Towards Responsive Open Learning Environments: the ROLE Interoperability Framework

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Abstract. In recent years, research on mashup technologies for learning environments has gained interest. The overall goal is to enrich or replace traditional learning management systems (LMS) with mash-ups of widgets and services that can be easily combined and configured to fit the learner needs. This paper presents the implemented prototype of the ROLE interoperability framework and a business and an educational case study. The framework provides a common technical infrastructure to assemble widgets and services in Personal Learning Environments (PLEs). Evaluation results indicate that the perceived usefulness and usability is high for one case study in which a mature LMS was enriched with ROLE technology. In the second case study, an early mashup prototype was deployed. The usefulness and usability of this early prototype were rated low, but the case study provides interesting insights for further research and development.

Keywords: personal learning environments, interoperability, mash-ups, widgets, standards and specifications

1 Introduction

The development and proliferation of Web 2.0 technologies (e.g. wikis, blogs and social networks) has impacted the way users retrieve and use information and how they interact with each other [19, 34, 1]. An important feature of Web 2.0 services is that they experience an exponential growth of both users and content, leading to potentially viral social networking, collaboration, communication and knowledge sharing opportunities.

The abundance of web-based tools and content creates many opportunities for Technology Enhanced Learning (TEL) that aims to bring together new technological developments and learning models to support learning processes. The EU project ROLE[9] aims to exploit web-based tools and technologies to empower learners to construct their own personal learning environments (PLEs). The overall goal is to create flexible, web-based, open technologies for the federation and mash-up of learning services on a personal level. The project also targets critical transition stages of lifelong learning, e.g. due to shifts in learner interests or when leaving the university and entering a company. The vision of ROLE is to empower the learner to build her own responsive learning environment. Responsiveness is defined as the ability to react to the learner needs - i.e. through recommendation, adaptation or visual analytics services that support the learner to be aware of and reflect upon her own learning process [**?**].

This paper presents an implemented prototype of the ROLE interoperability framework, which is a technical infrastructure to assemble widgets within responsive open learning environments. The framework provides bundles of widgets with communication channels, authentication and authorisation mechanisms, services for activity tracking and analysis. This ensures that the bundles have access to the necessary information to react to learner needs. The research contribution of this paper is threefold:

- First, we present technical building blocks of the ROLE interoperability framework.
- Second, we present evaluation results of the usefulness and usability of the approach within two educational and business case studies.
- Third, we present a future vision on the integration of pedagogical models to leverage the framework.

The paper is organised as follows: we first discuss related work in Section 2. Section 3 presents an overview of the ROLE framework. The case studies are presented in Section 4. Finally, conclusions and future work are presented in Section 5.

2 Related Work

LMSs primarily focus on distributing learning content, organising the learning process, and serving as interface between learner and teacher. LMSs are prevalently used by

[9] The ROLE project web site, `http://www.role-project.eu`

many European institutions [24]. Popular examples of LMSs are Moodle, CLIX, Blackboard, WebCT, Sakai, ILIAS and .LRN. Dalsgaard [4] notes that in LMSs generally different tools, such as discussion forums, file sharing, whiteboards and e-portfolios, are integrated in a single system bundling all tools necessary to manage and run courses.

LMSs place a strong emphasis on how to centralise and standardise the learning experience [13]. Learning activities in an LMS-based course are organised within a centrally managed system, which is driven by the needs of the institution. In contrast to an LMS, a PLE takes a more natural and learner-centric approach and is characterised by the freeform use of a set of services and tools that are controlled and selected by individual learners.

In recent years, research on mashups has been elaborated, for example widget mashups have been deployed at Graz University of Technology [6]. The widgets are combined with JavaFX[10] technology to improve flexibility, e.g. to install widgets on the desktop. In addition, researchers have focused on augmenting traditional LMSs with widgets to provide live-updating and flexible applications. Wilson et al. [35] implemented widget support for Moodle. Their big challenge is logging student activities with the widgets, as there is no communication between the widgets and the LMS.

Our research builds on this existing work, but incorporates additional core technologies such as inter-widget communication (IWC), automated user activity tracking and authentication and authorisation services to protect data. This is the basis to enable real-time communication between widgets and users, and to automate user activity tracking from tools and services. The analysis of such data and IWC provides the basis to develop responsive systems that can react to learner needs in a coordinated way.

3 The ROLE Interoperability Framework

The prototype contains a common technical infrastructure to support the assembly of widgets in responsive open learning environments. The infrastructure is presented in Fig. 1 with the interconnectivity between the components. These building blocks provide open interfaces for widget functionality and the necessary information and technology to enable responsiveness.

The core of the infrastructure is the widget container that enables the assembly of various widgets. Learners and teachers use the Widget Store to select learning widgets. User activities with widgets and resources are tracked with the CAM widget.

Widgets can communicate locally in the PLE or remotely to widgets in other PLEs via XMPP [27] to foster collaboration. They can also access the CAM service to provide personalised recommendations [11] and visual analytics of CAM data [12] as a basis for self-reflection and awareness. The central identity provider allows single sign-on for the whole infrastructure. The remainder of this section describes the different components.

3.1 The widget container

The widget container is an environment for widget rendering as well as management of, and communication between widgets. It also provides a user-friendly way to organise

[10] JavaFX, `http://www.sun.com/software/javafx/`

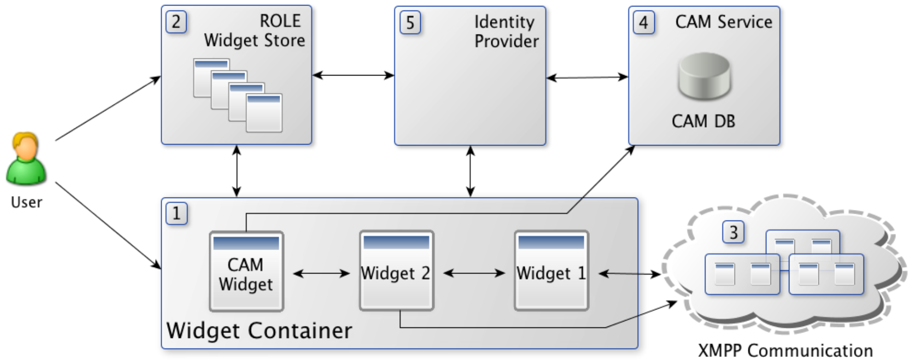


Fig. 1: The ROLE infrastructure

widgets visually, set preferences, navigate to the widget store for choosing additional widgets, etc. Such a widget container can be added in existing PLEs and LMSs [35].

There are two major widget specifications with very similar functionalities [26]: the OpenSocial [21] and the W3C widget 1.0 specification [3]. OpenSocial also provides a social API [21] to access social data from multiple web applications. Because of the higher availability of OpenSocial widgets, we currently employ OpenSocial compliant widgets, which run on major widget containers such as iGoogle[11] and Shindig[12] (for more info see [26]). We plan to also incorporate W3C widgets by using Wookie[13].

3.2 The Widget Store

The Widget Store provides a learning tool catalogue. Existing web widgets stores (e.g. iGoogle Directory[14]) do not focus on supporting learning processes. The ROLE Widget Store allows learners to search for fitting learning tools and rate them. Found widgets can be included in existing learning environments. Extensions of the store are planned on several levels. The assembly of tools and content for learning activities will be supported by intelligent recommender and social community features. Such a set of assembled widgets is defined as a bundle. Next to widgets, the store will also contain a variety of learning tools and will have features for social requirement engineering that will be the base for a community of practice for responsive open learning environments.

3.3 Inter-widget communication

IWC enables event-based communication between widgets following the Publish - Subscribe communication pattern [2, 7]. We employ both local inter-widget communication

[11] iGoogle, `http://www.igoogle.com`
[12] Apache Shindig, `http://shindig.Apache.org/`
[13] Apache Wookie, `http://getwookie.org`
[14] iGoogle Directory, `http://www.google.com/ig/directory`

(LIWC) within a PLE and remote inter-widget communication (RIWC) among different users and computers.

LIWC is realised in the OpenApplication Event API [18, 17] using the HTML5 Web Messaging standard [16] available in most major browsers, including backwards compatibility for the Google Gadget PubSub mechanism. Instead of 'hard-wiring' widgets with each other [33], all widgets within a PLE are notified of all events and then decide for themselves to react accordingly. The event payload format is designed for partial semantic interoperability, i.e. developers use a combination of established vocabularies in a simplified format with namespaced-properties (e.g. Dublin Core [5]).

RIWC enables communication among widgets in different browsers and on different machines in order to foster real-time remote communication and collaboration functionality. RIWC is realised with the Extensible Messaging and Presence Protocol (XMPP) [27, 28], an open standard for real-time communication. The power of XMPP lies in its built-in federation capabilities and extensibility through XMPP Extension Protocols (XEPs), such as for Publish/Subscribe [20] and Multi-User Chat [29] as applied in responsive and collaborative learning scenarios [8]. Since no Javascript XMPP library with PubSub support was available, we extended the dojo XMPP library by a set of common PubSub operations. Users can discover nodes, retrieve subscriptions, create, configure, and delete nodes, subscribe and unsubscribe nodes, and publish/receive IWC events in an XML-based payload format across a federated network of XMPP servers. However, current libraries using XMPP over BOSH [23] are not applicable in public containers such as iGoogle or Google Wave due to cross-domain issues. Furthermore, they are rather unstable and unreliable [8]. Our experiments showed that the upcoming Web Socket API [15] for XMPP [22] outperforms BOSH with considerable performance and stability improvements and availability in all containers.

IWC enables more responsive, collaborative environments with real-time notifications and richer user experience, although attention to usability is required [18].

3.4 CAM Tracking Service

User activities are tracked [30] using the Contextualised Attention Metadata (CAM) format [36]. CAM describes the interactions of the users with their learning environment, i.e. which resources are used within which applications and in which contexts. These data can be used for analysis and computing of personal, social and contextual information about users and applications [30]. CAM can be exploited to provide personalised recommendations and thus serves as a basis for enabling responsiveness in ROLE. A second important goal of tracking such data is to enable the evaluation of ROLE services based on user activities that have been captured in real-world settings.

The CAM monitoring is implemented as a database-driven client-server architecture. A JSON REST service provides persistence and data access of the CAM data. Each monitored user action is immediately committed to the CAM database, so that the current status of the user can be retrieved by self-reflection and recommendation applications. Because CAM is privacy sensitive, the service is protected with authentication and authorisation mechanisms (see Section 3.5).

The CAM client widget tracks all user actions within the PLE and sends them to the CAM service. The widget uses the OpenApplication library [18] to listen to all the events broadcasted by all widgets in the PLE. Performance test showed that the service and database worked reliable in real-world scenarios [9]. Implementing the tracker as a widget and not integrating it in the widget container achieves container independence.

3.5 The Authentication and Authorisation Service

CAM contains sensitive and personal data protected by law. The data access has to be trusted and allowed by the users. The data communication occurs at two different levels: service-to-service and widget-to-widget communication.

Service-to-service communication can occur when for example a recommendation service requires CAM relevance feedback on resources. Data can be transferred across institutions and countries with different laws. Thus, we decided to leave the decision of service-to-service authentication and authorisation (A&A) up to the service developers.

Widget-to-service communication occurs when for example a self-reflection widget wants to query the CAM service. Here some usability issues apply: the user needs an account for every service in his PLE and needs to login to all services. We surveyed many solutions, including Facebook Connect, Shibboleth, OAuth, OpenID and Mozilla Account Manager. We selected OAuth[15] because the technological maturity, support within OpenSocial widget containers, available libraries and usability (i.e. users are warned when an application wants to access protected data).

To solve the usability issues with multiple accounts and logins, we propose to use a central identity provider for Single Sign On, using OpenID[16] in combination with OAuth. This work is currently in the design stage and will be implemented soon.

4 Case Studies

This section briefly introduces the widgets developed for the case studies. Then, two case studies in a company (Festo) and a university (SJTU) are presented. In addition, evaluation results on the usability and usefulness of the prototypes are described.

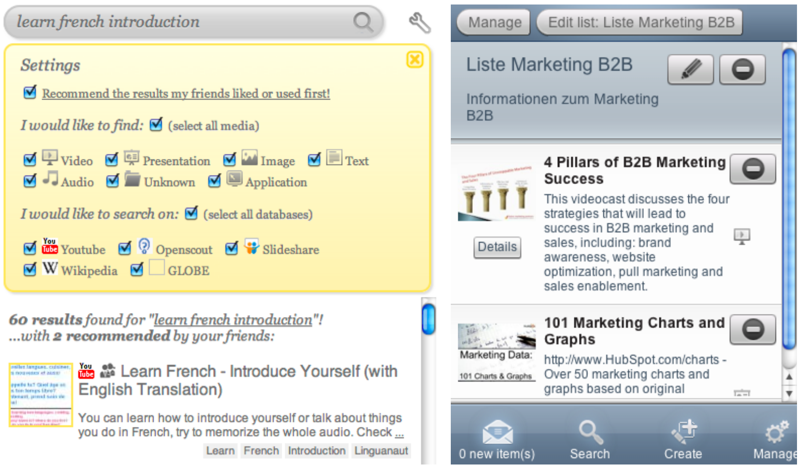
4.1 ROLE Widgets for the Case Studies

Many widgets have been developed that are compliant with ROLE technology, including language learning [26], self-reflection [12] and chat widgets [8].

To address the requirements of test beds that were used to evaluate first ROLE prototypes, two additional widgets were developed. We briefly present the widgets in this section. Case studies that assess the usefulness and usability of the deployment of these widgets in PLEs are presented in Section 4.2 and Section 4.3.

[15] The OAuth 2.0. Protocol Draft, `http://tools.ietf.org/html/draft-ietf-oauth-v2-15`

[16] OpenID specification, `http://openid.net/developers/specs/`



(a) The federated search widget (b) The media list widget

Fig. 2: Screenshots of the media list and federated search widgets

The Federated Search and Social Recommendation Widget. We developed a federated media search widget (see Fig. 2a) that provides access to a wide variety of learning content sources. The widget currently searches on YouTube.com, SlideShare.net, Wikipedia, OpenScout[17] and GLOBE[18] repositories.

Social recommendations are integrated that suggest resources based on preferences of peers. These recommendations are generated based on data that is captured by the CAM tracking service (cf. Section 3.4). The recommendation algorithm uses both explicit (ratings) and implicit (i.e. previews and selection of the results) relevance data [11]. In both case studies, the use of the widget has been evaluated in a real-world setting.

The Media List Widget. When finding interesting results, users might want to save and group them for later referral. The media list widget (Fig. 2b) stores and groups results for later use and allows sharing of the results with peers. The widget works in combination with the federated search widget. Local inter-widget communication (cf. Section 3.3) is used to enable communication between the widgets. When the user saves a result in the federated search widget, an OpenApplication event is sent. This event is intercepted by the list widget and stored. The federated search can also search in the media list database to find relevant results saved by peers. The media list widget was used in the Festo study to assist the sales department with re-occurring product searches.

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[17] The OpenScout repository, `http://www.openscout.net/`

[18] The GLOBE alliance, `http://www.globe-info.org`

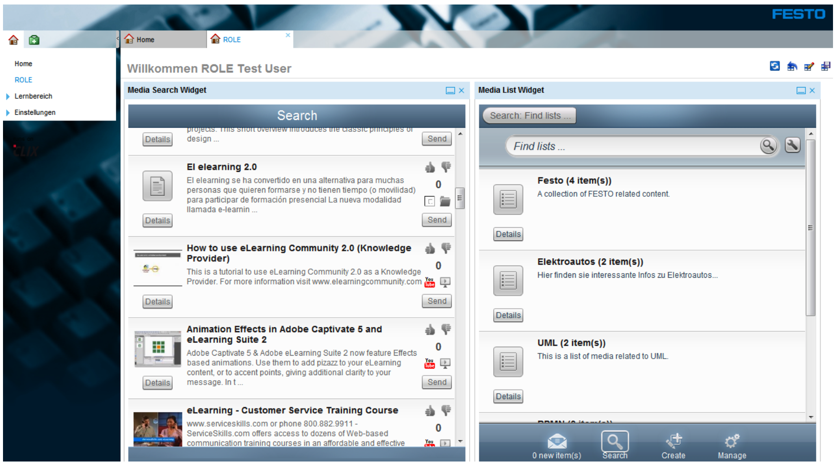


Fig. 3: Festo PLE example

4.2 The Festo Case Study

The Festo[19] test bed provides a responsive learning environment for further education activities in a company. The learners in this test bed are very heterogeneous. They differ in age, education, job-roles, learning requirements and learning preferences. This test bed provides a platform for federating and mashing-up different ROLE learning services within their LMS, the Festo Virtual Academy (FVA). The FVA focuses more on institutional learning than on self-regulated learning and is more or less restricted to internal resources. To support self-regulated learning it is necessary to open up LMSs and introduce features where learners can adapt the system according to their needs.

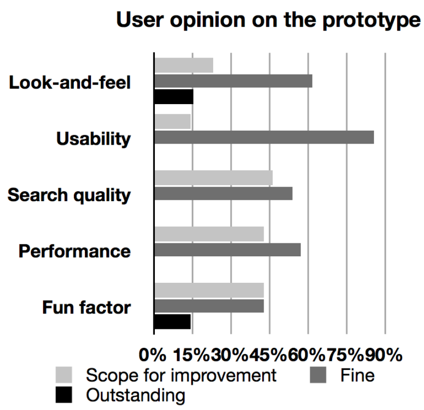
Festo uses CLIX[20] for running the FVA. We extended CLIX to support widget container functionality (cf. Section 3.1) and inter-widget communication (cf. Section 3.3). In this case study, we provided learners with a single access point to different learning resources (internal and external) and enable collaborative organisation and sharing of these resources. To achieve this functionality, the federated search and media list widgets were evaluated in the FVA (see Fig. 3). The graphic design of the federated search widget was adapted to the corporate style.

In a first stage, we evaluated the acceptance of a widget-enriched system by learners who are used to a classic LMS. The testing took place on the live FVA. The test group consisted of 25 employees and took place from March 9th 2011 until March 31th 2011. The usage of the system was demonstrated to the test users in a screencast. After using the system, the participants filled out a questionnaire that was targeted to assess the perceived usefulness and usability. The questionnaire was divided into three question blocks: demographics, assessment of the widgets and feedback for improvement.

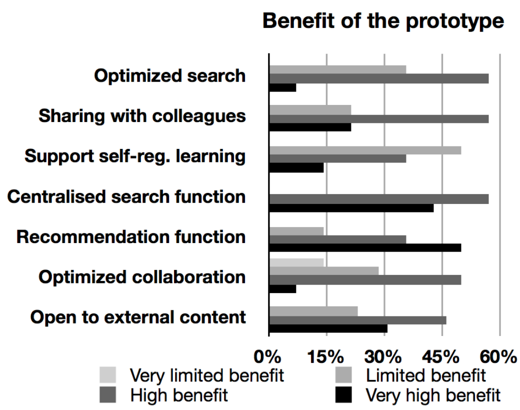
The preliminary evaluation showed that the majority of the users liked the look-and-feel as well as the usability (see Fig. 4a). For both criteria only a few people wanted

[19] Festo, `http://www.festo.de`

[20] http://www.im-c.de



(a) Prototype validation - first impression



(b) Benefit of the prototypes

Fig. 4: Evaluation results

improvements (23% for look-and-feel, 14% for the usability). People preferred to have higher quality search results (46%) and better performance (43%). This is in line with the earlier evaluation of the federated search widget in [11]. To solve this issue, we will add more repositories (e.g. Festo product databases) and adapt the federated search so that it shows results immediately after it has received initial results.

Most users see a high or very high benefit of the offered prototypes (see Fig. 4b). People benefited most from centralised search (90% high or very high benefit) and recommendations (86% high or very high benefit). The optimised information search was also quite beneficial, but could probably be improved by adding more repositories. Sharing media and openness of the LMS is important for the users. Some people see collaboration as slightly less important. The benefits of self-regulated learning were not clear for many users (50%). Section 5 elaborates on our plans to address this issue.

Overall, the use of the two widgets in the widget environment was positive. 88% of the users would recommend the tools to their colleagues. The perceived usefulness and effectiveness was evaluated by a question whether the offered services and the ROLE approach would help the users to work more effectively in their job, compared to today. 31% fully agreed with this point, 50% agreed and only 6% denied that they would not be more effective. This is also a positive result for this early prototype. In the future, we want to evaluate the usefulness for their job in more detail with more employees.

4.3 The SJTU Case Study

The Shanghai Jiao Tong University (SJTU) School of Continuing Education (SOCE) offers higher education to adults (24.000 in 2010) with a full-time job. The students form a very heterogeneous group caused by age, command of English and digital literacy. In ROLE, SOCE serves as a test bed to understand PLE usage in a context that is characterised by limited study time and low digital literacy. SOCE implements blended

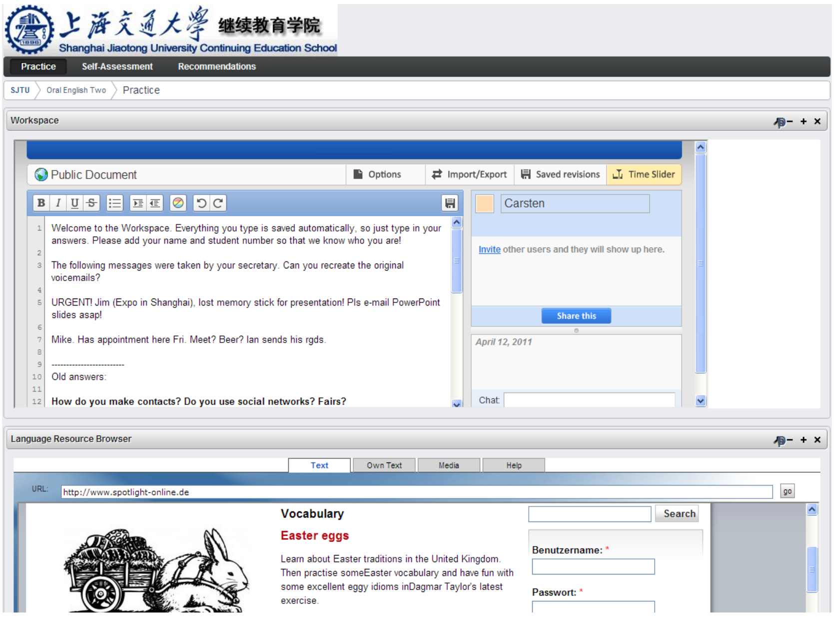


Fig. 5: SJTU PLE example

learning where the lectures can be attended in person, remotely by watching a broadcast using SOCE's LMS, which has limited support for active and self-regulated learning. PLE technology has the potential to overcome these limitations by enabling the integration of tools and recommendation services. To investigate this, SJTU set up an experimental PLE, configured by teachers and researchers, in Liferay[21]. Most of the functionality is offered by webpages or existing OpenSocial widgets (cf. Section 3.1) that are tracked by the CAM service (cf. Section 3.4).

In contrast to the evaluation at Festo with a mature learning environment and experienced users, the evaluation at SJTU was done with an early prototype of a learning environment that was entirely new to the students.

The evaluation focused on the use and usefulness of the PLE and the social recommendations of the federated search widget. It took place in the three on-going English language courses that started in February 2011 with 100-300 students each.

The setup was very similar for each class and consisted of the following pages:

- "Practice" (part of it is shown in Figure 5): a language resource browser; a translator; a vocabulary trainer; an Etherpad widget with exercises (Etherpad is an easy-to-use collaborative text editor); and the CAM widget.
- "Self-Assessment": a widget for testing the English level; and the CAM widget.
- "Recommendations": the federated search widget.

The students had to complete a task list, focused on exploration of the PLE and embedded tools, with an estimated duration of 15 minutes. After that, students were

[21] Open source portal system Liferay, `http://www.liferay.com/`

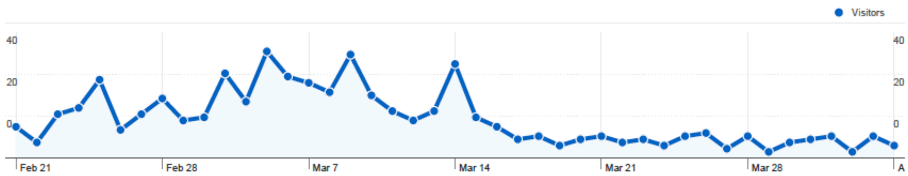


Fig. 6: The absolute unique visitors of SJTU test bed over the evaluation period

prompted to complete an online survey in Chinese. The evaluation ran during 3 weeks. Data about the PLE usage was collected through the survey, student interaction recordings with the PLE and web analytics data. The survey was designed to collect user feedback about the federated search widget and the overall usefulness and usability of the PLE. The questionnaire included 13 items pertaining to recommendations adapted from the ResQue (Recommender systems' Quality of user experience) framework [25] utilising the constructs accuracy, relevance, interface adequacy and intention of future use. The usability section of the questionnaire consisted of 14 items encompassing usefulness, navigational consistency, overall ease-of-use, satisfaction and enjoyment [32, 31]. A total of 13 completed responses were obtained.

Among the respondents, 69% used the federated search widget. Overall, 56% of the federated search widget users found the recommendations relevant to the course. Among the federated search widget users, 56% also reported that the recommendations were well presented and the widget UI was easy to understand. However, only 38% of these students wanted to continue using the federated search widget. The PLE as a whole was useful for the course for 23% of the respondents and 39% felt that it was easy to use. Only 15% of the users found the PLE to be navigationally consistent, which could have significantly influenced the usefulness and ease-of-use measures. In spite of the difficulties, 46% of the respondents were satisfied with the PLE. Additional comments provided via open-ended questions point towards performance issues. One such comment, "I like it for translation, but it works so slowly, I almost can't bear it", reflects the significant loading times that affect the user experience reducing future intention of use. This may relate to the slower Internet connections in China as opined by the teachers and because most widgets were remotely hosted across the globe.

Mouse tracking is a technique for monitoring and visualising mouse movements on a web interface to gain insights and discover usability issues. The Userfly[22] mouse tracking service was integrated in the PLE. The recordings provide some useful insights. For example, it confirms the findings from the survey pertaining to the lack of navigational consistency and specifically performance issues like loading time.

The web analytics for the first six weeks of the course (February 21 until April 4) show a total of 444 visits (10 visits a day), with a spike of 77 visits on the day the PLE was jointly used in the computer room.

The absolute unique visitors are shown in Fig. 6. After the first three weeks (the time in which the researcher attended class and motivated the students to use the system) the numbers declined. On average, users accessed 5.59 pages per visit. This number is

[22] Userfly, `http://userfly.com`

slightly higher as expected, as each lecture consisted of 2 or 3 pages. A detailed look at the data reveals that 18% visited a single page (the login page), 14% two pages (the login page and the first course page), 17% three and 50% more than three pages. Two third visited the site more than once. On average they spent 8 minutes on the PLE, which is lower than expected to finish the task list. We assume some visits were short and of an exploratory nature. The most frequently visited pages are the "Practice" pages.

Almost 1 out of 5 users did not get further than the login page. The analysis of the recordings of the user interactions highlighted that students used login credentials from another system. This demonstrates the importance of single-sign-on solutions.

In the future, we plan to enable the mouse tracking for a limited duration during lab-based sessions, followed by Retrospective Think Aloud [14] sessions with a few learners to extract some more detailed explanations. User interaction analysis of a larger group could also be achieved with the CAM data, which we currently have not done yet. Rather than merely triangulating data obtained from a survey, the proposed approach will help yield additional qualitative data for future design and development decisions.

5 Conclusion and Outlook

This paper presented the prototype implementation of a infrastructure for responsive open learning environments with support for widget assembly, inter-widget communication, authentication and authorisation services, and services for activity tracking. The infrastructure allows widget bundles to react to learner needs in a coordinated way.

Future work will integrate the infrastructure with the psycho-pedagogical integration model (PPIM) [10] for self-regulated learning. The learning process in the model is described by a four-phase cycle based on work by Zimmermann [37], where the learner: (1) (re-)defines his profile information, (2) finds and selects learning tools, (3) uses learning tools, (4) reflects and reacts on strategies, achievements and usefulness.

In the presented case studies, phases three and four are supported. Learners can use their widget bundles and receive feedback – i.e. by visual analytics of CAM data [12]. For now, phase two is done by the teacher who preselected widgets for the student. Phase one is discarded because the user profile service was not available.

The next step is to provide full support of the PPIM model within the ROLE infrastructure. Learners will be able to set up a user profile including the current and competencies to be achieved, preferences, learning history and progress. Suggestions will be automatically generated by analysing CAM data and can be revised by the learner.

In phase two, the Widget Store can recommend widget bundles for the defined learning goals based on the current competency profile. This requires a semantic machine-readable description of the available tools, content and bundles. Social recommendations will be also important in this phase. Our ongoing work in this area is described in [11]. After integrating the PPIM model, the infrastructure will be evaluated with the presented case studies and two new academic test beds.

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