Deploying Learning Analytics for Awareness and Reflection in Online Scientific Experimentation

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Abstract. Recent trends in online learning, most notably Massive Open Online Courses (MOOCs) and Learning Analytics, are changing the landscape in the education sector by offering learners with access to free learning materials of high quality, as well as with the means to monitor their progress and reflect on their learning experiences. This paper presents FORGE, a European initiative for online learning and experimentation via interactive learning resources. FORGE provides learners and educators with access to world-class experimentation facilities and high quality learning materials. Additionally, the deployment of Learning Analytics in the FORGE learning resources aims at supporting awareness and reflection both for learners and educators.

Keywords: Learning Analytics; Interactive learning resources; Widgets; Open Educational Resources; Massive Open Online Courses.

1 Introduction

Higher education is currently undergoing major changes, largely driven by the availability of high quality online materials, also known as Open Educational Resources (OERs) [1]. The emergence of OERs has greatly facilitated online education through the use and sharing of open and reusable learning resources on the web. The OER initiative has recently culminated in MOOCs (Massive Open Online Courses) delivered via providers such as Udacity[1], Coursera[2], edX[3] and FutureLearn[4]. MOOCs have very quickly attracted large numbers of learners; for example FutureLearn has attracted more than 1 million registered learners worldwide since its launch in 2013, with over 2.2 million course sign-ups. FutureLearn has recently

[1] http://www.udacity.com/
[2] https://www.coursera.org/
[3] https://www.edx.org/
[4] https://www.futurelearn.com

launched the largest ever MOOC, with over 400,000 enrolments of learners for a British Council course preparing for an English language test.[5]

Another recent development in technology-enhanced learning is the *"measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs"*[6] via Learning Analytics methods. The field of Learning Analytics is rapidly developing and it gradually shifts away from technology towards an educational focus [4]. It is essentially a *"bricolage field, incorporating methods and techniques from a broad range of feeder fields: social network analysis (SNA), machine learning, statistics, intelligent tutors, learning sciences, and others"* [9].

Following these trends, the European project FORGE (Forging Online Education through FIRE)[7] is developing multimodal interactive OERs that enable online experimentation using FIRE facilities. FIRE (Future Internet Research and Experimentation)[8] is a pan-European network of testbeds, including cloud computing services, wireless technologies testbeds, such as Wi-Fi, sensor networks, or LTE, infrastructures for High Performance Computing, and more. FORGE is specifying development methodologies and best practices for offering open courseware and online experimentation facilities to learners, related primarily to communications and IT.

One of the main goals of FORGE is to enable educators and learners to access and actively use FIRE facilities in order to conduct scientific experiments. We thus follow a constructivist approach to education where learning takes place by students creating artefacts rather than assuming the passive role of a listener or reader. Our approach is based on a wide range of studies that have shown that with the right scaffolding competent learners benefit greatly from *constructivist* or *learning-by-doing* approaches [3, 6, 7]. The experiment-driven approach of FORGE contributes to fostering constructivist learning by turning learners into active scientific investigators, equipped with world-class experimentation facilities.

FORGE is enabling students to set up and run FIRE experiments from within rich related learning content embedded as widgets inside interactive learning resources. Widgets are powerful software components that can be reused across different learning contexts and for different educational purposes. The portability of widgets as bespoke apps that can be embedded into a variety of online environments ensures that the FORGE learning solutions implemented as widgets have a high reusability factor across multiple learning domains and online learning technologies. Within FORGE, widgets enable educators and learners to access and actively use Future Internet facilities as remote labs in order to conduct scientific experiments. Learners and educators can setup and run Future Internet experiments from within rich related learning content embedded as widgets inside interactive eBooks and Learning Management Systems (LMSs).

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5 https://about.futurelearn.com/press-releases/futurelearn-delivers-the-largest-mooc-ever-as-nearly-400000-learners-convene-for-english-language-learning/

6 1st International Conference on Learning Analytics and Knowledge – LAK 2011 https://tekri.athabascau.ca/analytics/

7 http://www.ict-forge.eu

8 http://www.ict-fire.eu

The remainder of this paper is organised as follows. Section 2 presents the lifecycle of the FORGE learning resources. Section 3 presents the deployment of Learning Analytics in the FORGE widgets for supporting awareness and reflection. Finally, the results of this work are summarised in Section 4.

2 Course lifecycle

There are different available methodologies for deploying remote and/or virtual lab/courses in the literature, each of them targeting different facilities and tools. Bose [2] presents a methodology for creation of a virtual lab. This approach targets the Virtual labs project and guides the lab creator to deploy a lab within the scope of such project. In a similar basis, Frerich et al [5] present a lab lifecycle with the Excellent Teaching and Learning in Engineering Sciences (ELLI) project. Both mentioned projects, focus on virtual labs (software/simulation-based) rather than remote experimentation labs (experimentation-based) [8]. We focus on remote experimentation performed on top of FIRE facilities. The lifecycle of a FIRE-enabled course consists of the following steps:

- *Specifying course requirements.* In this step, the educator specifies the overall course requirements, including the learning objectives of the course, the required skills, the skills that will be acquired by learners after completing this course, the course timeframe, the number of learners and the method of delivery (online, face-to-face, or blended).
- *Identifying FIRE facilities.* In this step, the educator identifies the FIRE facilities that will suit the course requirements. These FIRE facilities will be selected based on their suitability for the learning objectives of the course and its associated skills. The number of learners and timeframe will also play a role in selecting a FIRE facility based on its availability.
- *Authoring educational content.* The educational content that will form the learning pathway of the course is authored in this step. Finding open educational resources that are suitable for the course is quite important, as these can be reused, adapted and repurposed to fit the course learning objectives and other requirements.
- *Integration of FIRE facilities and content.* In this step, the selected FIRE facilities and the educational content of the course are integrated in order to form the complete learning pathway. FIRE facilities are commonly integrated as widgets, which can be reused across different learning activities for different learning purposes.
- *Deployment.* The deployment of the course for delivery to learners is performed in this step. Depending on the course requirement for delivery (online, face-to-face, or blended), the educator can deploy the course within a LMS or as an interactive eBook.
- *Evaluation.* In this step, the educator evaluates the success of the course, based on qualitative feedback received from learners via surveys and questionnaires, or via quantitative data collected by Learning Analytics tools that track the interactions of learners with the course materials and with each other.

- *Reflection and adaptation.* By analysing the qualitative and quantitative data collected from the evaluation of the course, educators have the opportunity to reflect and draw some conclusions about potential adaptations and improvements to the course.

3 Deployment of Learning Analytics for awareness and reflection

With Learning Analytics it is possible to obtain valuable information about how learners interact with the FORGE courseware, in addition to their own judgments provided via questionnaires. In particular, we are collecting data generated from recording the interactions of learners with the FORGE widgets inside eBooks and online courses. We are tracking *learner activities*, which consist of interactions between a *subject* (learner), an *object* (FORGE widget) and are bounded with a *verb* (action performed). We are using the Tin Can[9] API (also known as xAPI) to express and exchange statements about learner activities, as well as the open source Learning Locker[10] LRS (Learning Record Store) to store and visualise the learner activities.

Learner activities performed on the FORGE widgets typically include the initialisation of an experiment, setting the parameters of the experiment and, finally, completing the experiment. Therefore, the learner activities captured by the FORGE widgets use the following types of xAPI verbs:

- *Initialised*[11]: Formally indicates the beginning of analytics tracking, triggered by a learner “viewing” a web page or widget. It contains the (anonymised) learner id and the exercise/widget that was initialized.
- *Interacted*[12]: Triggered when an experiment is started by the learner, containing the learner id, the exercise and possible parameters chosen by the learner. These parameters are stored in serialized JSON form using the result object, as defined by the xAPI.
- *Completed*[13]: The final verb, signalling completion of an exercise by the learner. We can also include the duration that a learner took to perform the experiment, formatted using the ISO 8601 duration syntax following the xAPI specifications.

More specialised learner activities are also recorded by the FORGE widgets depending on the functionalities offered by each widget. These statements are collected in the Learning Locker, which features a simple but effective dashboard, giving a quick overview of the activities over time, as well as the most active users and activities, as shown in Figure 1.

[9] http://tincanapi.com/
[10] http://learninglocker.net/
[11] http://adlnet.gov/expapi/verbs/initialized
[12] http://adlnet.gov/expapi/verbs/interacted
[13] http://adlnet.gov/expapi/verbs/completed

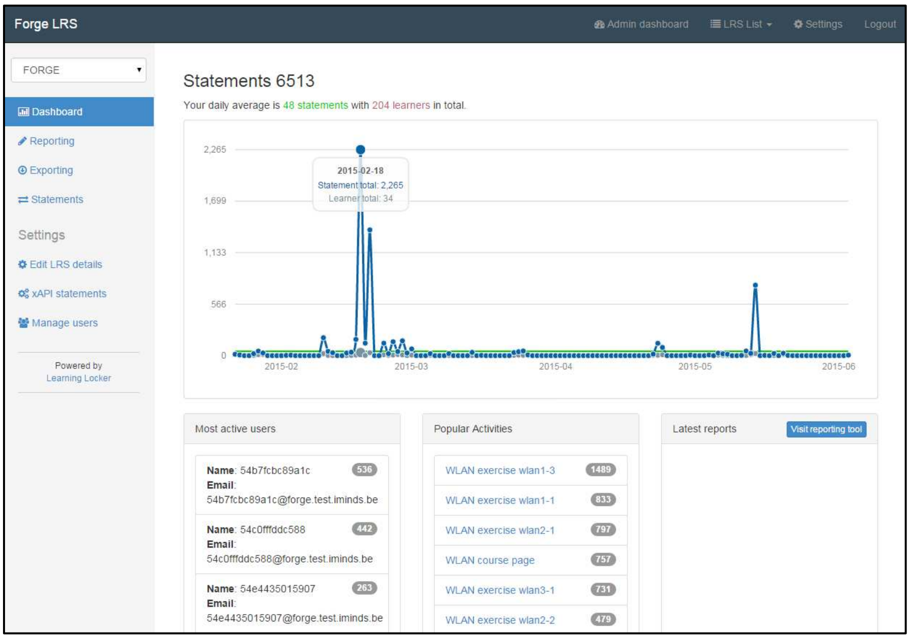

Figure 1: A screenshot of the FORGE LRS offering an overview of the captured learner activities.

The deployment of Learning Analytics within FORGE is aiming at facilitating awareness and reflection both for learners and educators. According to [10], educators need to ensure that learners are provided with (i) specific tasks, (ii) multiple learning resources, as well as (iii) learning supports (conative, scaffolds and social), in order to increase the potential for computer-mediated technologies to serve as catalysts in promoting critical reflection and meaningful learning. In the context of FORGE, learning activities for experimentation play the role of tasks; multiple resources are offered by the FORGE learning materials and other related OERs. Finally, Learning Analytics tools and visualisations provide learning supports in the form of scaffolds and social supports, as explained in the following paragraphs.

FORGE provides learners with Learning Analytics dashboards in order to raise their awareness of their learning activities by providing an overview of their progress or social structures in the course context. Learners are offered with detailed records of their learning activities, thus being able to monitor their progress and compare it with the progress of their fellow learners. Additionally, the Learning Analytics dashboards targeted to educators provide an in-depth overview about the activities taking place within their courses, thus making the educators aware of how their courses and experimentation facilities are being used by their students.

In order to improve the ways we facilitate awareness and reflection for learners and educators, we are developing further ways of analysing and visualising the captured Learning Analytics data. Our goal is to help educators better understand the use of experimentation facilities by their students, as well as to allow learners to compare their use of the experimentation facilities with that of other learners. Towards this goal, we are developing graph models in order to visualise the different sequences of steps carried out by learners when conducting an experiment via the FORGE widgets. Figure 2 shows the first four steps of the different sessions recorded by the PT Anywhere[14] network simulation widget. This model is customised by the learner or the educator, who specifies the different levels to visualise, i.e. the number of steps or actions to be displayed. In this particular model, the different states for each level apply to a network device, which is part of a network simulation experiment, and refer to its creation (ADD), removal (DEL), update (UPD), connection (CONN) and disconnection (DISCONN). Additionally, a NOOP state is used to represent the lack of action in sessions with fewer actions recorded than levels shown.

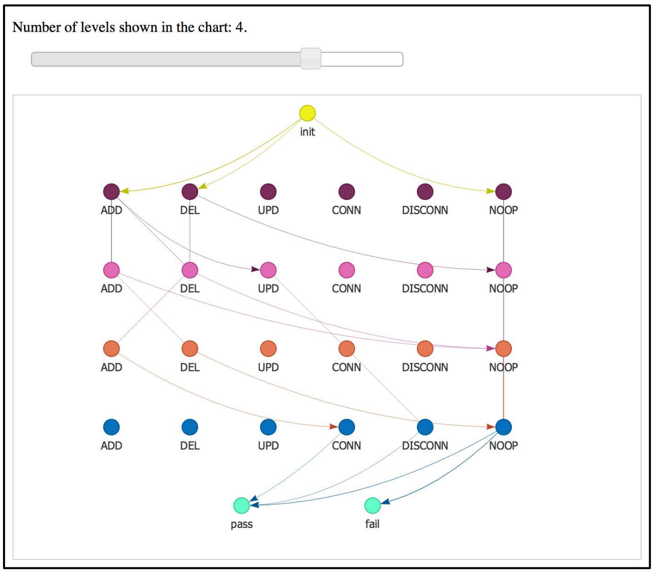

Figure 2: A model of sequences of user interactions recorded within a FORGE widget.

These models allow educators to get a more detailed view of how learners conduct experiments using the FORGE widgets. Learners can also use these models to replay their sequence of interactions with the FORGE widgets, as well as view the sequences of interactions of other learners. On top of providing awareness, these models also enable learners to reflect on their learning process, for example by being able to compare the sequences of interactions of other learners with theirs, as well as by comparing their experimentation results with those of their peers. Additionally, educators can reflect on the design of the experimentation facilities and the associated learning materials by studying usage patterns that can reveal common difficulties that learners have in conducting experiments. Educators can also provide suggested sequences of interactions to their students as a means of scaffolding their experimentation tasks.

[14] http://pt-anywhere.kmi.open.ac.uk

4 Conclusions

This paper presented the FORGE approach for online scientific experimentation, which is based on the use of widgets and interactive learning resources. Learning Analytics data are collected by recording the interactions of learners with the FORGE widgets and analysed in order to understand how learners conduct scientific experiments using the FORGE learning resources. Our work on Learning Analytics is ongoing and is targeting both learners and educators. In particular, we are using Learning Analytics tools and visualisations as learning supports in the form of scaffolds and social supports for learners. Additionally, we aim at facilitating educators in reflecting on the design of their courses based on the collected data about the use of the experimentation facilities.

Acknowledgments. This work has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreements no. 610889 (FORGE).

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