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Collaborative Development of a PLE for Language Learning

Abstract—This paper provides a report on the experimental collaborative and distributed development of a prototypic Widget-based PLE. The development process is described and detailed taking into account the requirements of a language learning scenario. First results are presented, and developer experiences are discussed critically with a focus on the development process as well as problems with current widget technologies and interoperability.

Index Terms—Collaborative Software Development, Technology Enhanced Learning, Personal Learning Environment, Widget Interoperability.

I. INTRODUCTION

Current endeavors in the domain of Technology Enhanced Learning (TEL) exhibit the need for increased openness and responsiveness of current learning environments. While older learning technology generations were often central and closed systems, often merely focusing on the management of learning processes, the next generation of Personal Learning Environments (PLEs) tackled by the ROLE project 1 concentrate rates on a highly distributed approach drawing on the combination of established open standard Web technologies in order to enable the learner-side integration of services and tools from a plethora of heterogeneous sources into customized learning environments. One of the major goals of ROLE is to deliver an appropriate technical infrastructure for the establishment of such open, on-line learning environments. Another goal of ROLE is to establish a community of open source and external developers outside the traditional developer community, contributing further tools and services based on this infrastructure. During the first project developer meeting, we thus agreed to work in parallel to the standard project plan towards a comm on goal, called the "Christmas Project" with the following objectives in mind:

- Experiment with promising combinations of emerging technologies towards an integration infrastructure for PLEs
- Explore the feasibility of a collaborative and distributed development process scalable to a large community of independent developers

While the first two objectives addressed the consortium's internal collaboration, the last two clearly address a broader audience. Thus, this paper reports on the results of the Christmas Project with a focus on the collaborative distributed development process and a first integrated PLE prototype resulting from this process. It gives the reader an insight into the challenges we faced during our work regarding the development process and the technologies we experimented with. After drawing the conclusion that current technology and development processes are often still insufficient for a seamless independent development of interoperating learning services and tools, it outlines possible improvements.

The rest of this document is structured as follows. In Section II we describe the development process to gain an insight of how our work was organized. In Section III we present details on the requirements elicited for a prototype PLE based on a language learning scenario. In Section IV we present the individual partner contributions in more detail. Section V presents our experiences and a critical conclusion of our work regarding current issues concerning Widget technology. In Section VI we end with a short summary and give a short outlook to further work.

II. DEVELOPMENT PROCESS

Following the objective of abolishing a community-oriented development process, we planned to explore such a process in a smaller scale within the consortium starting off with a community of nine partners across Europe, from both industry and academia and with different degrees of technical background. Since heavy-weight processes would in practice not be feasible and accepted with a large-scale developer community, we decided to keep the process as lightweight as possible, he weber ever bowing concepts from standard processes such as agile Development [1][2], e.g. short iteration cycles, shared code & documentation, continuous integration, re gular developer meetings.

D. Renzel1, C. Höbelt2, D. Dahrendorf3, M. Friedrich4, K. Verbret5, S. Govaerts5, M. Palmér6 and E. Bogdanov7

1 RWTH Aachen University, Aachen, Germany
2 ime information multimedia communication AG, Saarbrücken
3 Fraunhofer Institute for Applied Information Technology, St. Augustin
4 Vienna University of Economics and Business, Vienna, Austria
5 Katholieke Universiteit Leuven, Leuven, Belgium
6 Uppsala University, Uppsala, Sweden
7 École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

1 http://www.role-project.eu/
communication, etc. However, given by the spatial distribution of the community, concepts requiring physical attendance emphasized in Agile approaches had to be replaced by communication technology in order to avoid roundtrip unrealistic in a larger scale community. Furthermore, such a distributed approach requires technical means for code and documentation sharing and an integration environment with low entry barriers. Table I briefly shows the rather lightweight abstract schedule we pursued during our experiments. It should be noted that this process can be iterated. However, we reached a solution here is likely to be subject to refinement or even re-employment in next phases of the ROLE project.

In the following, we provide details on the first iteration conducted during the ROLE Christmas Project.

All of the participants dedicated themselves to contribute components for an integration framework, individual learning services, either implemented or as a mockup to reach the common goal of delivering an integrated PLE prototype.

After the collection of all contributions intended by the partners, we selected the ROLE OLE Christmas Project Big Picture (cf. Figure I). Given the heterogeneity of the partners' plans for contributions, we agreed on a common scenario serving as a concrete use case for a ROLE PLE prototype based on a Widget approach. That purpose we chose a language learning scenario described in detail in Section III.

As a basis for ongoing documentation we decided to setup a document to be edited collaboratively by all partners, starting with the Big Picture, an elaborate description of the scenario and a timeline plan. Every partner added a description of his contribution and how it would fit with the scenario. Thereby, we did not require a perfect match, but at least a high degree of relevance.

A ROLE XMPP Server was set up for direct communication. A ROLE developer chat room was configured to log all group conversations on the server side. Thus, everybody could easily keep track of previous discussions, which turned out to be a helpful feature. However, restricting firewall policies enforced by various partners in situations sometimes hindered the use of XMPP – a valuable experience for future considerations regarding its use in our software (cf. Section IV.E.)

![Figure 1. ROLE Christmas Project Big Picture](http://www.i-jet.org)

Furthermore, in order to maintain the source code of all partner contributions, we agreed on utilizing a git-based [3] repository at github.com for reasons of wide visibility and acceptance in the open source developer community. Besides SCM functionality, github provides an issue tracker, Wikis, repository statistics, etc. All of these features were frequently used during the development phase.

With regard to a development environment for the individual part ner contributions, we defined the following simple policy:

1. All partners setup development environments.
2. One partner maintains integration environment and regularly pulls from the ROLE github.

During a later physical meeting we discussed a few options and suggestions regarding the choice of technologies as a basis for development and integration environments. The following considerations were taken into account:

1. How to quickly move forward and succeed with Christmas Project on schedule.
2. Avoid using technologies that will hinder us or force us to start over completely later on.
3. Make as few decisions as possible at this point in time.

Since the prototype should be Widget-based, we discussed a pre-selection of promising technologies for software components such as Widget engines, containers, and repositories, as well as Widget communication mechanisms, protocols, etc. and started our developments after a first decision for one configuration.

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III. REQUIREMENTS

In this section we will present an overview of the requirements elicited for the realization of the Christmas Project. We start with the language learning scenario we agreed upon as well as the underlying psycho-pedagogical model. We then continue with technical requirements for the realization of our prototype and considerations on how to fulfill them.

A. Scenario

In our language learning scenario, the learner, Tim, is an employee at Travel Books that sells books and videos on travel destinations. He works in the sales department and has to go to international fairs and to speak with distributors, bookshops and other business partners. As most business communication is in English, Tim needs to improve his English skills, especially in Business English.

One part of his learning strategy is to read texts and learn vocabulary using his PLE. For that purpose he adds three widgets: a Language Resource Browser, a Vocabulary Trainer and a Translator widget. All of them are visible on one webpage.

In the Language Resource Browser, Tim searches for a text and starts reading it. Each time he misses a word he selects it and opens a context menu on it. The system then proposes him to either look it up in the Translator widget or send it to the Vocabulary Trainer widget (cf. Figure 2).

So he adds words that he considers as important to the Vocabulary Trainer and others he only looks up.

After reading the text, he has gathered a list of words he considers important to be repeated in future using the Vocabulary Trainer widget.

In the next days he cont inues reading new spaper articles regularly and his Vocabulary Trainer widget obtains more and more words. In an analogical manner he uses the Language Resource Browser widget to search for words and to test his Vocabulary knowledge.

One day, he is learning with his Vocabulary Trainer, memorizing the words on the list and testing whether he knows them sufficiently well. He recognizes that he has problems to remember a certain word because he does not know the context anymore where it originally appeared.

Fortunately the Vocabulary Trainer always stores the link to the original text. So Tim clicks on the word and the original text appears in the Language Resource Browser widget and shows the sentence where the word was taken from.

Reading the sentence and thinking of the context facilitates him to memorize the vocabulary. Furthermore he improves his language proficiency by knowing situations where he can use the word.

The scenario can be extended by a group of learners, e.g. st udents that have participated in an English Language course. The instructor sends them a list of newspaper articles that are available online. The students are asked to read and analyse the text and to learn the vocabulary. As they come from the same background (high school English level), they decide to jointly create a vocabulary list using the Vocabulary Trainer widget. Whenever a student finds an unknown word in the newspaper article, he adds it to the joint vocabulary list. The Vocabulary Trainer widget will also display words added by other students who have the same level in the English language. Words that have been added more often are sorted higher. Each learner in individually transistor the list of words an d the vocabulary widget keeps track of each student’s individual vocabulary knowledge. The group’s average knowledge (number of words learned) is displayed in the widget, together with the current student’s knowledge. Nevertheless it should be possible to deactivate the group functionality if the learner only wants to learn for herself.

B. Psycho Pedagogical Model

In this section we shortly present the ROLE psychopedagogical model [4]. The central element of this model is a cyclic learning process model consisting of several learning phases related to learning activities. Following the connections between learning phases, activities and tools, a sequence of learning tools can be derived. Furthermore, two different kinds of learning tools are defined, i.e. regular learning tools or advanced learning tools used for self-regulating the own learning process.

A navigation tool guides the learner through a self-regulated learning process by recognising learning activities and tools proposed. The partners created an interactive mock-up of such a navigation tool (cf. Figure 3) and presented it in the context of the scenario from the previous section.
The contribution of education professionals had a great impact on the technical developments and showed us once more that technical and conceptual work should be conducted hand-in-hand.

C. Technical Requirements

For the technical realization of a first ROLE PLE prototype, we decided to follow an approach of intercommunicating Widgets. The expect actions from choosing such an approach were a relatively loose coupling between individual widgets and different parts. It should not be noted that we al so experimented with such an approach, because in the future, separate widgets are developed outside the community should be able to work completely independent from other developers.

First, a technical infrastructure was needed as a basis for our prototype. Starting from the Big Picture, we identified requirements for the following components of such an infrastructure:

1. Widget Container/Engine
2. Widget Store/Repository
3. Widget Interoperability Mechanisms
4. Widget User Interface

As a solution for a Widget store/repository, we considered the following four solutions:

- No store/repository, fixed list.
- Wookie
- Google Widget directory
- ROLE widget store (remains to be built)

A fundamental requirement to Widget interoperability was that the support of various open architectures was needed. The reference implementation of an OpenSocial [6] container currently under implementation in Apache. OpenSocial defines a common API for social applications across multiple websites and also includes a specification for widgets — gadgets in OpenSocial terminology. As a further alternative we considered SocialSite [7], based on Grassp and Apache Shindig with the ability to run OpenSocial gadgets and have them backed by the same social graph. Furthermore, Apache Wookie [8] was taken into consideration as a solution for adding W3C Widgets [9] as well as OpenSocial and Google (Wave) Gadgets to web applications.

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1. Inter-Widget Communication

Uppsala University introduced the Open Application Container Event API to provide a generic solution to the requirement of inter-widget communication in the scenario. The most important aspect of the solution is that widgets need not be “hard-wired” against each other. Instead, they communicate using well-known data expressions, with the intention that widgets will understand the parts that are important to them.

The basic principle behind the event API is that all widgets are notified of all events. No specific subscription step is necessary. All widgets are given the opportunity to react to any event, which may choose to do depending on event type, message type, message content, etc.

1) Events types

The event type includes: state, load, modify, save, select, unselect, startDrag and stopDrag. A state event is different from other events in that it has no relation to the event source, and therefore no resource is sent along. Instead, a state event indicates a change of state in the widget that sent it.

2) Event Structure

Notifications of events are sent out as messages. The message consists of the relevant resource, if any, depending on the event. The message is wrapped in an envelope containing further event information.

- event - the event type (see previous section).
- type - the message type
- message - The message, for example a resource.
- uri - The message's URI, if any.
- date - Timestamp of when the event occurred sharing - How the event is allowed to be used.

At the moment, the event API consists of a Gadgets PubSub channel, in which the messages are published and thereafter sent out to all widgets.

An Open Application Container is a widget that subscribes to the PubSub channel when the widget is loaded. The shar-
ing property is intended to specify how the data may be used: on the same page, only on the user’s machine, by a service under the user’s control, by participants with access to the same widget instances, or that it may be transmitted to various services. Each level includes all the privileges of the previous levels.

3) Message Types

A number of message types are defined. These include: namespaced-properties, IDL, JSON, URL, HTML, XML and MIME content. Of these, namespaced-properties is intended for simple RDF-like metadata with direct properties, and MIME content for unparsed text or binary data.

B. Web 2.0 Platform for Collaborative Organization of Information and Tools

The EPFL team developed a Web 2.0 platform, namely Graaasp, to help users to collaboratively organize information and tools toward a given goal or activity. Tools in Graaasp are implemented as widgets. In addition to the standard add, remove, browse, group and share operations, Graaasp also supports tagging, rating and commenting. The widgets are imported/bought from a widget store and linked to the given Graaasp page dedicated to a learning activity.

Once the activity is configured the user can switch the view to play with instances of selected widgets. The widget instances are rendered in a widget container managed by a Wookie engine. Any widgets following the W3C widget specifications can be instantiated into Graaasp.

Based on both the created activity structure and the user ratings, a recommender system that would contain the data of selected widgets. The W3C widget specifications can be instantiated into Graaasp. The CAM schema provides a standardized data format to store user activity and thus foster widget interoperability since every widget could access these data.

Since the CAM widget is a simple subscriber widget, it listens to every event published from any other widget and collects the m. The collected events are then transferred into the CAM schema and afterwards stored in a database. As all control should be with the user, she can decide between different storage modes. The Christmas project therefore specified three different storage modes which can be selected by the user (cf. Figure 5).

If the user decides to store her activities remotely, the CAM widget transfers the data to a central CAM repository, where all events of every user are stored. After creating a CAM instance, the CAM widget calls a Web service passing the CAM information which is then stored in a database. The local storage mode uses the Gears plug-in to store CAM information in a local database. The Gears plug-in is available for any HTML5 browser and supports all common browsers. It provides a SQLite interface to easily create a database and store information inside of the local browser profile. An alternative approach to Gears is using HTML5 [16]. Since the specification of HTML5 is not finished yet and is currently not supported by every browser we have chosen Gears. If the user does not want her usage behavior to be monitored she can choose the storage mode off.

To generate recommendations based on CAM, these can either be based on the user's own previous behavior or the usage history of others can be taken into account as well. The different storage modes have effect on the generation of recommendations. In the remote mode the user can get recommendations, but also allows the system to use his information to generate recommendations to other users. The local storage mode only allows retrieving recommendations, and disallows the system to use her information to generate recommendations to other users. If the user does not want her usage behavior to be monitored she can neither get recommendation nor support the system to generate recommendations to other users.

As we have no Vocabulary Trainer CAM data for the Christmas project, we transferred some PLE monitoring data [21] into the CAM schema and provided a separate Web service which offers methods to generate recommendations and self-evaluation statistics.

D. Visualization of Monitored Activity

KU Leuven developed a dashboard that enables students and teachers to monitor learning activities. In the dashboard, students can monitor the progress they made...
on a certain course or task and compare themselves with other students working on the same task.

An important feature of the dashboard is learning material recommendation. Based on the learning material other students have used, who have progressed further, we can recommend interesting learning material to the student. A student can compare his activities with other students and a teacher can get a general overview of what is going on in the course, see if it meets expectations and detect potential problems.

Figure 9 illustrates the first version of the user interface for our application. The student can select the course and will be presented with 2 different charts, a course analytics overview and document recommendations. Every line in the chart in figure 1 is a student. The chart shows when the student worked (horizontal axis) and how long he worked on the course (vertical axis). The red line shows a selected student, we see that the student was very late in finishing the course and that he spent a lot of work in a small number of sessions. This view enables a student to compare his progress with that of his fellow students. Another visualization uses parallel coordinates [22]. It shows a set of metrics on parallel axes. A student is represented as a polyline with the vertices on every axis. The metrics are: the average and total time spent on the course, the number of documents used and the average time of the day that a student works. By visualizing these metrics next to each other one can grasp another view on the course activity and discover trends.

The widget is developed in Adobe Flex. To monitor user activities, we use CAM [17]. In order to test the tools, we used course data provided by U&I Learning [21]. Together with our partners at FIT, we experimented with the data to propose possible metrics and collaborated on a Web service providing methods to retrieve and calculate: a list of all courses, a list of recommended documents for a course, general statistics for a course, statistics of a student of a course and the student’s attention metadata for a course. The widget can be easily deployed on top of another Web service that uses different attention metadata to provide the same statistics.

In a teacher module, the student names may need to be anonymized. Privacy is an important issue when monitoring this kind of data. For the Christmas project, we want to simply anonymize the names of the students in the teacher view. This is not implemented yet, because the data from U&I was already anonymized.

Another design idea, not yet implemented, is a graph-based community visualization widget. This tool could allow students to find fellow students how have the same language proficiency as them to chat or collaborate with. The widget would communicate with the chat module of RWTH to provide chat functionality. We are currently implementing this widget.

E. XMPP Chat Widget

The contribution of RWTH Aachen University is a Chat Widget providing a simple Instant Messaging (IM) client (cf. Figure 7) based on the XMPP [12][13] protocol. The widget offers interface elements for 1-on-1 conversations, the management of buddy lists and user presence information. In its default configuration, the widget connects to the ROLE XMPP Server. However, connections to arbitrary XMPP Servers are possible. Regarding the ROLE Christmas Project’s language learning scenario, the XMPP Chat Widget connects to a synchronous communication between learners integrated in a PLE. The widget is as a rich source for communication events, e.g. updated presence information, incoming outgoing messages, etc. The integration of event publishing into the Open Application Approach to be captured by CAM is planned for the near future.

Besides the added value of XMPP chats between learners and basic communication statistics, these two widgets demonstrate how inter-widget communication could be realized between remote widgets (via sending messages over XMPP) and between local widgets (e.g. via a Gadget pub/sub). There already exist specifications on XMPP Extension Protocols (XEPs) for Publish/Subscribe [14] or Personal Eventing Protocol [15] mechanisms, which will be side red for a seam less remote/local inter-widget communication for future developments.

F. Language Learning Widgets

In order to fulfill the requirements of the language learning scenario, imec AG developed the English learning widgets: The Language Resource Browser Widget, the Vocabulary Trainer widget and the Translator Widget. These widgets demonstrate a reasonable use of the Inter-widget communication by sending a request receiving terms described by a term and its context and source.
1) Language Resource Browser Widget

The Language Resource Browser widget (cf. Figure 8) allows users to consume media and send terms to other widgets processing the information. Examples of such widgets are the Translator Widget where the term will be translated or the Vocabulary Trainer where the user can add this term to a vocabulary list. At the moment the widget offers three different tabs. The "Text" tab works like a web browser. It displays a page to a given URL where the user can select the term and context. The source of such a term item will be the URL from the page.

In the second tab "Own Text" the user can add her own text taken from an online or offline resource. The third tab provides support to browse for different media such as video and audio. While watching or listening to the media, the user can enter a term in a field. The source of such a term item will be the URL from the media and the context will be defined as "Media Context".

2) Translator Widget

The Translator widget allows a user to translate terms or sentences. It translates either a term which was entered from the user or a received term item. We combined different Web services (i.e. Wikipedia, Google Dictionary, DICT.ORG, Google Translate) for the translation process. At the moment only English to German is supported, but the language pool could be extended to all languages supported by the services above.

3) Vocabulary Trainer widget

The Vocabulary Trainer (cf. Figure 9) widget is implementing a slightly modified Leitner system [23]. A vocabulary list consists of five different buckets. If an item is added it will be put in the first bucket. If the user is training a list and knows the right translation the item will be moved to the next bucket and else it will be moved to the previous bucket.

The information is stored on a central server and accessed using REST Web services. Each user has a unique login and authentication is done by basic access authentication over REST. For translation the same Web services are used as in Translator widget, and Flickr is used to suggest pictures for term s. Vocabulary items are stored in a list which can be managed by the user.

The widget has four functionalities represented by four tabs: "Add", "List", "Train" and "Stats".

The "Ad d" tab allows users to manually insert new terms/sentences, the context of that term and its source. In combination with the Language Resource Browser the term item appears automatically in the Vocabulary Trainer widget.

The "List" tab provides an overview of the stored lists and vocabulary items. The user can create/delete lists and inspect the content of the different buckets.

The "Train" tab gives the learner the possibility to practice her stored vocabulary. After choosing a bucket that she wants to train a term from that bucket and its context will be displayed. The user can get help by viewing the source of that item or viewing the image to that item (if there exists one). The fourth tab "Stats" shows statistics of the training. It displays a global score and a score for each list.

G. Federated Search & Language Processing

In traditional educational scenarios, teachers typically provide appropriate learning materials and give feedback on student essays. Vienna University of Economics & Business contributed two widgets which are useful for these purposes and indicate their application for language learning.

ObjectSpot, a widget for federated search of academic papers in different digital libraries, has its origins in the iCamp project (http://www.icamp.eu). This search client allows plugging in different digital repositories, whereby the documents are retrieved via the Simple Query Interface (SQI) [24] standard. The central core of this widget is the ranking algorithm which has been developed over several itera tions and mixes in the search results from the repositories on the fly [25]. In practice, this widget is useful for both learners and teachers to retrieve the most appropriate literature for a specific knowledge domain. By default, the most important digital libraries are:...
academic papers, e.g. ACM, IEEE, Google Scholar, CiteSeer, EBSCO, etc., are included.

The screenshot shows the results for the query term 'open responsive learning environments'. At the top, the search term and the state of the repositories are displayed. At the bottom, the user can navigate through the pages. On the left hand side, a user can 'lock' appropriate results, thus giving explicit relevance feedback and recommendations for others. This mechanism can also be used to export search results through a feed-based API if another tool is attached to ObjectSpot. Pressing the option button, a user can configure SQI-enabled digital repositories for her search client, visualize the location of the repositories on a map, get statistics on the quality of the repositories, export the results as RSS-feed, get recommendations for a query term, or plug another tool to ObjectSpot.

Conceptalyzer comprises a language processing widget which builds upon a LSA-based Web services developed within the LTfLL project (http://www.ltfll-project.org).

This widget analyzes online resources (e.g. Wikipedia articles or RSS feeds) in terms of the concepts behind the text and visualizes them according to their relevance. Application areas of this widget comprise learner positioning, monitoring one's conceptual development. It can also be helpful for teachers in preparing learning materials or grading students [26].

The screenshot shows the result of the analysis of a Wikipedia article, whereby the relevant terms are visualized in the form of a 'concept cloud'. The size of a term indicates its relevance for the article while the color links to the text corpora used to train the LSA function.

V. DISCUSSION OF WIDGET TECHNOLOGIES

During the development process of the ROLE Christmas Prototype PLE, we collected a set of valuable however negative experiences to be shared with other developers working with the technologies we attempted to combine. These experiences will be discussed in this section.

One of the most surprising experiences from the developer perspective was the immature state of many widget technologies, especially with regard to inter-widget communication, one of our main requirements for the language learning PLE. During the development process we tested the following three OpenSocial compliant Gadget development environments:

1. Apache Shindig
2. SocialSite (based on Shindig within Glassfish)
3. OSDE (Eclipse Plugin with integrated Shindig)

With all of these experiences we encountered at least one of the following problems:

- Lack of Forward Incompatibility
- Client Browser Dependence
- Server Platform Dependence
- Inaccessible Bugs in Generated Code
- Incompatibility with External Libraries
- Lack of Developer Support

The first problem was related to the installation of a gadget container, in particular with SocialSite. First, the current SocialSite distribution is restricted to specific, already outdated versions of Glassfish and Shindig, and thus is not forward compatible - an essential property, when working with experimental systems. Given the diversity of devices and platforms available to the developers, we quickly had to find out that platform and browser independence was not given at all. Container-side or browser-side errors were the result. The most essential problem was the inaccessibility of bugs in JavaScript code. In many cases, problems occurred outside the source code under developer control. The reason was a malfunction in the code production performed by the container itself. Furthermore, error messages were cryptic and incomprehensible and thus did not provide any hint to the original location of an error. Furthermore, we lost a lot of time communicating possible alternatives. An excursion to the usage of Apache Shindig instead of SocialSite was also not successful for all of us. Further problems were related to the incompatibility of external JavaScript libraries with the gadget container, when a given result led to strange JavaScript errors and strange code rewriting effects. Especially with regard to the JavaScript library support for XMPP, we had to experience that libraries were not far enough for the realization of our goals and definitely need improvement. Finally, we had to experience that the developer support by the SocialSite team was not available at all. At the time of writing this document, it seems quite obvious, that SocialSite is dead.

We finally managed to deploy our prototype in Graaasp in a rather stable version, but still with a lot of open issues...
to be tackled in later development stages of the ROLE project.

Drawing the conclusions from our experiences, we can state that the technologies we experimented with were insufficiently mature for the deployment of a stable integrated prototype assembled from a set of innovative tools realized using different technologies. For further collaborative distributed development experiments we agreed on a short, but regular biweekly meetings in order to get aware of occurring problems earlier. The agenda will be inspired by action items of W3C meetings.

VI. CONCLUSION & OUTLOOK

In this paper we provided a report of the collaborative distributed development of the ROLE Christmas Project resulting in a prototype of a Widget-based PLE for language learning. We first described the development process conducted among different parts from both academia and industry, with varying technical backgrounds, motivations and interests regarding the role the hole project. We pointed out that regular communication and the clear definition of goals and a schedule was inevitable during the whole process. Furthermore, we listed useful technical means of collaboration such as communication media, shared document entation, shared code repositories, etc. Furthermore, we had to draw the conclusion that our approach did not work as expected, rising the necessity for an improved approach better suited for collaborative distributed development of Widget-based PLEs. In a section on requirements we presented our use case scenarios. On the other hand, we outlined possible technical work must happen together. We elicited technical requirements on a basic infrastructure for distributed PLE development and presented a set of solutions for its realization as foundation for our experiments. We then proceeded with an overview of the innovations resulting from individual parts of code repositories, ranging from integration technologies to scenario-dependent and independent learning services. Finally, we critically discussed the outcome of the ROLE Christmas project and reported a set of technical issues hinting to the conclusion, that Widget technology is not mature and stable enough to enable distributed collaborative PLE development without hassle at this point in time. However, we worked out the requirements and associated problems for distributed implementation of Widget-based PLEs and collected a lot of valuable experience that will shape future endeavors. In an upcoming consolidation phase, we developed services and technical means of collaboration to shape scenarios and then continue work towards a number of bundles for the implementation of the ROLE test bed scenarios.

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AUTHORS

D. Renzel (re nzell@dbis.rwth-aachen.de) is the Chair for Computer Science 5, RWTH Aachen University, Aachen, Germany.

C. Höbelt (christian.hoebelt@im-c.de) is the DMC information multimedia communication AG, Saarbrücken, Germany.
D. Dahrendorf (daniel.dahrendorf@imc.de) is with imc information multimedia communication AG, Saarbrücken, Germany.

M. Friedrich (martin.friedrich@fit.fraunhofer.de) is with the Fraunhofer Institute for Applied Information Technology, Sankt Augustin, Germany.

F. Mödritscher (fm.oedrit@wu.ac.at) is with the Vienna University of Economics and Business, Vienna, Austria.

K. Verbert (katrien.verbert@cs.kuleuven.be) is with the Katholieke Universiteit Leuven, Leuven, Belgium.

S. Govaerts (sten.govaerts@cs.kuleuven.be) is with the Katholieke Universiteit Leuven, Leuven, Belgium.

M. Palmér (matthias@nada.kth.se) is with the Uppsala University, Uppsala, Sweden.

Evgeny Bogdanov (evgeny.bogdanov@epfl.ch) is with the École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland.

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