thus future actions in the agenda are planned for the GPIM. On the one hand, in terms of technology a new release of the GPIM will focus on a better UI experiences. On the other hand, the research agenda will focus on the design of an evaluation that provides outcomes for the following research questions:

1. What is the impact on student's motivation using GPIM instead of PIM?
2. What is the added value for learning of using wearable devices instead of mobile devices?
3. What is the impact on perceived flexibility and usability using GPIM?
4. Can mobile technology and data collection enable the integration of "moments of curiosity" in the IBL process?

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