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## Toward the Cross-Institutional Data Integration From Shibboleth Federated LMS

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### Abstract

Through this study, we aim to examine a method for data integration in shared Learning Management System (LMS) in authentication federation. We proposed a method of transmitting ePTID and learning data with user's consent as a method for data integration across institutions. The method is compared with the other existing methods to realize the shared LMS. We discuss the suitable method for next version of GakuNinMoodle and conclude that our requirements are not fully satisfied by a single method.

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**Keywords:** data integration; LMS; Moodle; Shibboleth; ePTID

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### 1. Introduction

With the development of information and communication technology, the collaboration between institutes such as universities or some academic organizations are getting popular in recent years. We can take classes at other institutes through the streaming technology, the learning materials are distributed through WWW server accessing from all over the world. There are growing demands on the development of the common learning materials and sharing LMS used from many institutes. For example, e-Knowledge consortium Shikoku are organized by eight universities in Shikoku region of Japan [1]. Their LMS is shared by the eight universities where Shibboleth is used for sharing user ID to

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identify users of LMS. Another example is GakuNinMoodle where the information security learning materials are provided to more than 100 institutes in Japan through the GakuNin [2, 3, 4]. The GakuNin is the academic access management federation in Japan [5]. Also, there are many massive open online courses (MOOCs), which are offered on the big LMSs accessible from all over the world [6].

One of the purpose of operating “shared LMS” service between institutions is to collect the learning record for the learning analytics. The shared LMS is an ideal environment for the learning analytics because we can easily collect “big learning data” from many institutions [7, 8, 9, 10].

Furthermore, Learning Record Store (LRS) is proposed to collect the learning record in more detail. The typical standard of LRS are xAPI [11, 12, 13] and IMS Caliper [14, 15, 16] which is proposed by Advanced Distributed Learning and IMS Global, respectively.

Many technologies are proposed to support the realization of the shared LMS. One is the Learning Tools Interoperability (LTI) proposed by IMS Global learning consortium [17]. Applying LTI to the institution local and shared LMSs, we can use learning tools in the shared LMS as if it is running in the institution local LMS.

Another technology is Shibboleth developed by the internet 2 which is now widely deployed in the academic institutions all over the world [18]. Shibboleth is a standard middle-ware of authentication federation for Web system based on Security Assertion Markup Language (SAML) [19]. Shibboleth separates the authentication and authorization to provide system sharing across the border of institutions. More specifically, the authorization on shared web system, Service Provider (SP), located outside the institution, performs in response to the authentication performed in each institutional Identity Provider (IdP). Shibboleth federation has two advantages:

- (1) Reduction of ID management operational cost;
- (2) Security assurance by managed exchange of authentication information.

On the other hand, there is a problem of data integration from federated LMS which stores learning data, because normally it does not share authentication information across the institution border for security concern. It is necessary for data integration to share common key value such as unique ID corresponding to a learner because it is important for utilize the data in order to support and improve education. But, in fact, the IdP does not guarantee to provide the unique ID which can be used as the key to integrate the data to the SP including federated LMS located outside the institution. Therefore, it is needed the solution for cross-institutional data integration from federated LMS.

In this paper, we describe the problem of the shared LMS and properties of these technologies including the method proposed by authors [20] and discuss the availability of these methods for the next version of GakuNinMoodle.

## 2. The Requirement on the Realization of the Shared LMS

In this section, we describe the requirements on operating the shared LMS for the purpose of applying to the GakuNinMoodle. One of the important thing for operating LMS is the assignment of ID to the users. Though the assignment of ID is trivial in the small laboratories, it becomes serious problem in the institution-wide LMS because the management of account is a huge task such as assigning ID, delivering account with user identity verification. Usually each institute introduce institutional ID such as the student/faculty number or similar ID rule locally working in the institutions. We should use the institutional ID for logging in to the shared LMS because assigning another ID by the manager of shared LMS is almost impossible. Also user do not want to manage another account valid only for the shared LMS.

Some users transferring institutions may want to share user’s data between institutions. But we do not consider such integration of data between institutions because over-integration of the data concerns about privacy infringement.

Req. (a) Users can use the institutional ID to log in to the shared LMS.

Once the learning data is stored in the shard LMS, the researchers may want to analyze these learning data for their research or improve education through the “learning analytics”. Before analyzing the learning data, the researchers need to obtain user’s consent for using their data to the learning analytics.

Basically, we need to obtain the user's consent individually from each users. Then, the method to obtain the individual user's consent automatically should be equipped in the shared LMS which is used as an environment for the learning analytics. Otherwise, the researchers need to ask comprehensive agreement to use of the data for their learning analytics. One of the authors proposed a working draft for the policy for learning analytics. It seems to take much time to achieve comprehensive agreement to the policy [21].

Even though the user's consent of use of the data is obtained, it is not usually permitted to store the data records that can easily identify the user. Furthermore, the institution managing the shared LMS sometimes force to anonymize the stored data records because the institution cannot ensure safe data preservation or cannot take responsibility against information leakage from the shared LMS. The shared LMS, therefore, should have the anonymization function.

Req. (b) The user ID is anonymized.

Req. (c) User's consent should be obtained for analyzing their learning data.

Teachers as well as students use the shared LMS. Teachers should confirm the data of the student of their classes to give a grade to the student. The data includes the outcome and the learning record. The outcome is the returned value from the learning module such as the result of the final test. The learning record is more detailed information of the user's activity on the LMS such as elapsed time of activities. The teachers need to check the student's outcome and the learning records accumulated in the shared LMS.

Req. (d) The teacher can confirm their student's outcome/learning record only, can not access to the data of the other students.

Finally, we should consider to support various learning environment of user's institute. Most of institute have LMS nowadays. However we do not forget to support some institutes that does not have LMS.

Req. (e) The system should be available with or without LMS of their institutions.

In the following section, we will discuss how the LTI and shibboleth works or not works based on the above requirements.

### 3. Method

The LTI and Shibboleth are famous and strong standards to realize shared LMS. We will discuss how to realize shared LMS using these standards and propose our method in connection with Shibboleth.

#### 3.1. LTI

One of the method to realize shared LMS is the application of LTI standard with LRS to capture learning records. Figure. 1 shows the components of LTI and data transfer concerning the shared LMS. In the LTI standards, learning environment is composed by the LTI tool consumer and LTI tool provider. The LTI tool provider provides the tools for learning to the LTI tool consumer. The LTI tool consumer is usually the LMS managed by the institution. The following lists describe how users in the institute use the LTI learning tools.

Step. 1) The institutional user login to the institutional LMS.

Step. 2) The user click the link for the LTI learning tools.

Step. 3) The new browser window/frame opens displaying the LTI learning tools running at the LTI tool provider.

##### 3.1.1. User ID

The requirement (a) is satisfied in the application of the LTI method because the LTI tool can be accessed by the authenticated user of the institutional LMS where the user login using the institutional user ID.

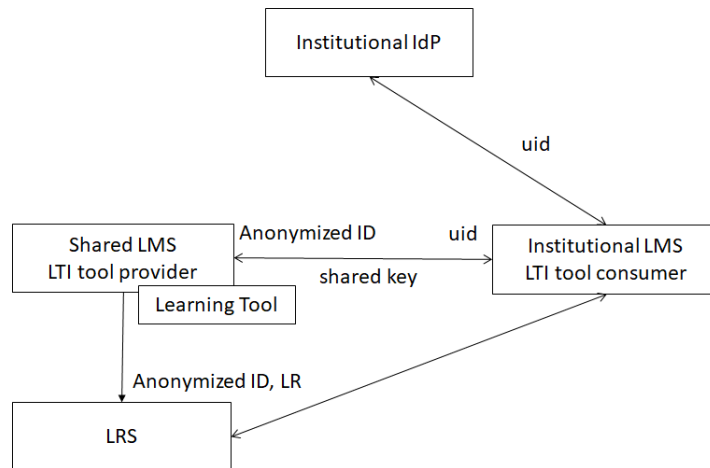


Fig. 1. The diagram for data transfer and anonymization of ID in the LTI.

### 3.1.2. ID Anonymization

As shown in the Fig. 1, shared LMS as a LTI tool provider and institutional LMS as a LTI tool consumer communicate each other using the pre-shared key. Using the shared key, the tool provider and consumer are authenticated as an administrator level and various information are transferred between the tool provider and consumer. Each user does not have to log in to the tool provider individually.

For example, in the LTI implementation of Moodle, the tool provider generates LTI user with the anonymized ID which is generated by hashing a combination of user ID and pre-shared key. The requirement (b) is satisfied because the learning record of the user is recorded in connection with the anonymized ID.

### 3.1.3. User's consent

The LTI scheme does not have standard method for obtaining the user's consent. On using or accumulating the learning records of users, the administrator of shared LMS or operating institution should obtain from user's consent on storing personal data. If not, one should obtain the comprehensive agreement of the institution using shared LMS. Then the requirement (c) is partly satisfied.

### 3.1.4. Confirmation of the outcome

Since the learning tools are running on the tool provider, the learning records or results are stored on the tool provider. The LTI standard supports to return the outcome to the learning information service (LIS) as the users of institutional LMS cannot confirm the results recorded on the shared LMS. In the LTI implementation of the Moodle, for example, the outcome is periodically sent from the tool provider to the tool consumer to synchronize the outcome.

To confirm student's outcome by teachers, each teacher installs the LTI module in their courses and check the outcome in the course reflected from the tool provider through the LTI module. The teacher can check the students in their course and cannot check student's outcome of other courses. Therefore requirement (d) is satisfied for the confirmation of the outcome.

### 3.1.5. Confirmation of the learning records

The learning record store (LRS) is proposed to store learning records. The famous standards are LTI Caliper and xAPI. To distribute stored learning record to the institutions of the tool consumer for the learning analytics in the institutions, we should consider another method to access LRS from each institution.

### 3.1.6. Institutional LMS

In the LTI, LMS is required at the both of the tool consumer and tool provider. The institution, therefore, needs to manage LMS locally and requirement (e) is not satisfied.

### 3.2. Shibboleth

The shared LMS using shibboleth consists of the shared LMS as shibboleth SP and the institutional IdP. Institutional user can login to the shared LMS with their institutional account since both IdP and SP are belonging to the same federation. We call, in the following, the shared LMS implemented by shibboleth as federated LMS. Different from the LTI, the institutional users directly use the federated LMS. The outcomes and learning records are accumulated in the federated LMS.

Some institutions have another Shibboleth SP in the institution. Figure. 2 and 3 shows the shared LMS using Shibboleth and related servers with ID transfer. The differences between Fig. 2 and 3 will be discussed in the following subsections.

The GakuNinMoodle is one of the federated LMS in academic authentication federation in Japan, GakuNin[5]. GakuNinMoodle stored the data of security awareness online courses of over 20,000 users from 100 institutions [22]. In the following, we discuss if the GakuNinMoodle implemented as a federated LMS satisfies the requirements discussed in the previous section.

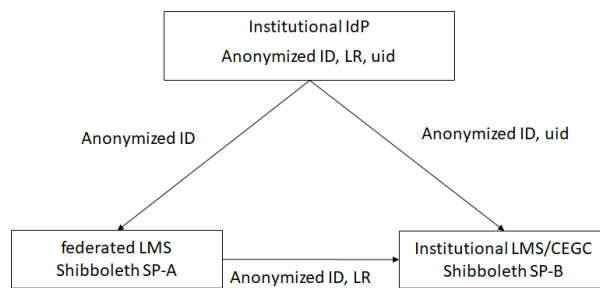


Fig. 2. The diagram of data transfer in the shared LMS using the virtual organization.

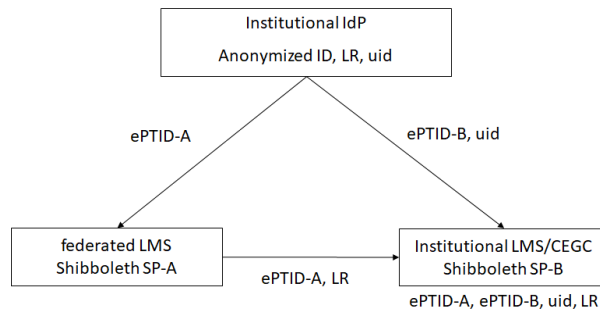


Fig. 3. The diagram of data transfer in the shared LMS using shibboleth with the proposed SP plugin.

#### 3.2.1. User ID

The requirement a is satisfied because the user can login to the federated LMS with the institutional account and able to use learning materials on the federated LMS.

#### 3.2.2. ID Anonymization

To see the anonymization of user ID in the GakuNinMoodle, we describe the data transfer procedure in the login process using the Shibboleth as following:

- Step. (1) Access the resource login-required on GakuNinMoodle;
- Step. (2) Redirect to the institutional IdP via Discovery Service (DS);

Step. (3) Authentication on the IdP;

Step. (4) The IdP send the eduPersonTargetedID (ePTID) [23] to GakuNinMoodle.

GakuNinMoodle receives ePTID from institutional IdP as a unique ID within the scope in a combination of the IdP and GakuNinMoodle. There are two methods of generating of ePTID, computedID and storedID[24, 25]. It depends on each IdP configuration that how to generate and send ePTID.

**ComputedID** The ePTID is generated at every authentication by hash function from the URL of SP such as GakuNinMoodle, the authentication credentials in institutional IdP and the SALT depends on IdP configuration.

**StoredID** The IdP searches the ePTID of the authenticated user from the database that stores the hash value generated in the same method to computedID.

The ePTID is the default attribute to identify users in the shibboleth SP, however, shibboleth SP can select another attribute to identify user. For example, if we do not need to anonymize user ID, we can choose the user ID (uid) itself or eduPersonPrincipalName (ePPN) as an attribute to identify users. The requirement (b) is, therefore, satisfied if ePTID is selected as user identifier. But if we select ePPN as the user identifier, the requirement (b) is not satisfied.

### 3.2.3. User's consent

User's consent function in Shibboleth version 2 called as "uApprove" is developed by SWITCH which is a federation for Swiss higher education community. The uApprove is improved to "uApproveJP" by GakuNin and deployed many universities in Japan [26, 27]. Shibboleth version 3 includes user consent features where the alert page appears after the shibboleth login Step (3) [28]. The Step (4) starts only if users agree to release attributes to SP as well as terms of use. The requirement (c) is therefore satisfied by using shibboleth user consent features.

### 3.2.4. Confirmation of the outcome

The outcome of users is accumulated in the federated LMS. If user ID is anonymized, we need to de-identify anonymized user ID with user ID of institution to confirm user's outcome. To de-identify the anonymized user ID, we need to map anonymized ID in the federated LMS and user ID in the institution. Then, we need to cross-institutional integration of data and related IDs.

Also, we should manage the teacher of the course and their students. Since the GakuNinMoodle provides a single course corresponding to the learning materials to the institution, we cannot manage correspondence between teacher and their students in the GakuNinMoodle.

The following methods for cross-institutional data integration were examined: StoredID; sending eduPersonUniqueId; Using Virtual Organization; Using SP plugin.

*StoredID.* It is possible to combine the data which includes ePTID and the institutional ID by searching the relational database in IdP. Strict access management of database table is required to the stored ID database in the institutional IdP. But, it could be a security hole.

*Sending eduPersonUniqueId.* It is concerned that individuals are re-identified easily because the eduPersonUniqueId (ePUId) means the unique ID within the federation. That is, it requires immutability and uniqueness even if the user moves to another institution within the federation. In addition, this method is not actionable because it is a heavy task to the IdP administrator to prepare ePUId.

*Using Virtual Organization.* The eduPersonTargetedID is a standard anonymized ID in the shibboleth. The eduPersonTargetedID is a permanent and unique ID in a SP of the federation. Therefore we cannot directly link users between the federated LMS and institutional LMS as shibboleth SP. To link user within a group of SP, we can use the virtual organization (VO) feature of shibboleth [30]. A VO is a virtual group within federated identities. To support this, shibboleth recognizes a virtual group within SPs to share users' VO memberships among the SPs. For example, we create a group whose member SP is the federated LMS and institutional LMS. As the virtual entityID can be assigned

to the member of the group, we can send the same eduPersonTargetedID to the member of the group; the federated LMS and the institutional LMS.

The VO technology has been used in the Grid computing field to share SP and across the member of different institutions where management system of VO is required [29]. Federation operators are also required the management of VO to apply VO feature to IdPs and the GakuNinMoodle such as the administration of the member of VO. Some element should be added into the federation metadata of GakuNin for IdPs to recognize the VO.

*Using SP plugin.* It is considerable to transmit the ePTID and learning data to another SP after login GakuNinMoodle via web link to another SP which contains encoded ePTID and learning data. Then, another SP can integrate ePTID, the learning data and the institutional ID which is required user login [20].

The user's consent can be implemented by appearing the window describing the terms of use on clicking the web link. This method is applicable without changing configuration of shibboleth metadata.

### 3.2.5. Confirmation of the learning records

The learning records are accumulated in the federated LMS and LRS. Though shibboleth can be also applicable for user authentication of LRS, we should implement access permission of users and institutions per record, which is not defined in the specification of LRS.

### 3.2.6. Institutional LMS

Basically, institutional LMS is not required in the federated LMS because the institutional user directly login to the federated LMS. However, we still need institutional LMS to confirm user's outcome/learning records if user ID is anonymized on the federated LMS. As the GakuNinMoodle is now using ePTID as an user ID, we need some system to confirm user's records. The cyberethics grade confirmation system (CEGC) is the minimal shibboleth SP to manage user's outcome of the GakuNinMoodle and the students of the classes and their teachers [20].

## 4. Prototype implementation of SP plugin

Fig. 4 shows the sequences of authentication, authorization and transmission data. The data integration procedure is as follows:

1. User login to GakuNinMoodle.
2. User pushes the button to report their records in GakuNinMoodle.
3. The plugin responses the web page which automatically posts ePTID and user's outcome to CEGC.
4. User's browser post ePTID and user's outcome to CEGC.
5. As user does not login to CEGC, CEGC returns web page which post SAML authentication request to IdP.
6. User's browser post SAML authentication request to IdP.
7. As user's browser is already authenticated, IdP returns the web page which posts SAML response to CEGC.
8. User's browser post SAML response to CEGC.
9. CEGC authorized user and redirects the web page accessed at first.
10. User's browser post ePTID and user's outcome to CEGC.
11. CEGC receives ePTID and user's outcome and also link them with the user ID received from IdP, which is saved in the browser environment variables.



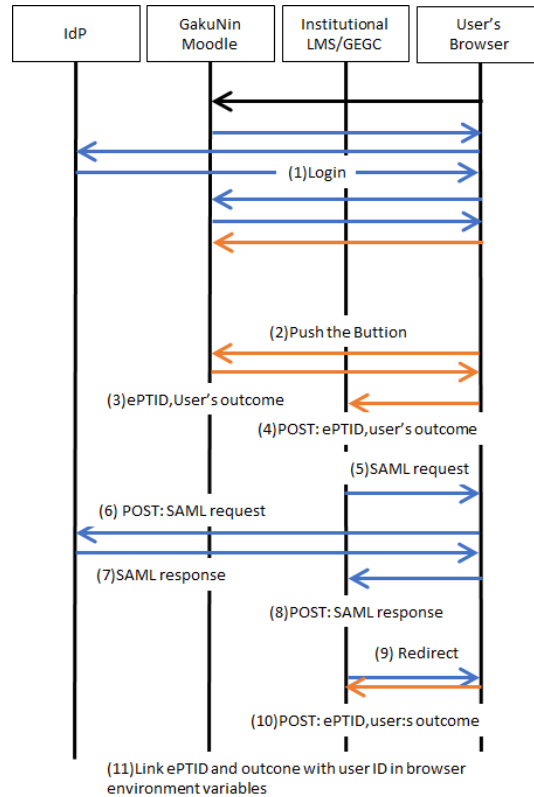


Fig. 4. The sequences of authentication, authorization and transmission data related to data integration of shibboleth SP plugin.

Table 1. Summary of the methods of the data integration.

	LTI	Shibboleth (ePPN)	Shibboleth(ePUId)	Shibboleth(VO)	Shibboleth(SP plugin)
Req a): institutional ID	✓	✓	✓	✓	✓
Req b): Anonymization	Consumer		ePUId	ePTID	ePTID
Req c): User's consent	Institution	user	user	user	user
Req d): Confirm the outcome	✓	✓	✓	✓	✓
Req d): Confirm LR	LRS	LRS	LRS	LRS	LRS
Req e): LMS Required	Required	Not Required	Not Required	Not Required	Not required
Comment	LMS Required	ID is not anonymized	Over-integration of data	VO required	The plugin required

Though the prototype plugin does not support to obtain user's consent, we can obtain the consent by popping up the dialog on pushing the button or write notifications in the web page near the button.

We set up local test environment that contains IdP, LMS and another SP for data integration. We adopted Moodle as LMS, and implemented the prototype module which provides on each course the link to send the ePTID and the learning data[20]. When the user click the "Send" button displayed by the prototype module, the web browser could post the ePTID and the outcome. At the same time, the data integration SP which is required login with IdP, could receive institutional ID for data integration.

## 5. Results and Discussions

Table. 1 shows summary of the comparison of the method for data integration. The LTI includes strong functions which support most of our requirements though a small problem that the user's consent is not obtained individually.

Though the LTI standard is already released, the standard itself is revising continuously and the behavior of LTI module is different by the type of LMS. Although LTI assumes that LMS exists in an institution, at present stage, not all institutions operate institutional LMS supporting LTI. However, it is expected that in future, LMS will support LTI standards and data integration will be simplified since LTI has a strong support from global organization IMS.

To use ePPN for user identifier in a federated LMS, strict measures against information leakage because learning records/outcomes are stored on the federated LMS without anonymization of user ID. On the other hand, we do not need to consider data integration. Using ePUID for user identifier in a federated LMS arises the critical problem that the range of the data integration can be extended to all SPs. Furthermore, assigning ePUID in institution is unrealistic.

We consider that virtual organization and SP plugin have sufficient function. But, the virtual organization is not popular and is not supported in some Shibboleth-compatible software. The development of the SP plugin is not based on Shibboleth, then we cannot expect long-term support as the implementation is based on the original specification.

As discussed above, every method has advantage and disadvantage. It is difficult to satisfy all requirements by using a single method. We consider to implement LTI to the next version of GakuNinMoodle for institutions having LMS supporting LTI. Also, we are considering to apply ePPN for data identifier to simplify data integration even though obtaining user's consent becomes not easy.

The learning records are not able to be delivered by using any methods/standards discussed in the paper. In the next version of GakuNinMoodle, we will construct LRS and develop the method to provide learning records to the institutions.

## 6. Conclusions

In this paper, we have compared existing methods and our method for data integration at shared LMS and institutional one. We have examined application of these methods to the next version of GakuNinMoodle. As the result, we find our method, SP plugin, is superior to other methods in obtaining user's consent or in not changing configuration of Shibboleth. However our method is not applied to the next version of GakuNinMoodle because the method is original and not based on the standards. On the other hand, we find that all requirements are not fulfilled by a single method. We argue therefore our method is positioned as one of practical and new efforts concerning data integration of web system in authentication federation even it was not acceptable for live environment this time.

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