Addressing the needs of today’s e-learning environments via an open and versatile architecture for assessment

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Abstract:

Today’s e-learning environments are highly flexible in terms of the learning activities they support, the learning resources they use and manage, and the technical means they offer to adapt to the learning situation and the preferences of the learner. Providing feedback through assessment is known as an approach to supporting self-regulated learning in such environments. This paper motivates that assessment in general (and formative assessment in particular) are of high value because they can support self-regulated learning by integrating a feedback cycle. This paper proposes a technology-based assessment platform consisting of an open and versatile architecture called TAO. This open-source system offers the necessary flexibility to cope with the requirements imposed by modern e-learning environments.

1 Introduction

Learning has become more learner-centred, collaborative, and self-regulated. Pintrich and Zusho define self-regulated learning as “an active constructive process whereby learners set goals for their learning and monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features of the environment [1]”. The characteristics of self-regulated learning require appropriate methods and technologies to support the learner and maximize the learning outcome (i.e., the acquisition of knowledge, skills, and competencies).

Today, assessment is increasingly considered to also be an aid during learning [2], in addition to summative and international high-stake assessments. Hopkins describes assessment through e-learning products as a “quiet revolution” taking place in education [3]. The latest developments in e-learning environments provide these tools with more flexibility with regard to learning activities they can support and learning resources they can manage, while also making them capable of adapting to many different learning contexts. This also entails new challenges for assessment technologies, which include:

- being integrated directly into existing e-learning environments
- coping with any kind of Technology Based Assessment (TBA) resources (subjects, tests, items, results, etc.)
- being distributed amongst different sites (e.g., servers, websites, devices, etc.)
- being adapted to different organizational TBA workflows
- tackling the definition of rich test items including structure, dynamic behaviours, and layout (e.g., multiple choice, media-based, simulation items, etc.)
The next section motivates assessment as a possibility to provide feedback. Section 3 describes the open-source platform TAO, its architecture, and its different layers. Section 4 uses national and international use cases to illustrate how the TAO platform and the technological choices made tackle the described challenges. The last section concludes the paper.

2 Assessment as a means for providing feedback

Modern learning environments are dedicated to giving more control and flexibility to the learners in order to facilitate their own learning processes. Learning can be personalized to their needs and preferences within a single learning environment [4]. Schmitz et al. state that this so-called self-regulated learning “requires self-monitoring of the learner and reflection of learning behavior [5]”. The activities of self-monitoring and self-reflection can be supported by providing different types of feedback.

Providing feedback to the learner enhances the learning process, as the learner can recapitulate what he has done [5]. As far as the learners are concerned, feedback can considerably impact their control over their own motivation, cognition, and behavior. Feedback is meant to make learners and educators rethink and adapt learning and teaching strategies, to improve learning content, to find solutions to learners’ weaknesses, and, most importantly, to support the learners in reaching the learning goals. In the particular context of assessment, it turns out that feedback received during a formative assessment process and information on how to improve work by not focusing on errors made are felt as constructive and helpful for learners [6].

Very recently, AL-Smadi and Gütl have stressed that there is an increasing need for technology-based assessment (TBA) for modern environments in educational settings [7]. A special type of assessment is formative assessment. It gathers valuable data for instructional adjustments, which might yield immediate benefits regarding a student’s learning. Formative assessment refers to assessment that “is specifically intended to generate feedback on performance to improve and accelerate learning [8]”. Formative assessments let the learner become self-regulated learners [9]. From a general perspective, the main objective of formative assessment consists of giving qualitative feedback (e.g., cognitive process engaged) as well as quantitative feedback (e.g., scores obtained) to both learners and educators.

Formative assessment confers more responsibilities, self-control, and autonomy to active learners so that they become self-regulated learners [9-10]. To a certain extent, formative assessment covers diverse methods of assessment, such as instructor-based assessment, self-assessment, collaborative assessment, or peer-assessment.

Integrating formative assessment into modern e-learning environments requires the methods and technologies to be open and versatile enough to address the flexible characteristics of these environments.

3 The TAO platform

The open-source project TAO, which stands for Testing Assisté par Ordinateur (French for ‘Computer-Based Assessment’ or ‘Computer-Assisted Testing’), has been jointly developed by the University of Luxembourg and the CRP Henri Tudor as a sustainable generic system to support all the different phases of technology-based assessment. The following sections will explain how TAO copes with the different variabilities in assessment, describe the open and versatile architecture based on the different layers of TAO, and finally elaborate on the delivery of items and tests by using the language BLACK.
3.1 Technology-based assessment challenges

Considering the range of variability of TBA, a versatile architecture that makes use of specific innovative technologies was designed to tackle the needs of the different TBA stakeholders. Several types of variabilities need to be addressed, not only in the context of assessment, but also to support the integration of TBA in e-learning environments:

**Context variability:** In the educational context, for instance, many different data models are created and managed, e.g., the specification of the classrooms where the students sit, their teachers, their learning options, etc. Besides that, modern learning environments provide personalized learning situations that enforce the need to describe assessment items accordingly. The annotation of the item could be used to personalize the assessment instrument, such as item selection or item layout adaptations that reflect, for example, disabilities or learning styles. These annotations could also be used to select more appropriate learning activities based on a student’s performance on the different items. This model variability also applies to other resources in a TBA system, like subjects, tests, or management of the test results. From an IT perspective, this model variability is challenging since it prevents the definition of the data models a priori and the design of a classical database structure. To tackle this variability, we used the semantic web-related technologies RDF and RDFS. Both are standardized languages that enable us to express information about resources at any level of abstraction. They allow the system users to define the data model (i.e., to define classes of resources and describe their properties) as well as the data itself (e.g., to define values of properties that describe a particular student). All these data models are defined by using RDF/RDFS. They are created and adapted easily by the users of the system through intuitive user interfaces – no further implementation efforts are needed when the data model requires changes.

Using RDF repositories instead of a classical database design solves the model variability issue. The TAO platform makes use of the *generis*4 RDF/RDFS repository. This implies that, from the point of view of the application layer, the source code needs to be independent of the model and all the user interfaces for resource management need to be generated by first inspecting the model that was defined by the user.

**Interoperability:** TBA systems need to be integrated into existing business processes and legacy software. This may also require replacing some existing feature subsets or extend the system with new features, which involves defining APIs within the architecture that provide customized plug-ins to handle all the TBA resources (e.g., for computing statistics, creating proficiency reports, using existing subject databases, etc.). TAO provides two APIs, one for direct PHP calls and one for remote access using SOAP Web services (see next section).

**Distribution:** TBA involves pedagogues, psychometricians, statisticians, item encoders, and item translators, and may also involve stakeholders located in different geographic areas, such as a ministry of education guaranteeing access to subjects, a pedagogic institute defining tests, private software companies creating rich media for items, etc. All the different stakeholders manage different kinds of resources. This requires all the TBA resources to be spread on the TBA platform across a network of different collaborating institutions. Subject management, for example, is probably allocated to a specific accredited institution. Item management may be located at a different site to prevent items from being stolen. Such a distribution of tasks calls for the architecture of a TBA platform to be modular and distributable using the existing communication channels. This can be tackled through the use of Web services. Such distribution also allows sharing of resources and can be combined with a peer-to-peer network protocol, which would enable, for example, test creators to search across the entire network for items based on item model properties.

**Organizational variability:** The involvement of different stakeholders may require workflow-based work in order to make sure that the right person accesses the right feature of
the TBA platform at the right moment. This also addresses the need for a quality layer to optimize the processes that lead to the creation of a measurement instrument. From an IT perspective, this involves the use of a workflow engine tool and a process design tool so that the person responsible for the assessment can design the TBA process according to his or her needs. This also requires that features from the TBA platform are split into autonomous services that can be triggered independently.

**Item versatility:** Authoring of items should not be restricted by the specificities of the TBA platform. It should allow simple item creation, like multiple-choice questions, but also more complex items, such as simulations. Maximum freedom should be given to the item developers at the level of the item layout and structure, as well as at the level of item behaviour (interactivity). This can be achieved by a) defining a high-level language that supports layout, structure, and behaviour description, and b) implementing an authoring tool that facilitates the design of items as well as an interpreter capable of rendering such items.

### 3.2 TAO architecture

The global architecture of TAO for TBA resource management is close to common architectures used in many PHP-based applications (see Fig 1.). On the server side, a database management system is used for data storage. An **application layer** written in PHP implements all the specific functions for TBA and relies on the database management system layer (**persistency layer**). This application layer follows a **Model View Controller** software architecture and builds views that are delivered to the Web browser on the client side. Javascript on the client side queries the application layer located on the server side and may also update the views if needed (or retrieve a new view from the server). Communication between the client and server side takes place by means of the Ajax mechanism, thus preventing complete page reloading upon a user's operation. The jQuery library [11-12] is used to facilitate this Ajax-based communication.

**Fig. 1 General architecture of TAO**

**TAO Persistency Layer:** The persistency layer of TAO relies on the use of *generis*. This differs from classical applications and enables users to manage their own models of resources (i.e., this technology addresses the model variability issue). This means that users may
themselves define the relevant information they will manage regarding their subjects, based on their needs such as classroom, course, teacher, etc. Thanks to generis, users benefit from this flexibility at the level of the model, in contrast to classical persistency layers where the model is hardcoded by the developers into tables and fixed columns in the database.

**TAO Application Layer:** The TAO application layer is split into extensions (see Fig. 2). Each extension manages a specific subset of functions pertaining to a specific phase of TBA. The sub-domains are subject management (anybody expected to take a test), group management (populations of subjects), test management, item management, result management, and delivery management (i.e., configuration of circumstances under which subjects may take the test, such as the period, the number of times they may take it, etc.). Thanks to the distribution facilities, it is possible to distribute the TAO platform on a network, where different nodes can be used for a particular sub-domain of the resources management. The various TAO nodes will communicate with each other based on a subscription mechanism for exchanging data. A subscription can be, for example, a URL of the node containing the required items, a login, and a password to be encoded in a node used for test management. This allows, for example, a test developer to use a TAO installation dedicated to test management, to populate his test with items coming from remote installations of TAO devoted to item management (created and shared by other institutions).

![Fig. 2 The TAO application layer can be distributed over different nodes in the network](image)

**TAO Workflow Layer:** The complete application layer of TAO (i.e., all the extensions) have been split into more fine-grained autonomous services that the user can access independently of each other (e.g., preview of an item, authoring tool, translation tool, etc.). An extension of TAO called “Process” allows assessment managers to design organisational processes where users are assigned to some specific activities and to some subsets of the autonomous services that are expected to be used during the activity. In addition to the workflow engine driving the processes, the process designer is the tool intended for assessment coordinators or quality managers. It allows them to design their own specific processes based on their specific quality needs. They have to design all relevant services, organise them into the flow of activities, and assign them to specific roles. The workflow layer added to the TAO platform and to the user interfaces allows assessment
managers to improve the quality of their assessment by automating their organisational processes for the assessment setup.

Test and item delivery architecture

It is mandatory for tests and related items to be delivered the same way on any Web browser in order to prevent discrimination. It is also important to have the opportunity to track behaviours for possible analysis as well as to be able to design rich items including media content. Those constraints have led to the choice of flash technology for delivering the test to the end user. The test and the item runtime engine read XML descriptions of the items that are authored beforehand with the authoring tool. The XML-based items are based on the Business Layout Actions Content Knowledge Model (BLACK), which was developed at CRP Henri Tudor. The BLACK model is a high-level language used to address the freedom required at the level of item creation. Thanks to the authoring tool, the user may edit his item graphically and does not have to handle the item description file directly. BLACK is composed of different sections (see Fig 3.)

The business section of an item description gives overall information about the item. It describes those parts of the item that constitute the stimulus (set of materials given to the subject, the part of the item that constitutes the task itself, the response categories). In addition to that, it also defines the right expected answer and the evaluation algorithm to be used. The layout section describes all graphical elements to be used in the item like radio buttons, checkboxes, images, etc. by using the XUL markup language [13]. The action section is used for items representing simulations, where certain elements of the item are expected to have a certain type of behaviour. For instance, a pressed button might cause a Montgolfier picture to move up and down. The content section is language dependent and contains all text messages available in the item or all links to media, such as pictures or movies. Finally, the knowledge section contains meta-data annotations of the item using XML RDF and describing potential skills, context of use, overall difficulty of the item, etc.

Fig. 3 Rendering test items during runtime

4 TAO use cases

TAO has been used and evaluated in different projects. At the national level, it was used to support the monitoring of competencies achieved in Luxembourg and to guide the national education system in order to better reflect educational objectives [14]. Other national research projects used TAO especially for improving performance in language training. TAO users
specify competency models by means of items and TAO automatically computes the adequate learning settings. At the international level, TAO is being used in the context of the Programme for the International Assessment of Adult Competencies (PIAAC) study running in 26 countries. This study collects general information about the population and adults’ competencies in different domains. The assessment adapts itself during the interview based on general proficiency in some competency, but also based on background information acquired during the interview. It was thus necessary to model the subject population and the decision rules to make the test adapt once information for a particular subject is available during the test. TAO is also used in the study Programme for International Student Assessment (PISA) as an assessment platform in 53 countries worldwide.

5 Conclusions

One of the main challenges in terms of integrating assessment into modern e-learning environments is to keep the learning and assessment activities aligned with the learner’s everyday practices and situations. Since e-learning environments are highly dynamic, assessment tools need to be flexible enough to adapt to contextual changes. AL-Smadi and Gütl list the requirements for technology-based assessment applications [7]: a flexible design; user-friendly interfaces; suitability for various learning and assessment settings; management and (semi-automatic) support over the entire lifecycle; design of educational objectives, subjects, measurement criteria; result analysis and feedback provision; standard-conformant information and services in order to be sharable and reusable; security and privacy.

In this article, we presented the TAO architecture, which is entirely based on a RDFS-based data store and offers its features through Web services. Hence, it provides maximum flexibility for modelling all assessment concepts (e.g., test items, tests, subjects, groups, deliveries, etc.) in accordance with modern e-learning settings and for distributing the services across sites and other platforms. The usage of BLACK allows rendering any kind of interface for the delivered test items.

Unfortunately, until today, the field of assessment has not received much attention in e-learning outside educational institutions, especially for learning at the workplace, where self-regulated learning is essential. Therefore, the aim of this article was to motivate that assessment in general (and formative assessment in particular) are of high value in e-learning environments and hence can support self-regulated learning.

Based on the technological developments and the evolution of educational environments, we can think of new innovative item types, including the activities of creating and sharing them (i.e., following the trend of user-created content (UCC)). This especially applies to using multimedia content for assessment purposes via modern Web 2.0 services.

As Wilson et al. and others have emphasized: This is not about integrating tools within a single context; rather, it is about coordinating connections between the user and a range of services, which allows PLE to coordinate many different contexts appropriate to each single learner [4, 15]. Amongst common Web tools such as browsers, email clients, and search engines, social software services are frequently used in self-regulated learning situations and have already been integrated into modern learning environments [16] – TAO is ready to be integrated into those environments as well.

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