

# Towards Personalized Content in Massive Open Online Courses

Nour El Mawas<sup>1</sup>, Jean-Marie Gilliot<sup>1</sup>, Serge Garlatti<sup>1</sup>, Reinhardt Euler<sup>2</sup> and Sylvain Pascual<sup>3</sup>

<sup>1</sup>LabSTICC, IMT Atlantique, Brest, France

<sup>2</sup>LabSTICC, University of Brest, Brest, France

<sup>3</sup>Education Sector, Immanens, Palaiseau, France

**Keywords:** Personalization, MOOCs, Learner Model, Course Model, Lifelong Learning.

**Abstract:** Despite the growth of MOOCs, Lifelong learners confront many difficulties related to the attendance of courses on MOOCs. Lifelong learners are often very different in terms of background, ability, experience, and prior knowledge but they are required to follow the same content. This explains the low average completion rate for MOOCs. The research presented in this paper aims to define the functional and technical architecture to personalize content in Massive Open Online Courses in a Lifelong Learning perspective. The term content refers to videos, tutorials, documents, exercises, and quizzes in MOOCs. This work is dedicated to teachers, MOOC designers, MOOC providers, pedagogical engineers, and researchers in e-Learning and learning analytics. This work takes place within the context of a European project called MOOCTAB (Massive Online Open Course Tablet).

## 1 INTRODUCTION

Lifelong Learning (LLL) refers to systematic and purposeful learning throughout a person's life involving formal (schools) and informal (work, recreation, leisure, social relations, family life) domains (Cropley 1978). The original concept of Massive Open Online Courses (MOOCs) is to offer free and open access courses for a massive number of learners from anywhere all over the world (Yousef et al. 2014). Access to and effective use of relevant information and continuously learning in MOOCs is essential for lifelong learners. LLL as a concept has gone through a lot of changes over the years especially with the arrival of MOOCs and the increase of their learning resources. The number of courses (started/scheduled) has grown from about 100 MOOCs in 2012 to almost 4200 starting 2016, with a duplication of the number of courses between 2015 and 2016. However, according to (Jordan 2014) by the International Review of Research in Open and Distributed Learning, the average completion rate for MOOCs has only been about 6 percent. There is a growing trend of researches in the possibility of MOOC personalisation and adaptation in order to improve users' engagements, and hence reduce MOOCs' drop-out rate problem (Sunar et al. 2015).

In order to understand the reason behind this low rate, we have relied on the MOOCs annual report published by the École Polytechnique Fédérale de Lausanne (EPFL) ("MOOCs Annual Report 2015" 2016) as EPFL is one of the first universities to experiment with MOOCs, and among the few in Europe to integrate the use of MOOCs on its own campus.

The motivation that drives users to register to an EPFL MOOC varies according to the need of each learner. Six reasons are behind the registration to the MOOC: Finding a new job, getting a promotion, meeting family expectations, earning a higher salary, solving a specific problem, and helping to pass class. The "solving a specific problem" motivation is the main motivation for 60% of the courses. The academic degrees held by users of the EPFL MOOCs are very diverse. The highest degree obtained are high school, associate degree, bachelor degree, master degree, and doctoral degree. The percentage of MOOC users who are currently enrolled in an educational program is low. Only 34% of registered learners are students (including part-time students). The remaining enrollees are not in an educational program. Therefore, it is important to understand that users do not have the same background.

The diversity of users' background who followed

a MOOC is a key issue (Kizilcec, Piech, and Schneider 2013). For example, in the matter of the Analyse Numérique course, 34 % of learners have Mathematics, Computers, Engineering backgrounds, 21% of learners have Architecture, Civil Engineering backgrounds, 12% of learners have Education and Training, 2 % of learners have Business, Finance, Sales, Management backgrounds, 4% of learners have Arts, Design, Entertainment backgrounds, 13% of learners have Construction, Food, Utilities, Healthcare, Life Sciences backgrounds, and 2% of learners have Legal, Administration, Social Services backgrounds. It means that learners do not have the same prior knowledge for this course.

In this context, the motivation behind our research work is that (1) differences exist among learners in terms of background, ability, experience, prior knowledge, and (2) MOOC platforms unify the educational content to all learners without taking into account these differences. According to (Sloep et al. 2011), learners' personalization and social learning are essential concepts in Lifelong and Life wide Learning contexts. The next challenge is about how to insure adaptive learning that gives each student a personal experience in a MOOC. (Amo 2013) also believes that MOOCs should offer student-centered learning for effective and quality education in order to meet each individual learner's learning expectations in MOOCs. Furthermore, (McLoughlin 2013) and (Knox et al. 2014) point out that MOOCs environment is convenient for offering personalized contents and feedbacks to learners based on their learning goals. This is because MOOCs provides learning flexibility and sense of independence between learners and teachers which are important when implementing personalization in technology enhanced learning.

This work takes place within the context of the European MOOCTAB (Massive Online Open Course Tablet) project. Its main goal is to create a Tablet-based platform dedicated to LLL (primary, secondary, higher and continuous) using an on-demand MOOC platform with a personalized content. The MOOCTAB project intends to offer a cloud based European MOOC on Demand platform with a Plug & Play approach deployable in Europe and developing countries. This platform is based on existing technology bricks and existing open source platforms like edX.

The paper is organized as follows. Section 2 proposes the theoretical background of the study. Section 3 presents several existing solutions for personalized MOOCs. Section 4 details our scientific positioning and defines our functional and technical

solution. Finally, Section 5 summarizes this paper and presents its perspectives.

## 2 THEORETICAL BACKGROUND

In this section, we discuss theoretical background directly related to the personalized of MOOC content.

Personalization is the process of providing relevant content based on individual user preferences or behaviour (Vignette Corp. 2002). It is the explicit user model that represents user knowledge, goals, interests, and other features that enable the system to distinguish among different users (Brusilovsky and Maybury 2002).

In the e-learning field (U.S. Department of Education Office of Educational Technology 2010), personalization is education, where participants have different learning objectives, depending on their learning needs. The training is customized, so this is possible, and personalized instruction may also provide opportunities for differentiation and individualization. In this context, differentiation is education, where participants have the same learning goals, but the teaching method varies so they adapt to the individual student's needs. Individualization is teaching, where the participants also have the same learning goals, but participants can move forward at different speeds and relate to a particular content area or a given activity in different ways, and teaching is tailored to individual needs.

According to (Germanakos and Mourlas 2006), personalization is classified in categories: Link Personalization, Content Personalization, Context Personalization, Authorized Personalization and Humanized Personalization. In this paper, we focus on content personalization. (Ioannidis and Koutrika 2005) defines four forms of content personalization: information filtering systems, recommender systems, continuous queries, and personalized searches. Information filtering systems screen out irrelevant data from incoming data streams and distribute relevant data items according to a user profile. Recommender systems have automated the everyday procedure of relying on recommendations from other people whenever personal experience is not sufficient for making choices. Continuous queries are issued only once and executed continuously over the database. Personalized searches are based on the observation that "to enhance user searches one needs to take into account the fact that different people find different things relevant". In our research work, we

are interested in the form of information filtering systems.

To allow the personalized content, we need to model the learner. The model must depend on the learner himself and the domain which is the course in our case. The next section details existing projects on MOOC personalization. Note that we consider the personalization as a specific concept of the adaptation where adaptation is based on the personal preferences and background of the learner.

### 3 RELATED WORK

In this section, we consider existing projects related to personalized MOOCs and we deduce important elements to ensure this personalization.

#### 3.1 The MOOC Personalization for Various Learning Goals project

The MOOC Personalization for Various Learning Goals project is a project funded by the Bill and Melinda Gates foundation. It aims to identify how students' goals are expressed through their activities on the edX learning platform, and how they evolve over time.

The objectives of this project were: 1) classify student learners by learning goals; 2) cluster learners by engagement with the platform, comparing various groups by learning outcomes (i.e., certificate attainment), and aiming to predict user transition from one cluster to another; 3) study how the clustering could be used for platform customization and personalization of learning experience.

This research was expected to proceed in the context of HarvardX, (Harvard's division for online learning) and to be based on the data on 17 HarvardX courses running on the edX platform, focusing on 5 courses that must be completed by December 2013. Since December 2013, there are no research papers that concern the project.

#### 3.2 The POEM Project

The POEM (Personalised Open Education for the Masses) project aims at designing a platform that reconciles Massive Education — as with the strong redevelopment of MOOCs (Massive Open Online Courses) — with Personalized Education. According to (Collet 2013), one of the important concepts that allows personalized education is the deconstruction of courses and curricula into hundreds and thousands of short independent units that will interact together

as a complex system. The objective is then to get these thousands of small independent courses to self-organize into optimal pedagogical paths that allow individual students to validate curricula as fast as possible depending on their personal skills, aims and previous knowledge. POEM is developed under Creative Commons and will be as interoperable with edX. Students involve in many individual and collective educational activities for their mutual benefit: assessment, inter-tutorship and construction of dynamical Knowledge Maps of domains to provide different learning paths to learners.

#### 3.3 The Knowledge Map on Khan Academy

Khan Academy proposes math courses with a knowledge map that makes learning objectives and individual progress available to learners. The motivation behind the map is that learners miss an overview of how all the math exercises tie in together. The concept of the Knowledge Map is behind the Math Missions in the sense that exercises build on another and basic concepts are introduced before advanced ones. This knowledge map is in forms of skill-meter (display and badges) (Thompson 2011). It contains a starry night, containing all of the stars. The stars represent lessons. Yellow stars with a blue border are lessons, users are proficient at, green borders mean recommended lessons, and others are lessons that are not recommended. An orange border means a lesson a user should review. It also tells the user how skills are connected to each other. The Knowledge Map also has a navigation bar, with which students could search for a particular skill.

#### 3.4 The ECO Project

Brouns et al. (2014) proposes the European ECO (Elearning, Communication and Open-data: Massive Mobile, Ubiquitous and Open Learning). The motivation behind this project is that MOOCs are proving to be inconsistent with the European standards for formal higher education due to their low-level of learner support and lack of an enriched pedagogical approach. This project introduces the notion of sMOOCs ("social" MOOCs) which provides a learning experience marked by social interactions and participation.

The sMOOCs are accessible from different platforms and through mobile devices and integrated with participants' real life experiences through contextualization of content via mobile apps and gamifications. It also supports adaptive learning

strategies and ubiquitous, pervasive and contextualized learning. ECO sMOOCs have the potential to adapt to the changing intentions of participants during the course.

### 3.5 The aMOOC Project

(Sonwalkar 2013) proposes an adaptive MOOC (aMOOC) platform, providing a strong pedagogical framework and a personalized learning experience in a MOOC learning environment. The aMOOC allows for different ways to organize content, offering different context and perspective for learners. It also aims to identify the way a learner would like to learn by conducting diagnostic assessments on the learning preference. It uses assessment results to provide continuous intelligent feedback that motivates and provides guidance to overcome concept deficiencies and maximize learning performance.

In this project, learning strategies are related to five learning pedagogies: apprentice (learning through mentor–student interaction), incidental (learning through case study), inductive (learning through example), deductive (learning through application), and discovery (learning through experimentation). The content of the aMOOC is presented to students based on the learning style of preference. For example, in the incidental learning study, learning happens primarily within a context of case studies. Content provided by the expert is sequenced in ways that explain the events involved in the case study.

### 3.6 Discussion

This state-of-the-art allows us to define important elements for our content personalization approach (Table 1): learning goals, learning experience, learning recognition, learning path, and content granularity.

Note that for clarity reasons, in Table 1, E1 refers to learning goals, E2 to learning experience, E3 to learning recognition, E4 to learning path, E5 to content granularity, P1 refers to the MOOC Personalization for Various Learning Goals project, P2 to the POEM project, P3 to the knowledge map on Khan Academy, P4 to the ECO project, and P5 to the aMOOC project.

The learning goals are a key element in content personalization. It is a very personal decision that has its roots in a social environment providing examples, discussions and opportunities. A learner has a set of realistic and achievable goals and based on these goals the content must be delivered to him. The

learning experience refers to Learning by doing which takes place through on-the-job and leadership experiences. The learning recognition is important in our approach. It acknowledges achievements and constitutes certified evidence. It includes formal learning such as diplomas, certificates, and recommendations. The learning path makes learning objectives and individual progress available to learners. It allows an overview of how all learning concepts tie in together and where is the learner's current position in the learning path. The content granularity is related to the pieces of learning content that are combined to form the whole MOOC content. For example, if a content package is comprised of only a few pieces of large grained learning content then re-sequencing them to form a new learning path for another learner may not be possible. This issue is paramount in the delivery of any personalized content.

Table 1: Important elements / levels for content personalisation based on existing projects.

	Learning			Visualisation	Content
	E1	E2	E3	E4	E5
P1	✓	-	✓	-	-
P2	-	✓	-	✓	✓
P3	-	-	-	✓	-
P4	-	✓	-	-	-
P5	-	-	-	✓	-

These elements can be categorized in three levels (Table 1): (1) the learning level includes learning goals, learning experience, and learning recognition; (2) the visualization level includes the learning path; (3) the content level includes the content granularity.

To highlight all these ideas, we are going to detail in the next section our approach that takes into account these elements and provides innovative solutions in this domain.

## 4 OUR PROPOSED APPROACH

In this section, we present an overview of our approach. Then we detail our functional architecture and our Domain / Learner Models before discussing the presence of our elements categorized in three levels as defined in Section 3.6.

### 4.1 An Overview of Our Approach

The difference between a course completion in a classic MOOC and in our approach is the personalization of the course content.

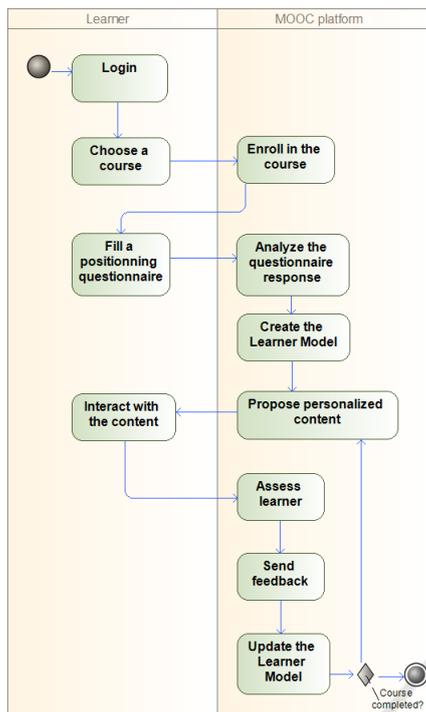


Figure 1: The course completion.

Figure 1 shows how the personalization occurs during the course completion. The learner logs in in the MOOC platform. He can, therefore, choose a course to take. Before starting the course, the platform asks him to fulfil a positioning questionnaire. This questionnaire is about the current professional situation, his diplomas, his certifications, and the platform permission to access to his LinkedIn profile. Once the questionnaire is submitted by the learner, the platform analyses the questionnaire response and creates the Learner Model for the learner.

Note that the Learner Model is addressed in Section 4.2. Based on the Learner Model and while the course is not completed, the platform proposes a personalized content to each learner who can interact with it. Then the learner will be evaluated on this specific content before updating his Learner Model.

In the next section, we will detail our functional architecture that allows this personalization.

### 4.2 Our Functional Architecture

Our learning architecture (Figure 2) is designed in order to be compliant with different MOOC platform architectures. In general, MOOC platforms distinguish two main components dedicated to different steps in the course lifecycle: the Content

Management System (CMS) and the Learning Management System (LMS). The CMS is used to manage students’ enrolment, track students’ performance, and create/distribute course content. The LMS focuses on course management including user registration, tracking courses, recording data from learners, and analysis purposes.

In our vision, we consider three main roles: the pedagogical engineer, the teacher, and the learner. In a standard course creation, the pedagogical engineer has to provide the course structure and populate it with the course content. In our approach, the course structure is becoming a part of the Domain Model (DM). We propose an LMAP editor that enables to define the structure of the Domain Model with related content and provision of potential exercises. The LMAP editor replaces the classical linear description of a course in traditional platforms while the content description does not change. When the DM is created, the course structure and content are uploaded by the pedagogical engineer in the LMS.

When the learner will access the course, he will get personalized content through our “Course Navigation” plug-in. Content will be proposed according to his own current Learner Model (LM). He can also visualize his current progress through the LM Dashboard and point specific topics in the DM. Other MOOC activities such as forums and quizzes are maintained in our approach.

Teachers have standard access to learner progress and productions on the platform. They have also aggregated access to LM of the learners registered in their course.

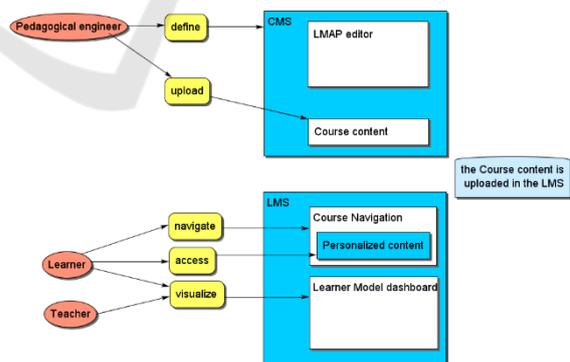


Figure 2: Our functional architecture.

Now we will detail the domain and the Learner Models which are main elements in our approach.

### 4.3 Domain and Learner Models

Our Domain Model is shown in Figure 3. It has three layers: subject, topic, and concept. The Domain Model is composed of a set of subjects, each subject is composed of many topics, and each topic refers to many concepts.

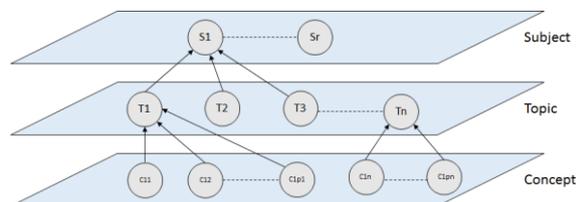


Figure 3: The structure of our Domain Model.

Our Learner Model (Figure 3) is based on the Generic Bayesian Student Model (GBSM) (Millán et al. 2013). It is composed of two different kinds of variables: knowledge and evidential variables. Knowledge variables (K) represent students' knowledge (either declarative or procedural knowledge, but also skills, abilities, etc). These are the variables of interest in adaptive e-learning systems, in order to be able to adapt instruction to each individual student. Their values are not directly observable (i.e., they are hidden variables). In the GBSM, all knowledge variables are modelled as binary, and take two values: 0 (not-known) and 1 (known).

Evidential variables (Q), which represent students' actions, are directly observable. For example, the results of a test, question, problem solving procedure, etc. The values of such variables will be used to infer the values of the hidden knowledge variables. In the GBSM, evidential variables are also considered to be binary, with values 0 (incorrect) or 1 (correct).

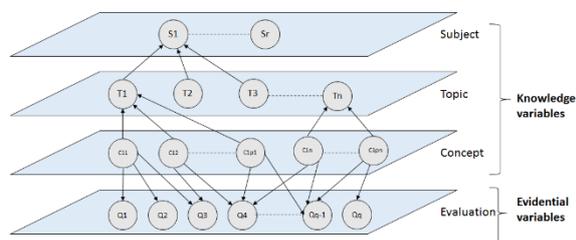


Figure 4: The structure of our Learner Model.

In Figure 4, there are two types of relationships: aggregation relationships and causal relationships. Aggregation relationships are between knowledge nodes (basic concepts, topics and subject). Causal

relationships are between knowledge and evidential nodes (concepts and evaluations).

### 4.4 Our Technical Architecture

Technically, our architecture (Figure 5) relies on three main components: the learner environment, the Learning Record Store (LRS), and the Learning Map (LMAP) core.

The learner environment is composed of different learning tools. The LMS platform is the main component of this environment. It contains the Course Navigation module that gives the learner a personalized access to content. In the learner environment, MOOCs are central but there are also other assessment platforms and social networks offering learning services.

Since we have different learning services and platforms, we need to collect learning experience and performance data from many different sources and present them in a meaningful way. That is why we choose the use of the LRS that supports the open standard, xAPI (Experience Application Performing Interface). In this way, all learning traces collected from the learner environment are transferred to the LMAP core via the LRS. Note that a statement (to be approved by the teacher) can be made by the user himself based on a certification or on a previous/current job.

The Learner Models are dynamic and must be updated. As such, we used the LMAP core to (1) store the Domain and the Learner Model, and (2) update the Learner Models. In the LMAP core, we have two main components and two interfaces. The main components are the Learner Model Updater (LMU) and the Selector. The LMU updates the Learner Model based on new assessments and learner achievements collected by the LRS. The Selector chooses the personalized content from the Domain Model according to the current Learner Model. The access to the models is provided separately by the Domain Model (DM) Interface and the Learner Model (LM) Interface. The DM interface enables Domain Models creation, modification, and deletion. It is defined for the DM editor in the CMS. The LM interface enables achievement updates, and access. It enables interactions with the learner and the teacher through LM Dashboard in the LMS.

Our first implementation is based on the edX platform, as it is the main open source platform with an active developers' community. We have developed xAPI connectors in order to collect learner traces of statements. Course Navigation is integrated

by using LTI standard that permits seamless integration of external components.

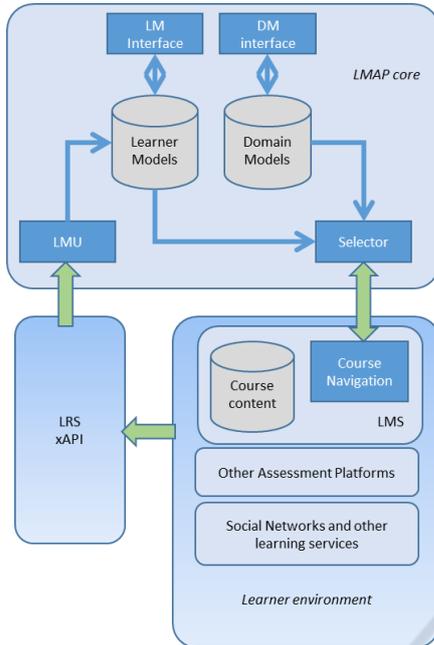


Figure 5: Our technical architecture.

As we explain in Section 4.3, the pedagogical engineer defines the Domain Model. The Domain Model is created via the LMAP editor which we have developed for this purpose. The frontend of our LMAP editor is based on Javascript, html, css, and svg. The backend is created using open source software LAMP (Linux-Apache-Mysql-PHP) server technology and PHP-framework Symfony 2. When the pedagogical engineer adds a new element (subject, topic, concept, or evaluation) in the LMAP editor, he needs to define properties below: the name of the element (label), its priority, the order it has in relation to other elements, its acquisition link (link to an online content), its acquisition mode, its validation link (if it exists), its validation approval, and the number of hours and weeks for acquisition.

#### 4.5 Discussion

Our functional and technical architectures take into account the important elements for MOOC content personalization as detailed in Section 3.6 (see Table 2).

At the learning level, the positioning questionnaire (Section 4.1), the statements made by the user himself based on a certification or based on a previous/current job, and all learning traces are transferred to the LMAP.

At the visualization level, the LMAP shows the learning path of the learning and his current position in the learning path.

At the content level, we have three layers of granularity: subject, topic, and concept (Section 4.3). These layers are comprised of a large number of pieces of small grained learning content which allow to re-sequence them to form personalized learning paths for each learner.

Table 2: The presence of the important elements / levels for content personalization in our approach.

	Learning			Visualisation	Content
	E1	E2	E3	E4	E5
Statements + traces	✓	✓	✓	-	-
LMAP	-	-	-	✓	-
3 layers of granularity	-	-	-	-	✓

To summarize, in this research work, we propose a functional and a technical architecture to allow personalized content for each learner who attends a MOOC course.

## 5 CONCLUSION AND PERSPECTIVES

This study addresses the problem of unified content in Massive Open Online Courses for Lifelong learners. The main questions of the study are how to address differences between learners (in terms of background, ability, experience, prior knowledge), what are the approaches allowing MOOCs to take into account these differences, and how to promote personalized content in MOOCs in order to propose suitable content and increase learning among learners.

We investigate the problem from its theoretical background, and we consider existing approaches related to personalized MOOCs in order to see if any existing approach can meet our requirements. Unfortunately, no one can respond to our needs in terms of the support of learner's level of knowledge, learner's background, learning goals, navigation preference, and the presence of a concept map for the course and a graphic path indicator. To achieve this, our approach is proposed as a functional and technical solution to our problem. This solution allows personalized content in MOOCs. Thanks to this solution, learners in MOOCs have more choice; they take more ownership of their learning and develop their learning strategies as well as self-regulated

learning behaviours that are necessary for meeting immediate goals and for LLL.

Now we will refine our learner and domain models and implement them before deploying our solution in classrooms in France and Turkey, in the framework of the MOOCTAB project. Then we will evaluate our approach, focusing particularly on results achieved in terms of knowledge learning by learners. For that purpose, the learning will be estimated by placing the learners in two groups: for a controlled period of time, the first group will attend a course on a standard MOOC platform and the second group will attend the same course on our personalized MOOC platform. The selection of the learners is based on a preliminary questionnaire to test prerequisites for each learner and to drive down inequalities in knowledge. The content of this questionnaire also depends on the knowledge addressed in the course which confronts learners in order to decrease knowledge heterogeneity of the two groups. To interpret the evaluation results, we will base on different variables tracked by our platform and that we consider as learners' traces such as learning outcomes (i.e., course completion, course grades) and parameters related to the platform use (time spent on watching videos, on answering questions, on passing an exam). These variables will be used to compare the various learners in the two groups. Next, we will consider how learners' interactions with the platform evolve over time in order to track changes in their learning goals.

## ACKNOWLEDGEMENTS

This research was supported by The ITEA 2 (Information Technology for European Advancement) Massive Online Open Course Tablet, MOOCTAB (2014-2017) project.

## REFERENCES

- Amo, Daniel. 2013. "MOOCs: Experimental Approaches for Quality in Pedagogical and Design Fundamentals." In *Proceedings of the First International Conference on Technological Ecosystem for Enhancing Multiculturalism*, 219–223. ACM.
- Brouns, Francis, José Mota, Lina Morgado, Darco Jansen, Santiago Fano, Alejandro Silva, and António Teixeira. 2014. "A Networked Learning Framework for Effective MOOC Design: The ECO Project Approach."
- Brusilovsky, Peter, and Mark T Maybury. 2002. "From Adaptive Hypermedia to the Adaptive Web." *Communications of the ACM* 45 (5): 30–33.
- Collet. 2013. "POEM (Personalised Open Education for the Masses)." *Educpros : Actualités et Services Pour Les Professionnels de l'éducation*. 2013. <http://www.letudiant.fr/educpros/>.
- Cropley, Arthur J. 1978. "Some Guidelines for the Reform of School Curricula in the Perspective of Lifelong Education." *International Review of Education* 24 (1): 21–33.
- Germanakos, Panagiotis, and Constantinos Mourlas. 2006. "Adaptation and Personalization of Web-Based Multimedia Content." *Digital Multimedia Perception and Design*, 284–304.
- Ioannidis, Yannis, and Georgia Koutrika. 2005. "Personalized Systems: Models and Methods from an Ir and Db Perspective." In *Proceedings of the 31st International Conference on Very Large Data Bases*, 1365–1365. VLDB Endowment.
- Jordan, Katy. 2014. "Initial Trends in Enrolment and Completion of Massive Open Online Courses." *The International Review of Research in Open and Distributed Learning* 15 (1).
- Kizilcec, René F, Chris Piech, and Emily Schneider. 2013. "Deconstructing Disengagement: Analyzing Learner Subpopulations in Massive Open Online Courses." In *Proceedings of the Third International Conference on Learning Analytics and Knowledge*, 170–179. ACM.
- Knox, Jeremy, Jen Ross, Christine Sinclair, Hamish Macleod, and Siân Bayne. 2014. "Mooc Feedback: Pleasing All the People." *Invasion of the MOOCs* 98.
- McLoughlin, Catherine Elizabeth. 2013. "The Pedagogy of Personalised Learning: Exemplars, MOOCs and Related Learning Theories." In *EdMedia: World Conference on Educational Media and Technology*, 266–270. Association for the Advancement of Computing in Education (AACE).
- Millán, Eva, Luis Descalço, Gladys Castillo, Paula Oliveira, and Sandra Diogo. 2013. "Using Bayesian Networks to Improve Knowledge Assessment." *Computers & Education* 60 (1): 436–447.
- "MOOCs Annual Report 2015." 2016. MOOCs Annual Report 2015. Center for Digital Education , Ecole Polytechnique Fédérale de Lausanne.
- Sloep, Peter, Jo Boon, Bernard Cornu, Michael Klebl, Paul Lefrere, Ambjörn Naeve, Peter Scott, and Luis Tinoca. 2011. "A European Research Agenda for Lifelong Learning." *International Journal of Technology Enhanced Learning* 3 (2): 204–228.
- Sonwalkar, Nishikant. 2013. "The First Adaptive MOOC: A Case Study on Pedagogy Framework and Scalable Cloud Architecture—Part I." In *MOOCs Forum*, 1:22–29. Mary Ann Liebert, Inc. 140 Huguenot Street, 3rd Floor New Rochelle, NY 10801 USA.
- Sunar, Ayse Saliha, Nor Aniza Abdullah, Su White, and Hugh C Davis. 2015. "Personalisation of MOOCs: The State of the Art."
- Thompson, Clive. 2011. "How Khan Academy Is Changing the Rules of Education." *Wired Magazine* 126: 1–5.
- U.S. Department of Education Office of Educational Technology. 2010. "Transforming American Education

- Learning Powered by Technology. National Education Technology Plan.”

Vignette Corp. 2002. “Personalization Strategies-Fit Technology to Business White Paper.” 2002, TX: Author edition.

Yousef, Ahmed Mohamed Fahmy, Mohamed Amine Chatti, Ulrik Schroeder, M Wosnitza, and H Jakobs. 2014. “A Review of the State-of-the-Art.” *Proceedings of CSEDU*, 9–20.

