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Beyond xMOOCs in Healthcare Education: Study of the Feasibility in Integrating Virtual Patient Systems and MOOC platforms

Background: Massive Open Online Courses (MOOCs) are an emerging method of online teaching. However in the field of healthcare education their technology is not adopted yet. Reaching beyond the xMOOC type of courses in order to foster interactivity in the healthcare education requires domain specific software. Virtual Patients (VPs) have been integrated in the past with Virtual Learning Environments (VLEs) but extending MOOCs with VPs has not yet been discussed. **Objective:** To investigate the technical possibilities of integrating VPs with MOOCs for the purpose of discovering a pragmatic basis were the potential pedagogical benefits can be later studied. **Methods:** We selected OpenEdx and Open Labyrinth as examples of a MOOC platform and of a VP system. We conducted a literature review to identify technical requirements and e-learning standards apt for the integration. One fundamental requirement was prototyped and verified by use cases. **Results:** A Single–Sign on mechanism connecting Open Labyrinth with OpenEdx, employing the IMS LTI standard, has been successfully implemented and verified. **Conclusion:** We investigated the technical perspective of integrating VPs in MOOCs, aiming to set a base for future investigation on the topic. The results point out new opportunities arising from the infrastructure of MOOCs for integrating specialized software aiming to support the healthcare education.

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1. Background

Significant changes in the healthcare sector and increased learning expectations call the contemporary healthcare education to reform and respond to the challenges. In particular, demographic transitions and growing population demands [1] increase the trainees' required competencies and call for the increasing training of higher order skills. The learning opportunities provided to the medical students in hospitals for observing the treatment process are diminished [2]. The same time, limited access to public medical education, the technological innovations entering the field of healthcare [1] and the rapid expanding of new medical knowledge generated by clinical research [3] highlight the need for massive and continuous healthcare education.

1.1 Massive Open Online Courses

In the evolving process of online education, Virtual Learning Environments (VLEs) have undergone considerable changes [4]. Currently, VLEs are being prepared to be used at massive scale in Massive Open Online Courses (MOOCs), an emerging method of online teaching. MOOCs, easily and widely accessible on the Internet, promise to provide open access to elite universities' courses in an unlimited number of participants [5].

MOOCs are decentralized and networked, based on the development of internet technologies, offered mainly by cloud computing infrastructure [6]. A VLE for MOOCs that holds the content of the course has diminished importance and constitutes usually only one software node in the MOOC's network. A VLE for MOOCs is mainly used for management purposes, such as students' registrations, and for hosting the discussion boards. The remaining nodes regard tools where the students' activity and the information they generate are concentrated. The information is combined by links and descriptions and is distributed to the participants by the form of newsletters [4].

The first MOOCs, known as cMOOCs, explore new pedagogies besides the traditional classroom context and allow the learners to construct self–organized and social learning processes based on interaction. The learners' participation generates the content of the course, while the level and type of their participation depends on each individual learner [4]. Many of the massive courses that followed however are an extension of the lectured–base pedagogical models practiced in institutions [5]. Their name, xMOOCs, is associated with the non–profit platform edX [7], launched by Harvard and Massachusetts Institute of Technology, to provide online courses to mass audience [8].

Besides their technical innovation, xMOOCs are based on the theoretical presentation of the learning context, supplemented by interactive activities and discussion boards. Medical educators are actively investigating the potential of adopting MOOCs into the healthcare and medical education [9]; MOOCs may have the potential to address some of the current challenges of the healthcare education [10]. They assert however that the lectured–based courses regard only a part of the education which should be provided. In particular, MOOCs' technological infrastructure may foster the learners' communication and interaction but not necessarily to the extent that healthcare education requires [9].

1.2 Virtual Patients

VPs are defined as "interactive computer simulations of real–life clinical scenarios for the purpose of healthcare and medical training, education or assessment" [11]. This definition distinguishes the VPs from devices, human standardized patients, part task trainers and high fidelity manikins [12]. VPs have established their practice in healthcare teaching and assessment. In particular, VPs are suggested as the key technology to enhance the fundamental skill of clinical reasoning in a similar level as whilst training on real patients [13].

Although there is evidence about the effectiveness of training clinical reasoning skills by the VPs [14], VPs "play only one part in the development of skilled health professionals" and coordination with other instructional activities is suggested [13]; positive effects have been reported when VPs are used as an additive resource or as an alternative to traditional methods [14].

In order to successfully deliver e-learning resources in the healthcare context an important factor to consider is accessibility [15]. For the purpose of enabling accessibility of the VPs among other e–learning material included in the curriculum, VPs may be integrated in VLEs. Requirements and integration strategies to integrate the VPs with VLEs have been proposed and demonstrated, in order to achieve the optimal results of both educational environments. One of the requirements suggested regards the Single–Sign on mechanism (SSO), indicating that "it is a significant drawback of the current VP implementations to require separate authentication mechanisms" [16]. The integration can be achieved partially or fully by applying e–learning standards.

A significant barrier that medical faculties often encounter in integrating VPs in their curriculum is the timely, costly and complex process of producing and authoring VPs. VP systems have been extended in the past in order to support content transfer and by that to enable the technical sharing of the VP cases among institutions. That was achieved by applying the MedBiquitous Virtual Patient standard (MVP) [17].

Besides the technical sharing of the VPs, the cases require meeting ethnic, language and socio-economic aspects of the institutions in which are used [18]. The process of adapting the VP cases to meet these requirements is known as "repurposing". The electronic Virtual Patient project (eViP) is an initiative in which nine European institutions and MedBiquitous collaborated to create a repurposed and enriched collection of VPs publicly available [17].

1.3 Problem Description

Whilst xMOOCs rise up concerns associated with the educational benefits that they may offer, this paper addresses the challenge of reaching beyond the xMOOC type of courses by fostering interactive learning and assessment activities that are appropriate in healthcare education. The proposed novel approach is to leverage existing technologies such as virtual patients by integrating them to MOOC platforms.

1.4 Aim

The aim of this study was to investigate how to, technically, integrate virtual patient systems to MOOC platform in order to extend the latter with interactive patient cases. Such knowledge would inform on the feasibility of further educational research on the benefits of such type of integration.

2. Material and Methods

Initially we followed the exploratory study design since there is no previous research on the topic of integrating VPs with MOOCs. The exploratory design allowed us to discover the technical requirements for the integration and the e–learning standards having the potential to address them. In order to construct a functional prototype to address a requirement that we isolated, we followed the build methodology. By that, we demonstrated that the integration of VPs with MOOCs is feasible.

2.1 Study Material

EdX initiative [7] was launched by Massachusetts Institute of Technology (MIT) and Harvard and offers not–for–profit online and in the classroom education; EdX platform is hosting MOOCs of global partner institutions and organizations. The open–source release of the edX platform is named OpenEdx and was selected as an instance of a MOOC hosting platform, for the purpose of authoring a pilot course in which the VP system would be integrated. The selected MOOC platform is comparable with other available ones such as Coursera [19] and Udacity [20] and by that this selection is not influencing the generalizability of the study.

As an example of a VP system to be integrated into OpenEdx platform we selected Open Labyrinth [21]. Open Labyrinth is a web application for creating and navigating VP cases and currently the most advanced, free available, open–source system.

We set up Open Labyrinth on a virtual LAMP server, launched through Amazon Elastic Compute Cloud (EC2) in order to prepare and finalize the adjustments required for the integration [22]. The advantage of this solution is that EC2 includes an auto–scale option which allows the instance to meet potential increased users' demands. EC2 is also a cost–effective solution: the cost is analogous to the actual capacity used. For the particular pilot implementation, the Ubuntu 13.10 Micro instance was selected to host Open Labyrinth system which offers 750 hours of free hosting for one year.

For the purpose of providing test content we imported manually a VP case from the eViP project [23]. The selected case refers to bronchogenic carcinoma which is an important topic in medical education, since it is the most common cause of cancer-related deaths worldwide [24].

2.2 Exploring viable ways to integrate VP systems with MOOC platforms

To identify the technical requirements and standards apt for the integration, we conducted a literature review in the databases of Scopus, ERIC and PubMed. The review was chronologically limited to publications of the range 2008–2014, to discard outdated technologies. The review was performed using the following queries:

- Integration AND "Virtual Patient*"
- Integration AND MOOC*
- E–learning AND standard AND integration

We also considered and reviewed for appropriateness in the MOOC environment technical requirements and proposals for integrating VPs in VLEs that have been explored earlier [16]. At the final stage, we analyzed the outcome of the review in search of standards applicable in the context of OpenEdx and Open Labyrinth systems.

2.3 Verification using test cases

We verified the technical implementation by performing test cases: the test cases were designed in order to verify the system's response to different input requests. The following test cases were proposed based on the aim of the implementation to provide transparent authentication:

- A registered in OpenEdx user (instructor) gets authorized in Open Labyrinth in the OpenEdx platform.
- A registered in OpenEdx user (student) gets authorized in Open Labyrinth in the OpenEdx platform.

3. Results

In this paper we explored how to achieve a technical integration of VP systems and MOOC platforms by isolating one of the technical requirements identified and addressing it by the use of an e–learning standard.

3.1 Technical requirements to be addressed

From the technical requirements derived out of the literature review we isolated one fundamental one to be implemented: the transparent authentication, enabled by an identity management mechanism. This can be achieved by implementing the SSO, which was not applied so far to connect a MOOC platform with a VP system.

The user having an account in the OpenEdx platform may access the Open Labyrinth VP cases without requiring a separate log–in. In a proper integration of the two systems the users' access is transparent and it is not obvious that the users are actually accessing a second system.

As it has been already described in a previous study proposing requirements of integrating VPs in VLEs, it is an important disadvantage of VP implementations to require a separate authentication mechanism; in such cases the students are required to remember many different log–in credentials, fact that could affect a future evaluation of the educational benefits that integrated systems may offer, by the students' perspective.

An important dependency supporting additionally this technical implementation is the fact that students and instructors require to access both systems in order to have a comprehensive perspective of the students' evaluations and results in the whole. The SSO would facilitate the process of accessing the students' generated activity in both educational environments.

3.2 Enabling integration using the LTI standard

One of the e–learning standards identified in our review, having the potential to support the implementation of the SSO, is the IMS LTI standard [25]. The IMS LTI is a framework for integrating e–learning tools and content into VLEs. According to the terminology followed in the specification of LTI, the VLE is referred as a "Tool Consumer", meaning that it "consumes" the external tool to be integrated, while the tool is named "Tool Provider". The specification defines two modes of the integration:

- Full LTI which entails a formal agreement of the Tool Consumer and the Tool Provider about: "(i) the run–time services that will be used to support tight integrations between the systems, (ii) the security policies that will apply, and (iii) the set of destinations within the Tool that can be launched from the Tool Consumer system" [25].
- Basic LTI which establishes a one-launch mechanism from the consumer to the provider with one security policy, while there is no access to the Full LTI run–time services in the Tool Consumer. The Basic LTI (BLTI) is a subset of the overall functionality of the LTI.

EdX and OpenEdx platforms conform to the Basic LTI standard. By that, they can act as a tool consumer. Open Labyrinth however required adjustments to function as a tool provider. The Basic LTI makes use of the OAuth protocol signing approach [26] to secure the message interactions between the consumer and the provider, which requires a set of credentials: a key and a secret. The OAuth is a standard used for authorization. In particular it is a security mechanism used to protect POST and GET requests.

The implementation focused on adjusting Open Labyrinth in order to function as a tool provider integrated in the OpenEdx platform. The user of OpenEdx platform while having an account for the course can select the provided link of Open Labyrinth and have access to the included case without a second authorization since is recognized by the data provided by OpenEdx. This is because the OpenEdx user, by selecting the Open Labyrinth's link to access the content, enables a Basic LTI launch request, where a HTTP POST message transmits a set of data elements required to authorize the user. The POST request includes a set of parameters imposed by both the oAuth standard and the LTI specification. Table 1 depicts the parameters required by the oAuth standard.

Table 1: *Instances of the parameters required for the OAuth signing approach that are transmitted through the POST request [25].*

oauth_consumer_key
oauth_signature_method
oauth_timestamp
oauth_nonce
oauth_version
oauth_signature

The oauth_consumer_key and the oauth_consumer_secret are the important values required for the signing mechanism. The oauth_consumer_key is passed in the message and enables the tool provider to look up for the corresponding secret value, which should be stored locally instead of being transmitted. The signature is calculated based on the values of the key and secret; the tool provider after identifying the value of the secret, re–computes the signature and compares it with the transmitted one, to verify the credentials of the sender. The oauth_signature_method implies that the tool provider must at least support the HMAC-SHA1 signing method.

The oauth_nonce is a random value, used in all oAuth requests to prevent replay attacks. The oauth_timestamp value represents the time that the request is sent [26].The timestamp and nonce parameters should be validated in each request; the timestamp should be validated within a specific time interval while the nonces should be recorded and allowed on a single time.

The parameters required and/or recommended by the LTI specification to be included in the POST request are listed in Table 2. Besides these values, other optional or recommended ones can be included to provide further information about the user or the course, but were not required for the particular implementation.

Table 2: *Parameters required and/or recommended by the LTI specification to be included in the POST request.*

lti_message_type
lti_version
resource_link_id
user_id
role

The lti_message_type parameter reveals that the launch message conforms to LTI standard; by that parameter the tool provider may accept a set of different LTI message types at the same launch URL. The parameter lti_version indicates the particular version of the LTI standard used in the transmitted message. The resource_link_id is an identifier unique for every placement of the link within the tool consumer, while the user_id is a sequence of random characters and numbers that should not contain any identifying information for the user. In the particular case of OpenEdx platform as a tool consumer, the user_id is automatically created and bound to each user's username as an identifier. The user_id is unique and kept hidden from regular OpenEdx

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users. Finally, the role parameter defines the rights that the user has to the content. Particularly for the OpenEdx platform it may obtain the values of "instructor", "staff" or "student".

3.3 Adjustments to the Open Labyrinth VP system to act as a tool provider

In order to create the LTI interface we created the elementary framework classes of Basic LTI (files blti.php and oauth.php) as indicated by the IMS-LTI specification. We also created two new files named user–handler.php and database.php and we modified the index.php page of Open Labyrinth. In the database of Open Labyrinth and particularly to the table "oauth_provider" we added a new entry to maintain the credentials (key, secret).

Then we modified the landing page page of Open Labyrinth to intercept the data that are passed from a LTI launch request; index.php receives the data and transmits them to the BLTI and OAuth classes in order to be verified: the BLTI class firstly confirms that a minimum set of values to meet the protocol has been received and then, based on the received key is looking in the database for the corresponding value of the secret.

Next, by the use of the OAuth signing approach the signature is re–computed and compared with the one received from the LTI launch request, to verify the credentials of the sender. The values of nonce and timestamp are also checked for their appropriateness according to the protocol. If the values are not appropriate the BLTI class will return an "invalid context" message to reject the connection. The connection establishing and the queries handling to the database are managed through the homonymous file. If the signatures' comparison is successful, the user– handler class is called to manage the user.

The user–handler class, on receiving the user's details by the blti.php is looking firstly in the database to identify whether the user's entry already exists and if not it creates a new one to register the user. Then by using the log–in function, it allows access to the user and returns to the index class. The user–handler class is also matching the user's role acquired by the BLTI class to the corresponding one in Open Labyrinth, in order to provide the appropriate user rights. Moreover, it includes the function to encrypt the user's password that will be maintained in the Open Labyrinth's database.

3.4 Connecting OpenEdx MOOC platform and Open Labyrinth using LTI

The process for adding the adjusted Open Labyrinth to the OpenEdx platform can be synopsized in the following steps:

- We created a pilot course in OpenEdx (Figure 1).
- We added the LTI module in the advanced setting of the course, by registering customized values for the lti_id, key and secret. The lti_id is an extra parameter included in OpenEdx that can maintain any value; its role is to label the integrated component and bind the values of key and secret (Figure 2).
- We added an LTI component within the pilot course, including the lti_id parameter and a link to the modified Open Labyrinth. (Figure 3)

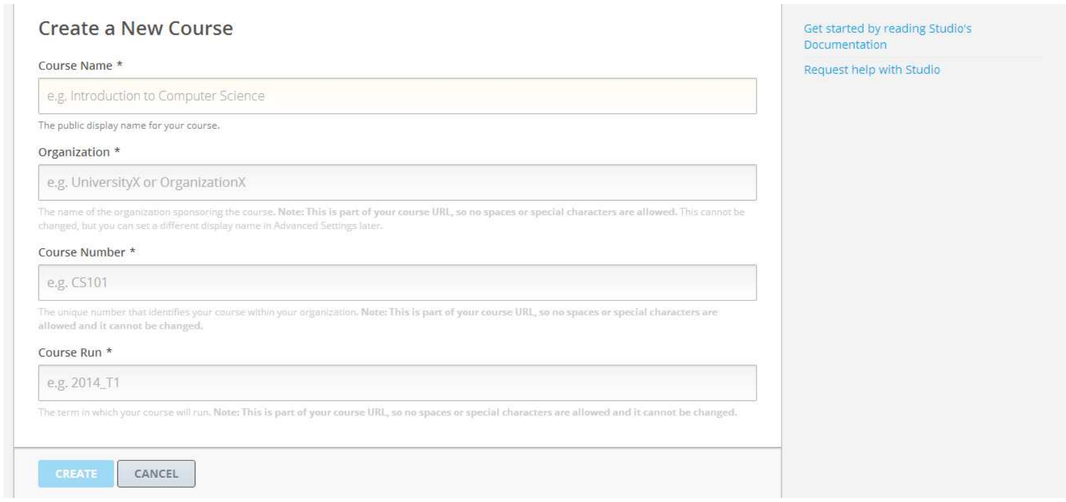

Figure 1: *Creating a new course in OpenEdx.*

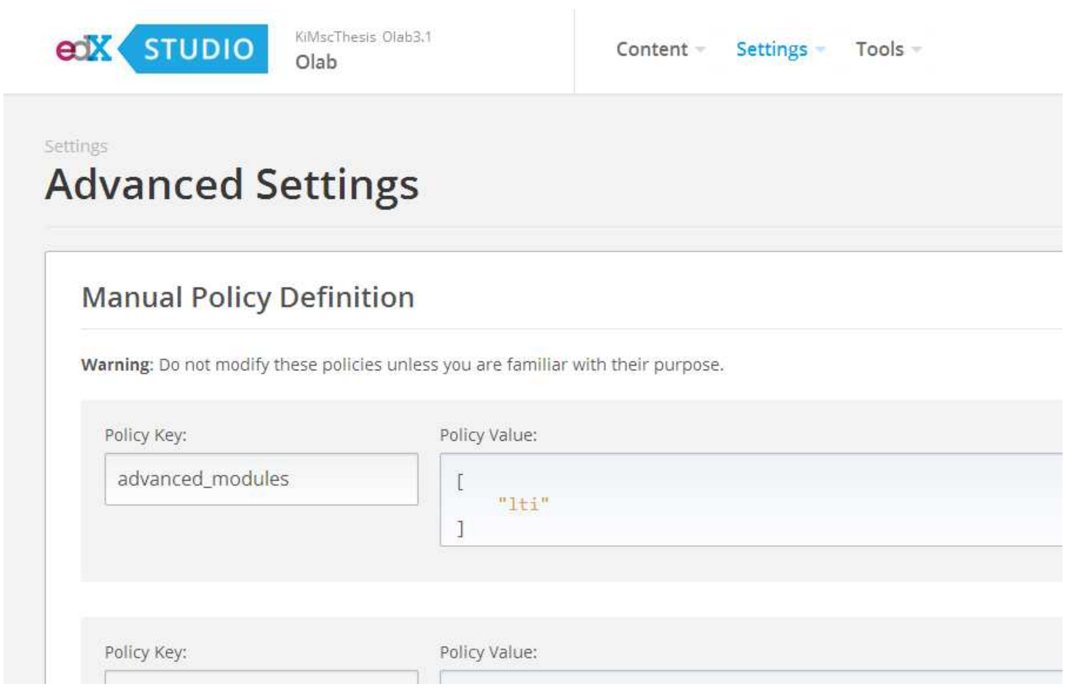

Figure 2: *Setting the LTI module within OpenEdx to register values of lti_id, key and secret.*

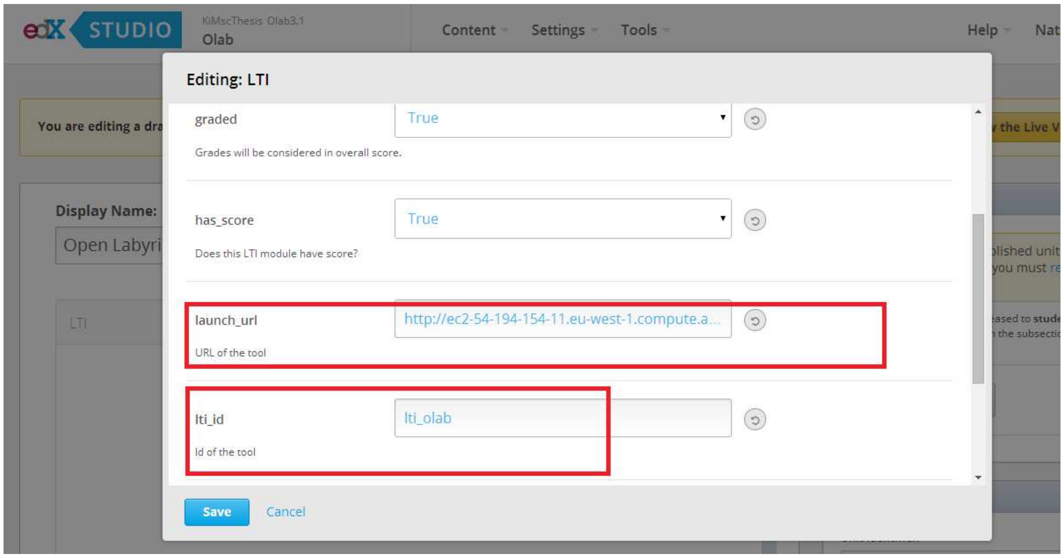

Figure 3: *Creating a LTI component within the course, pointing at the Open Labyrinth's server IP and including the lti_id value.*

3.5 Verification of the technical implementation

In the following tables (tables 3–4) we present the test cases which we performed to verify the pilot technical implementation. The selection of the test cases was informed by the aims of the implementation for providing a transparent authentication of the users with the appropriate credentials.

Table 3: *Test Case 1 – An instructor gets authorized in Open Labyrinth in OpenEdx.*

Test Case id	1
Title	A registered in OpenEdx user (instructor) selects the link of Open Labyrinth through the platform
Result	Successful
Comment	Open Labyrinth authorizes the user, provides access to the content and authoring rights as a result of conforming to the BLTI standard

Figure 4 depicts the integrated Open Labyrinth in the OpenEdx platform from the perspective of the instructor after getting authorized. The instructor is provided with the user rights imposed by the corresponding administrator's role of Open Labyrinth. By that, the instructor can create, edit or delete the content in Open Labyrinth.

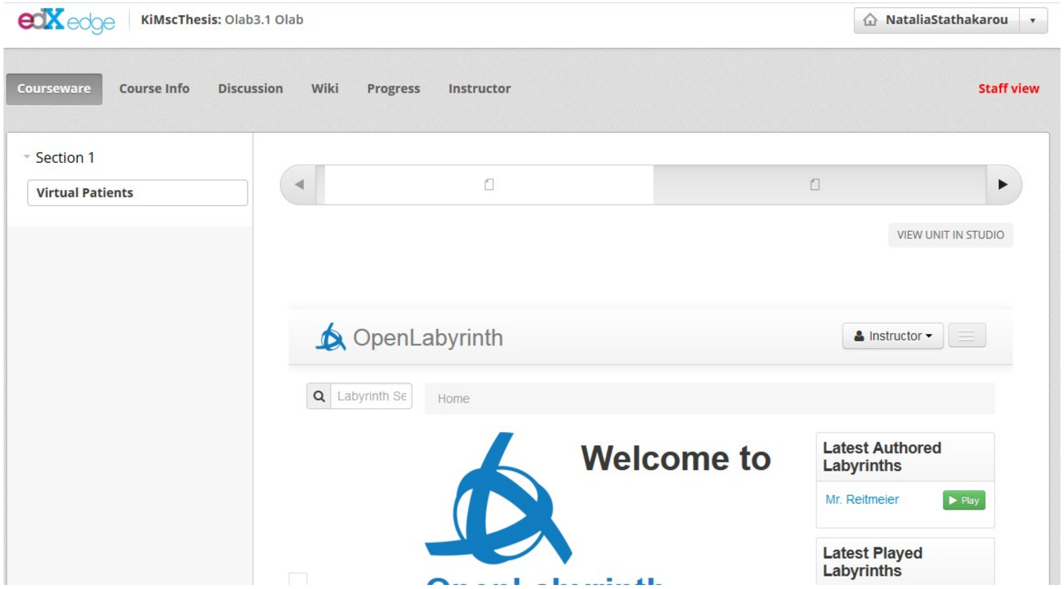

Figure 4: *An instructor is authorized in Open Labyrinth and accesses the content.*

Table 4: *Test Case 2 – A student gets authorized in Open Labyrinth in OpenEdx.*

Test Case id	2
Title	A registered in OpenEdx user (student) selects the link of Open Labyrinth through the platform
Result	Successful
Comment	Open Labyrinth authorizes the user and provides access to the content as a result of conforming to the BLTI standard

The following pictures depict the students' perspective while accessing the content by getting authorized in Open Labyrinth (Figure 5) and try the VP case (Figure 6).

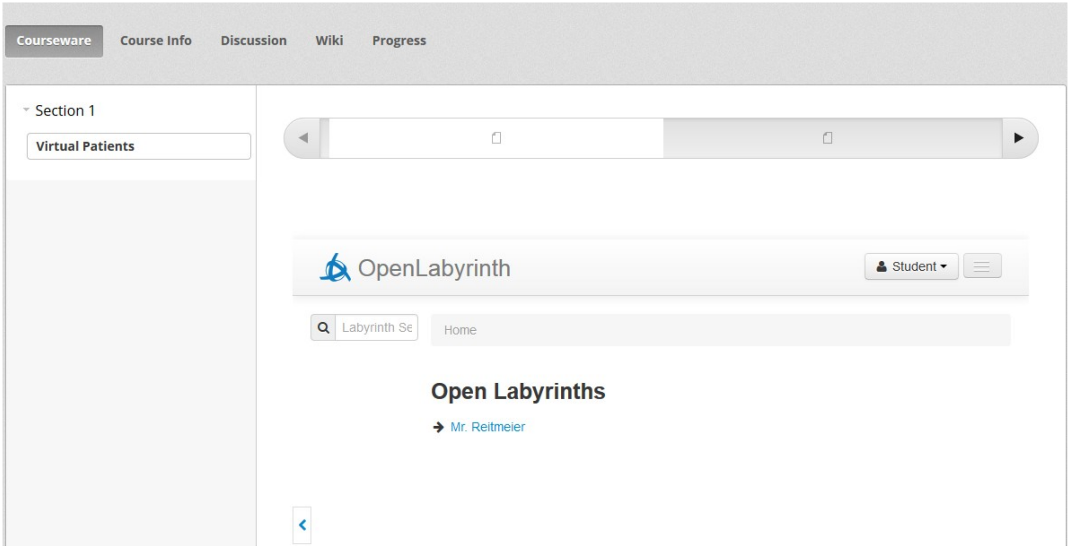

Figure 5: A student is authorized in Open Labyrinth and accesses the content.

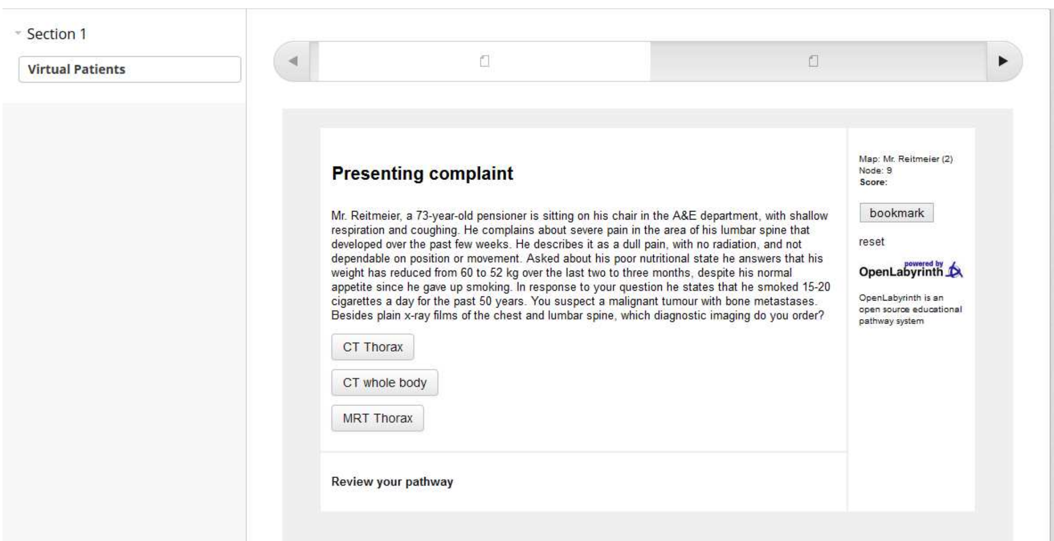

Figure 6: A student tries the VP case.

For all the test cases we also verified that providing wrong credentials does not allow the user entering the system.

4. Discussion

4.1 Discussion on the results

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In this paper we investigated the possibility of extending MOOCs with VPs in terms of technical feasibility. The planned objectives of the study have been reached; open Labyrinth has been integrated into the OpenEdx platform as an example of integrating VP systems with MOOC platforms. The SSO was achieved by the use of the Basic LTI standard. The pilot implementation enabled the SSO mechanism in a transparent manner between the two systems. The implementation was verified by the use of two test cases that were imposed by the aim of the technical implementation for transparent authorization.

Open Labyrinth was hosted on an EC2 server since it provides scalable computational capacity and control of the resources, while it is a cost effective solution. In a limited free for a year instance such as Ubuntu 13.10 Micro instance, used for the particular implementation, the public DNS is dynamic; changing each time that the server is stopped and restarted. A static IP bound to a Secure Socket Layer (SSL) certificate is required to be obtained in order to provide a secure (https) domain, appropriate for the integration of Open Labyrinth with OpenEdx. In particular, since the edX platform uses an SSL encrypted connection (https), some browsers do not allow displaying at the same page of mixed, encrypted and non–encrypted, content (https and http) and may restrict the identified insecure content.

4.2 Limitations and future studies

From the reviewed and identified technical requirements we isolated and implemented one for the prototyping. Potential mechanisms and standards to support a tight integration of the systems could be identified and implemented in future studies.

Future studies may also implement the integration by the use of LTI version 1.1.1 to allow the transmission of the grades by the tool provider to the tool consumer. This can be achieved by the use of the LTI Basic Outcomes Service which supports setting, retrieving and deleting results of a particular user of a particular MOOC/VLE system [27].

The verification of the pilot technical implementation was based on two proposed test cases, imposed by the technical aim to implement the SSO mechanism. A complete integration however should be tested systematically in order to identify potential failures of the system to respond to a wider range of predicted inputs of the users.

The integration demonstrated in the current study was based on the example of a single VP system and a MOOC platform: even though there are no reasons to suspect that the selected platforms were non-representative, next studies may investigate the integration strategies in a wider scale between different VP and MOOC systems.

In the particular context of Open Labyrinth and OpenEdx, for simplicity of the implementation, we extended manually Open Labyrinth's database to include the tool consumer's (OpenEdx) id and credentials. Other tool consumers may be added manually in the database to allow the integration of Open Labyrinth. However this functionality could be automatized by letting the tool consumers including the appropriate credentials (key, secret) to be added in the database of Open Labyrinth using a graphical user interface. This would require a careful design to ensure security during the control process of the consumers' credentials and the users' information.

Moreover, Open Labyrinth should be modified in order to accept and store potential extra parameters parsed through the launch messages, since the set of parameters may differ between the consumers.

Future studies may also investigate the potential educational benefits that such integration may provide. Extending MOOCs with interactive functionalities may have the potential to address part of the current challenges by fostering the massive and continuing healthcare education.

5. Conclusion

Besides MOOCs' innovative technical infrastructure, their contemporary form is limited to a model of transmission of knowledge, based mainly on video-based lectures combined with self-assessment questions. Moreover their application in the healthcare education, where the lectures are just a part of the education that should be provided, is still in early stages of investigation. Extending xMOOCs in order to support the healthcare education can be achieved by integrating domain specific software.

In this paper we investigated the technical perspective of integrating VPs in MOOCs, wishing to set a base for future investigation on the topic. The results point out new opportunities arising from the infrastructure of MOOCs that have the potential to support the healthcare education and foster clinical skills in a more interesting, interactive way.

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7. References

[1] Frenk J, Chen L, Bhutta ZA, Cohen J, Crisp N, Evans T. Health professionals for a new century: transforming education to strengthen health systems in an interdependent world. The Lancet, 376, Dec 2010;376(9756):1923-58

[2] Kononowicz AA, Hege I. Virtual Patients as a Practical Realisation of the E-learning Idea in Medicine, E-learning Experiences and Future, Safeeullah Soomro (Ed.), 2010; ISBN: 978-953-307-092-6, InTech, DOI: 10.5772/8803. Available from: http://www.intechopen.com/books/e-learning-experiences-and-future/virtual-patients-as-a-practical-realisation-of-the-e-learning-idea-in-medicine

[3] Marya D, Zilberberg MD. The clinical research enterprise – time to change course? JAMA. 2011;305(6):604-605.

[4] Masters K. A Brief Guide to Understanding MOOCs. [Internet]. IJME. 2009;1(2). Available from: http://ispub.com/IJME/1/2/10995

[5] Yuan L, Powell S, MOOCs and Open Education: Implications for Higher Education, JISC CETIS White Paper, The University of Bolton, 2013.

[6] Sonwalkar N. The first adaptive MOOC: a case study on pedagogy framework and scalable cloud architecture –Part I, MOOCs Forum. 2013;1(P):22–9.

[7] edX [Internet] [cited 2014 Aug 02]. Available from: https://www.edx.org/
[8] Grünewald F, Meinel C, Totschnig M, Willems C. Designing MOOCs for the support of multiple learning styles. LNCS. 2013;8095:371–82
[9] Harder B. Are MOOCs the future of medical education?. BMJ. 2013;346:f2666.
[10] Mehta NB, Hull AL, Young JB, Stoller JK. Just imagine: new paradigms for medical education. Acad Med. 2013;88(10):1418–1423.
[11] Ellaway R, Candler C, Greene P, Smothers V, An Architectural Model for MedBiquitous Virtual Patients. Technical report, Baltimore: MedBiquitous, 2006.
[12] Talbot TB, Sagae K, John B, Rizzo AA. Sorting Out the Virtual Patient: How to Exploit Artificial Intelligence, Game Technology and sound Educational Practices to Create Engaging Role-Playing Simulations, JGCMS 2012;4(3):1-19.
[13] Cook D, Triola M. Virtual patients: A critical review and proposed next steps. Med Educ. 2009;43(4), 303–311.
[14] Consorti F, Mancuso R, Nocioni M, Piccolo A. Efficacy of virtual patients in medical education: A meta-analysis of randomized studies, Computers and Education. 2012;3(59):1001-8.
[15] Childs S, Blenkinsopp E, Hall A, Walton G. Effective e–learning for health professionals and students–barriers and their solutions, A systematic review of the literature–findings from the HeXL project. Health Info Libr J. 2005 Dec;22 Suppl 2:20-32.
[16] Kononowicz AA, Hege I, Adler M, de Leng B, Donkers J, Roterman I. Integration Scenarios of Virtual Learning Environments with Virtual Patients Systems, E-mentor 2010;5(37):52–54.

[17] Hege I, Kononowicz A, Pfähler M, Adler M, Fischer MR: Implementation of the MedBiquitous Standard into the learning system CASUS, Bio-Algorithms and Med-Systems, 2009;5(9):51-55
[18] Fors UGH, Muntean V, Botezatu M, Zary N. Cross-cultural use and development of virtual patients, Med. Teach 2009; 31: 732–738
[19] Coursera [Internet] [cited 2014 Aug 01]. Available from: https://www.coursera.org/
[20] Udacity [Internet] [cited 2014 Aug 01]. Available from: https://www.udacity.com/

[21] Openlabyrinth.ca [Internet] [cited 2014 Aug 01]. Available from: http://openlabyrinth.ca/
[22] Amazon EC2. [Internet] [cited 2014 Aug 01]. Available from: http://aws.amazon.com/ec2/
[23] eViP: electronic Virtual Patients [Internet] [cited 2014 May 10]. Available from: http://www.virtualpatients.eu/referatory/
[24] Ferlay J, Shin HR, Bray F, Forman D, Mathers C, Parkin DM. Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. Int J Cancer. 2010 Dec 15;127(12):2893-917
[25] IMS Global Consortium: LTI v.1 specification [Internet] [cited 2014 Aug 01] Available from: http://www.imsglobal.org/lti/blti/bltiv1p0/ltiBLTIimgv1p0.html
[26] OAuth [Internet] [cited 2014 Aug 01] Available from: http://oauth.net/
[27] IMS Global Consortium: LTI v.1.1.1 specification [Internet] [cited 2014 May 10] Available from: http://www.imsglobal.org/LTI/v1p1p1/ltiIMGv1p1p1.html

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