SyncME – A Solution for Integration and Synchronization between Moodle and EscolaNaNet

Bruno Miguel Pereira da Silva 49618
Orientador: Alberto Silva, Co-Orientador: David Ferreira
MEIC, Alameda, Instituto Superior Técnico, Lisboa, Portugal

Abstract: There is a huge adherence by educational establishments in eLearning platforms. So for a school management system as EscolaNaNet it constitutes a competitive advantage its integration with Moodle, which is the learning management system of choice in the Portuguese education panorama. Even though that a school management system and a learning management system are supposed to address different objectives, both systems deal with similar education processes and information which brings integration opportunities. This paper resumes the thesis with the same name and address the integration of Moodle with EscolaNaNet, not only by specifying use cases for integration that are identified as also by describing the implementation of some of these features. The global integration solution is called SyncME and was designed to be configurable, extensible and adaptable, with minor effort, to support new versions of Moodle or EscolaNaNet. The greatest difficulties to overcome were the differences in information format and the matching of concepts and entities between the two systems. These problems were already addressed by researchers in the past and some analysis of their work allowed us to conclude that the best option was to design a library with a well-defined API that provides integration services to transfer and synchronize information and whose core operates with information in an interchange format. To meet the flexibility requirements mentioned above is necessary to maximize the isolation of transformation logic between the information interchange format and each of the system's local formats.

Keywords: School Management System, Learning Management System, EscolaNaNet, Moodle, Integration, Information Interchange Format.

1. Introduction

1.1. Context

When talking about technological support to education is crucial to distinguish between two types of information systems: School Management Systems and Learning Management Systems. A School Management System is intended to support the main administrative processes in schools and can also support the management of issues such as human resources, course enrollments, classes, assiduity, evaluations, school hours, financial information and assets, among others. Such systems are usually complex and comprehensive for most of the administrative procedures in educational establishments. Learning management systems (LMS) are integrated systems for the management and use of digital learning content for students and instructors [3]. Usually built to be accessible via the Internet, these systems provide a wide range of features for creating dynamic activities, publishing and using learning contents and also enhance the communication among the participants in a course. A LMS allows education to occur anytime and anywhere, enriching the learning experience and encouraging participation and interaction among the participants.

Despite the different objectives that try to meet, school management systems and learning managements systems deal with similar processes and information (see Figure 1). Such contact points correspond to integration opportunities and were the motivation for the thesis that this paper resumes. As such, the main focus for the thesis that this paper resumes, was the integration between a school management system named EscolaNaNet and the most popular learning management system solution deployed in educational establishments in Portugal: Moodle.

EscolaNaNet is a complex information system for school management developed in 2001 at INESC-ID that aims to function as an integrated portal for education supporting the main administrative processes in educational establishments and functioning as a platform for supporting
communication and information sharing among the various stakeholders in the education panorama.

**Moodle** is considered the largest free and open-source eLearning software platform permanently increasing the number of users and deployments worldwide since its creation in 2003. Moodle provides a wide range of resources and activities, static or dynamic, which creates a rich learning environment with different types of interactions between teacher/student and student/student [5].

![Diagram](image.png)

**Figure 1 - Contact Points between a School Management System and a Learning Management System**

1.2. Problem

EscolaNaNet includes an eLearning module to support the classroom teaching, but the use cases supported by this module are limited to the creation and use of areas where teachers provide static content for students. The interaction between students and teachers is also supported by a Forum module and a module for digital publications, however, students have a predominantly passive role when using the system to enhance their learning and supplement classroom lessons [1]. Schools need richer digital learning support to their community. Combining the mass adhesion to Moodle in Portuguese educational establishments with its integration with EscolaNaNet one foresees a competitive advantage for the latter, since the competing platforms do not consider eLearning features or provides integration with solutions less accepted in the educational community [7] [8].

One should conduct a careful reflection to find parallels between the actors/roles of both systems and to establish similarities and relationships between some of the use cases supported. The aspects that such integration should consider are:

- **Users** – Creating or changing a user account on EscolaNaNet should induce similar operation in Moodle and one must know, from the universe of real world entities, which ones are found in only one or in both systems. Personal information in user accounts should be synchronized.

- **Courses** – Moodle course comprises a set of users, and is where teachers create and manage activities and learning content to be accessed by students. Naturally, there arises the problem of creation and synchronization of groups of entities on both platforms, whether in terms of its constituents or in terms of the roles that each user plays within them.

- **Others** – Other aspects may be considered to be addressed by the integration solution, such as academic years (which can relate to platform lifecycles), grades, events, lesson summaries or school hours.

1.3. Objectives

The overall objective for the thesis was the analysis, planning and implementation of an integration solution (called **SyncME**) between EscolaNaNet and Moodle in order to solve the problems outlined in the previous section. In more detail, the goals to achieve with the thesis were:

- Detailed analysis of the processes and information belonging to EscolaNaNet and Moodle in order to establish correspondences between related use cases and entities and thus specify all integration opportunities which correspond to the integration features proposed by **SyncME**.
• Implementation of the use cases for integration and synchronization of users and courses. It includes the implementation of a simple Single-Sign On mechanism to allow users to navigate from EscolaNaNet to Moodle without the need to provide authentication credentials again.
• Analysis of the added value that the integration solution brings to EscolaNaNet and educational establishments.

The decisions made in architectural design and implementation of SyncME also pursue the following non-functional requirements:
• **Non Intrusion** – SyncME should not cause changes in existing features in EscolaNaNet and should not disturb the normal functioning of existing production platforms Moodle in schools.
• **Performance** – Especially in transferring and synchronizing mass quantities of information.
• **Portability** – The solution should be designed and implemented to facilitate, in future, their adaptation to newer versions of Moodle, changes in EscolaNaNet, or even different school management systems. This objective is the hardest to achieve.
• **Extensibility** – The solution should have a modular and extensible architecture facilitating, in the future, the support for new integration features.
• **Flexibility** – The aim is to provide parameterization features in order to comply with certain preferences or policies about the use of the system defined in each educational establishment.
• **Easy to Use** – The solution must have an appealing and easy to learn user interface.

2. Target Systems

For the understanding of the proposed integration solution it is relevant to briefly describe the target systems (EscolaNaNet and Moodle) specially his user roles and features (use cases):

2.1. **EscolaNaNet**

A user in EscolaNaNet can take one or more of these roles [1] [2]:

• **Administrator** – Administers the platform by managing the modules and controlling accesses and permissions for users with other roles.
• **Administrative** – Corresponds to the staff working in the secretariat and responsible for performing administrative processes regarding to human resources, course enrollments, classes, school hours, assiduity and grades.
• **Teacher** – Performs the tasks relating to the subjects in courses which teach. Records the student assiduity, defines their grades, controls the issuing of alerts and notices about events and functioning rules and fills the class book with lesson summaries. Also moderates forums and digital publications enhancing student participation.
• **Student** – Typically these users interact with the system to find information that relates with themselves, in particular, alerts, events, grades, absences or school hours. To enrich the students' involvement they also take part in digital publications, forums and access content available in the eLearning areas belonging to course subjects in which they are enrolled.
• **Educators** – These users use the system to visualize information related with their students, in particular, grades, absences, school hours, events and meetings with class directors.
• **Others** – Such as **Class Directors** which corresponds to teachers with increased responsibilities about scheduling class meetings and sessions with educators and **Executive Body Members** which are users responsible for managing some information about the school.

In EscolaNaNet architecture one can identify several modules which realize the use cases supported by the platform:

• **Human Resources** – Module that manages the users and their respective user accounts. It assigns the roles described previously to the persons registered in the system.
• **Education** – It is the main module and it is where are performed the key administrative processes, such as enrollment management, classes formation, student grading (interim and final) and assiduity (students and teachers). It is also in this module that is created and maintained the educational structure and program in force at the educational establishment. As such it allows the managing of scientific areas, courses, course subjects and academic years.
• **School Hours** – Module that allows the definition and visualization of school hours for classes.
SyncME - A Solution for Integration and Synchronization between Moodle and EscolaNaNet

- **Events Calendar** – Module that allows an administrative or teacher to keep track of events happening in the academic year. Each event is directed to a group of users and can be visualized in their respective events calendar.
- **Communication** – Build to enhance the communication among the learning community, it comprises forums and digital publications as long as an alerts mechanism which allow any user to create messages that can be directed to any other user or group.
- **Class Book** – The class book is where teachers can record lesson summaries.
- **ELearning** – As said in “1.2 - Problem” the use cases that this module provides to teachers and students in order to enhance their learning experience are very poor compared with the ones provided by Moodle. There aren’t dynamic activities and the students have a very passive role.
- **Others** – Such as School Configuration and Reports for the generation of valuable management reports.

2.2. **Moodle**

Moodle is course-oriented and a user can assume different roles for each course in which he is enrolled. Nonetheless, there are global roles, which once defined have precedence over all local roles defines for a course. Moodle considers the following roles (appearing in descending order of privilege) [4] [5] [6]:

- **Administrators** – Can do anything in the system and in any course.
- **Course Creator** – Can create courses, teach in them, and assign other to teachers' roles.
- **Teacher** – Can do everything inside a course including manage their activities and evaluate students.
- **Non-Editing Teacher** – Can teach in a course and evaluate students but are not allowed to change their activities. It can represent an assistant teacher or a part-time teacher.
- **Student** – Can participate in activities created by teachers inside a course, either individually or in groups (when applicable), but cannot change them. They can also see their grades.
- **Guests** – Typically cannot change any information and the viewing can also be very limited.

In user management, Moodle maintains a variety of information associated with each user account such as, name, address, photo, description, contact information, etc. It also allows the creation of new attributes to describe the user.

As stated above, Moodle decomposes the platform in spaces with similar structures and policies: the courses. A Moodle course can be structured in different formats:

- **By Week** – All activities and resources are relative to a week from the period of time in which the course will be taught.
- **By Topic** – The activities and resources are organized based on subjects.
- **Others** – Such as social, LAMS (the course serves as a front-end to the LAMS LMS) or based on learning objects complying with SCORM (Sharable Content Reference Model) standard.

In Moodle a course combines non-interactive material (such as text, documents, images or hyperlinks) with interactive or social material such as learning activities, defined by teachers and performed by students. Much of the popularity and richness of Moodle comes from the wide range of activities supported. Among them, stand out the following activities: assignments, glossaries, lessons, quizzes, chats, forums, wikis, surveys, workshops, etc. Students may be evaluated by his performance in the activities in which they participate and Moodle has a powerful grade book where, on a single page, it can be viewed and edited the grades belonging to students in a course, and may be defined calculation formulas as long as rating scales.

**Blocks** are another feature in Moodle and correspond to small widgets that are added to courses, typically at the margins of the layout in order to increase their functionality. There are dozens of blocks such as the block to indicate the recent activity that occurred, the search block, the RSS block, or the schedule block.
3. Related Work

3.1. Identity Information Management in a Network Environment

As the Internet became popular, users are required to register in a lot of Web sites in which they need to provide their personal information. The result is the distribution and the proliferation of replicated information for which the management and consistency maintenance are problems to overcome [13]. In identity information management there are two main issues to address. The first is the recognition that information and entities from different sources refer to the same real world entity. The second depends on the first and is the effective combination and synchronization of information, possibly heterogeneous, between different systems [14].

3.1.1. Entity Identification

The univocal identification of entities places at two levels:

- **Heterogeneity of Vocabulary** – the same concept (e.g. Person) or property (e.g. address) must be recognized as the same concept or property among different systems.
- **Entity Recognition** – The same real world entity (e.g. John) must be recognized as the same entity among different systems.

Many researchers have work on the subject of entity identification and have conceived systems that address the previous issues following different strategies such as by centralized approaches or by decentralized approaches. In decentralized approaches each entity must have a unique identifier recognized by all systems that we wish to integrate. This approach requires some changes and development effort, since each system needs to communicate with the others and trust in them as entity ID providers. The major success case adopting this approach is OpenID [15] [16] [17].

In the context of a project named OKKAM, Bouquet, Stoermer, Niederee and Maña have proposed a centralized system, the **Entity Name System** (ENS), to provide unique identifiers to entities so that they can be recognized and used by a network of systems for integration purposes. ENS tries to overcome the biggest difficulty in entities mapping and systems integration pointed by the researchers: the many different aliases that a real world entity can have which can lead to false negatives in entities mapping. When a system needs to identify an entity, queries ENS sending a particular description of the entity, such as the text or the value of some property. The ENS verifies if it has an identifier for that entity, possibly using algorithms for entity matching. The ENS may thus return an existing identifier, an ordered list of possible identifiers or may also issue a new identifier registering in its internal data structures [14].

3.1.2. Information Transfer and Synchronization

In his paper about representation and sharing of knowledge and information [18] Ginsberg discusses the development of intermediate representations of information, called Knowledge Interchange Format (KIF), to reduce the effort needed in information transfer and sharing among a set of systems with heterogeneous formats.

![Figure 2 – Information sharing without (left) and with (right) the use of interchange formats.](image-url)
As it can be seen in Figure 2, in the absence of an interchange format, for an effective information sharing and transfer between N systems are necessaries N (N-1) conversions and format translations (represented by arrows in the figure). Using an intermediate format to represent information, each system needs to know how to translate between his format and the interchange format, which amounts to 2N translations. The complexity of integrating information in a group of N systems with heterogeneous formats is reduced from \( O(N^2) \) to \( O(N) \). To minimize the impacts that future changes in local formats may induce on the suitability of the interchange format, Ginsberg advocates that the intermediate format should be minimalist but also flexible and extensible with the capacity to evolve, if necessary, to respond to changes in information formats.

Identity Management Server (IMS), a centralized system proposed by Zhang and He, facilitates the personal information management by propagating changes made by a user at one site [13]. IMS requires a previous user registration in order to bind all user accounts. For each information attribute, it only records the location where it was made the last change, and it instructs the systems to communicate with each other’s, delegating in them the responsibility to perform the effective transfer and synchronization. This approach increases the scalability but imposes some effort regarding to the installation on each system of the pieces of software required for the interoperability with IMS and with the other systems. IMS imposes some restrictions about the attributes that can be integrated and about their formats which limits the flexibility of the system.

3.2. Moodle Integration Features

Through plug-ins Moodle, supports different ways to authenticate and share users registered in others systems. When a user authenticates in Moodle, the system assess the legitimacy for that user to access the platform and, on each access, Moodle can also synchronize some information attributes based on information retrieved from those external systems. Next we highlight the major plug-ins to authenticate and register a user based on external information:

- **LDAP** – A directory service is used to check the legitimacy of a user in accessing the platform.
- **External Database** – A database belonging to other system is shared with Moodle.
- **User Files** – Through an information transfer file containing the users on a specific format.
- **Others** – Such as by CAS (a Single-Sign On solution), POP3, IMAP, Shibboleth, among others.

Moodle also supports different plug-ins to enroll students in courses based on information externally retrieved:

- **LDAP** – A directory service defines the groups of users that can be enrolled in a course.
- **External Database** – A database associates users with a course and can also define the roles.
- **Text Files** - Through an information transfer file that associates users with a course.
- **Others** – Such as through payment systems like Paypal or Authorize.Net.

Despite the fact that these integration mechanisms are interesting, the conception of SyncME did not considered them for several reasons. First, there were reported some bugs when trying to authenticate users in Moodle with the EscolaNaNet database, possibly because this is a SQL Server 9 database, which is less supported than a MySQL database. Second these integration mechanisms did not support the integration and synchronization of all desired attributes. Finally, some integration alternatives (such as by LDAP) may require changes in the EscolaNaNet.

4. SyncME - Conception

4.1. Correspondence between Roles

Before delve into the solution and specify the uses cases for integration proposed in SyncME, it is important to establish connections between actors and roles of the two systems. This correspondence is important in order to discover possible break points (in the sense of using both systems for equivalent functions) during the execution of administrative and educational processes. Table 1 establishes a typical correspondence between roles, which may vary according to internal policies of each educational establishment.
<table>
<thead>
<tr>
<th>Role in EscolaNaNet</th>
<th>Role in Moodle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrator</td>
<td>Administrator</td>
<td>Typically, when the IT in education establishments is managed by the same group of persons.</td>
</tr>
<tr>
<td>Administrative</td>
<td>Administrator or Course Creator or None</td>
<td>When an administrative is responsible for managing users in EscolaNaNet it may make sense to make him administrator in eLearning platform.</td>
</tr>
<tr>
<td>Teacher</td>
<td>Teacher or Non Editing Teacher</td>
<td>In Moodle, this is a role belonging to the context of a course.</td>
</tr>
<tr>
<td>Student</td>
<td>Student</td>
<td>In Moodle, this is a role belonging to the context of a course.</td>
</tr>
<tr>
<td>Executive Body Member</td>
<td>Administrator or Course Creator</td>
<td>To an executive body member it may make sense to give extra capabilities in platform usage.</td>
</tr>
<tr>
<td>Educators</td>
<td>None</td>
<td>Typically, educators don’t interact with the eLearning platform.</td>
</tr>
</tbody>
</table>

Table 1 - Typical correspondence between EscolaNaNet Roles and Moodle Roles

4.2. Use Cases

Despite the implementation effort, in the thesis, had only addressed the integration for users and courses, in order to satisfy the first objective stated in “1.3 - Objectives” the dissertation that this paper resumes state all functional requirements for SyncME attending all integration opportunities identified between EscolaNaNet and Moodle. However, this resume focuses on the integration for users and courses.

4.2.1. Users

Typically when a user is created in EscolaNaNet it is necessary to reflect this creation in Moodle. The same is true when some information concerning to a user is modified in one of the systems, as for example when a user accesses some system to change their personal data. The management of the administrative staff and executive board members in EscolaNaNet can lead, not only to the operations of creating and editing users in Moodle, but also to the operations of assigning global roles for a more administrative usage of the platform (see Table 1). The non-integration of systems forces the users to move between platforms to maintain synchronism. This inefficiency is very notorious in the last case because, typically an administrative in EscolaNaNet and an administrator in Moodle correspond to the same person (see Table 1).

It can be concluded that there is a break point (in the sense of transition between systems) which forces the users to perform similar operations both on EscolaNaNet and in Moodle to maintain the consistency and synchronism at user level on both platforms. So, SyncME should provide a series of services for transfer, mapping and synchronizing users such as:

- Map user accounts present in both platforms belonging to the same real-world person.
- Transfer users present in EscolaNaNet but not in Moodle.
- Reflect the user roles at one system on the other, but also taking into account the objective regarding to flexibility stated in “1.3 - Objectives”.
- Synchronize some information attributes relative to user accounts present on both platforms and mapped by SyncME.
- Identify equivalent user accounts present on both platforms (i.e. relative to the same real-world person). This feature is very important as it allows to an instance of EscolaNaNet already populated with a certain universe of users integrate and synchronize with an existing instance of Moodle and also already populated, through the mapping of their user accounts.

It is noteworthy that, considering the human resource management a fundamental process in educational establishments that should be strongly focused in a school management system importing users from Moodle to EscolaNaNet should be restrict or strongly restrained.
4.2.2. Courses

As presented in "2.2 - Moodle" a Moodle course is a common space where groups of students enhance their learning experience by performing learning activities under the supervision of a group of teachers. In EscolaNaNet the creation of user groups occurs, mainly, at two related moments: at course enrollments, where students are combined with academic years (e.g. 12 Grade), courses (e.g. History and Social Sciences) and course subjects (e.g. World History) and at the time of the creation of classes (e.g. Class 12B) where teachers and enrolled students are grouped to form the more elementary class subjects (e.g. World History in Class 12B).

The course integration between EscolaNaNet and Moodle involves managing user groups and controlling the roles that the users play within those groups. Once again, it is necessary to operate both systems in order to maintain the coherence between the classes/class subjects defined in EscolaNaNet and the courses created in Moodle. This increased effort also occurs in the maintenance of the coherence about the user membership at those groups. In order to address the previous issues we specify the following functional requirements to be provided by SyncME:

• Create a course in Moodle based on a set of class subjects defined in EscolaNaNet. Later in this paper it will be explained why class subjects constitute the elementary piece in the association.
• Edit some information attributes belonging to a Moodle course. It involves associating class subjects defined in EscolaNaNet with that Moodle course.
• Maintain a mapping between courses in Moodle and class subjects defined in EscolaNaNet. This feature has a strong relation with the previous ones.
• View the details belonging to a class subject defined in EscolaNaNet showing the Moodle courses associated, and vice-versa.
• For each course created in Moodle, view the following information:
  o Enrolled users - the ones mapped (present on both systems) and the ones only present in Moodle.
  o Not enrolled users in the Moodle course but enrolled in the associated class subjects at EscolaNaNet. For these, it should be viewed the ones mapped (present on both systems) and the ones only present in EscolaNaNet.
• Enroll and remove users in Moodle courses. These users must be mapped by SyncME (present on both systems) and enrolled in the associated class subjects at EscolaNaNet. It should be possible to determine the roles each user will play in the Moodle course.

Similarly with what it happens on user integration, we consider that school information regarding to enrollments, classes and class subjects must be managed exclusively by the school management system. As such, there weren't considered any facilities to changing those entities in EscolaNaNet based on information retrieved from Moodle.

4.2.3. Other Aspects

Various integration possibilities were identified in the dissertation which this paper resumes, and were suggested innumerable use cases for integration between EscolaNaNet and Moodle. However in this resume those integration aspects will be not be detailed.

Series of Moodle courses are normally created or replaced at same moments clearly defined throughout the academic year. It can be said that a Moodle platform crosses, throughout its existence, several time cycles marked by a renewal of existing courses. The most obvious example is the start of new academic year. Typically, that replacement involves the creation of the new courses and the categorization or the hiding of the old ones. A Moodle category is a classification that is assigned to a Moodle course and this cataloging is a facility offer by the platform to structure and group the existing courses. SyncME should provide mechanisms to support the transitions between the lifecycles that occur in Moodle. In particular, it should provide facilities for cataloging and hiding sets of Moodle courses.

Moodle has a very flexible and comprehensive gradebook to evaluate the students allowing the classification of each activity, interim evaluations, final evaluations and all of this combined with the creation of grading scales and calculation formulas that can use a large number of mathematical functions. When Moodle is used for maintaining the student's evaluation, teachers and the administrative staff have to repeatedly enter the same grades (those also supported in EscolaNaNet) in both systems. Moreover, for a user to have a comprehensive perspective of his
evaluations it may be forced to access both systems. SyncME should provide use cases for transfer grades, as such for mapping grade scales. The flow of information for this integration aspect can be bidirectional.

EscolaNaNet has a module called Calendar capable of recording events that happen at the educational establishment throughout the academic year. Moodle also allows the administrators to add a block called Calendar to each course that can record events with four different scopes (Global, Course, Group or User). There is not a unique space where users can get an integrated view of the events happening in the school and the corresponding synchronization may force the administrative staff and teachers to create the same events on both platforms. To overcome the constraints identified SyncME should provide mechanisms to synchronize and transfer calendar events. The flow of information for this integration aspect can be bidirectional.

EscolaNaNet can define, through a specific module, school hours for each class. For the creation of a rich and integrated environment it is interesting to convert the school hours of each class defined in EscolaNaNet to course events in Moodle that should appear in the corresponding calendar block during the period of time in which the course will be taught. SyncME should realize use cases to ease and support this conversion.

4.3. Information Architecture

4.3.1. Users

In EscolaNaNet, a user is captured by the concept of person. Each participant in the educational environment is viewed as a person with a set of personal and account information which can take several roles in the platform. Each person is also associated to his activity information, either learning or teaching information. In EscolaNaNet all information about a person is spread across several entities and several physical tables. On the other hand, Moodle concentrates all person and account information in one entity.

Although respecting to same real-world concepts there are some differences in structure and data format between users from Moodle and EscolaNaNet. SyncME could map between any two different visions of users belonging to Moodle and EscolaNaNet and perform the corresponding data transformations, however that approach focus SyncME on a particular version of Moodle and difficult their adaption to later versions, especially to the ones with more distinct vision of the concept.

Looking for the benefits of designing an interchange format entity, as proposed by Ginsberg [18] (see “3.1.2 - Information Transfer and Synchronizaton”), it was been created an intermediate vision about the concept of User over which the integration operations occur. The information entity is called UserIF (UtilizadorIF in implementation), were IF stands for Interchange Format, and is an approach that isolate the core of SyncME from the specific Moodle versions or from their underlying database providers.

Physically, UserIF is convertible to the entities of the target systems and vice-versa, but the logic of transformation, which varies depending on the platform versions, is kept isolated from the core. With the interchange format, adapt SyncME to a newer version of Moodle, to a new database, or ultimately to a different school management system involves adding a new software package to make the conversion between formats, whereas the core of SyncME continues to carry out the integration operations in the interchange format without disruption, invoking procedures defined in an well-defined interface that this new software package should realize. This strategy addresses the portability objectives stated in “1.3 - Objectives”.

For a deep understanding of UserIF it may be relevant to consult the data model (available via the digital resource that accompanies the dissertation). Figure 2 shows an abstract view of the UserIF and the types of information attributes that SyncME allows integrate and synchronize.
It must be noted that the attribute “Other Information” is intended to contain arbitrarily textual information also identified by textual identification codes (in implementation it was implemented as a hash map of strings). This attribute is aligned with that suggested by Ginsberg [18] (see “3.1.2 - Information Transfer and Synchronization”) and provides the capacity for evolution and extensibility of SyncME meeting the objectives stated in “1.3 - Objectives”.

4.3.2. Courses

The information architecture regarding to the education structure in EscolaNaNet is characterized by a complex schema of relationships between information entities such as Student Teacher, Class, Class Subject or Enrollment. On the other hand, Moodle tries to deviate from the details marking the education structure in each country, one of the reasons for its success, does not consider concepts like Class, Class Subject, School Year or Academic Year. Basically, in Moodle, there are a set of Courses with Users enrolled in, and this enrollment is a set of permissions and a role played by the user at that course.

It was analyzed a set of Moodle courses in some education establishments and there were found different criteria’s underlying their creation [10] [11] [12]. In particular, there were found Moodle courses representing the following aspects:

- Class Subject (e.g. Math in class 12ve B)
- A set of class subjects (e.g. Math in class 12ve A and in class 12ve B)
- Class Subject in a grade (e.g. Math in 12ve Grade).
- Class (e.g. Class 12ve B)
- Teacher activity in some Grade (e.g. Peter Parker in 12ve grade)
- Teacher activity (e.g. Mary Jane in 2nd grade) (common in elementary teaching).
- Others (e.g. Math club)

It does not exists a common criteria for mapping Moodle courses to educational establishment concepts. If for the integration of users it was possible to devise a single interchange entity to comprehensively represent the user concept, for Moodle courses the difference in the concepts semantics causes the necessity for finding some mapping criteria in SyncME, in order to comply with the flexibility objective stated in “1.3 - Objectives”.

It was taken the decision to map, in a many-to-many relation, Moodle courses with instances of class subjects present in EscolaNaNet. Viewing the aspects listed above as sets of users, aggregating instances of class subjects, it can be, conceptually represented all those sets except for the last, which is a course in Moodle for which the user membership may be defined in a more relaxed way.

Instances of class subjects constitute the basis to obtain equivalent sets of users. Then, for the examples of courses listed above are showed the mapping that SyncME proposes:

- Math in class 12ve B – Math class subject belonging to class 12ve B (elementary case).
- Math in class 12ve A and in class 12ve B - Math class subject belonging to class 12ve B and 12ve B.
- Math in 12ve Grade – Set of all instances of Math class subjects belonging to all classes in 12ve grade.
- Class 12ve B – Set of all instances of class subjects taught in class 12ve B.
- Peter Parker in 12ve grade – Sets of all instances of class subjects taught by Peter Parker in 12ve grade.
• Mary Jane in 2nd grade - Sets of all instances of class subjects taught by Mary Jane.

Seeking for the benefits of building interchange format entities, it was conceived information entities to support the mapping described above. Figure 3 shows a conceptual view of these information entities:

![Figure 3 - Interchange Information Entities Conceived for Course Integration in SyncME](image)

**ClassSubjectIF** (DisciplinaEscolarIF in implementation) tries to represent an instance of a class subject taught in some class in the school. The entity seeks to aggregate all fundamental information that characterizes the concept, regardless of the underlying school management system. **MoodleCourseIF** (AreaMoodleIF in implementation) is intended to contain the fundamental attributes belonging to a Moodle course, which are expected to remain unchanged in all versions of Moodle for which SyncME could be adapted.

### 5. **SyncME – Architecture**

#### 5.1. Global Architecture

Figure 4 presents the software architecture in SyncME and how it relates to other architectural elements of EscolaNaNet. In the model the elements shaded in blue represent those that have been developed for SyncME. The overall solution is based on a library (DLL) placed within EscolaNaNet which, directly manipulating EscolaNaNet and Moodle databases, provides an API with integration operations for use by the interface module.

![Figure 4 - SyncME Global Architecture](image)
The interface for SyncME was implemented as a module integrated into EscolaNaNet and respecting the styles used in that platform. The idea is to have all integration tasks and controls concentrated in a module which uses exclusively the library isolating the other modules in EscolaNaNet from aspects related to the integration. This approach intends to couple SyncME in EscolaNaNet in a non intrusive manner and is a step further in accomplishing the extensibility objective stated in “1.3 - Objectives”, since it allows to the evolution of EscolaNaNet to occur in a more independent manner from the development and evolution of SyncME. Also, the similarities in layout and styles between SyncME interface module and the other modules in EscolaNaNet ease the learning relative to SyncME operation to users with experience in manipulating EscolaNaNet.

The integration database is handled by SyncME and contains the tables to associate the entities between EscolaNaNet and Moodle required to perform the integration operations.

5.2. SyncME Integration Library

SyncME integration library directly manipulates Moodle and EscolaNaNet databases, manages the mapping between entities and realizes an API (called SyncME Integration API) with the operations necessary to transfer, synchronize and differentiate entities, which is used by the interface module. This library is the main component of SyncME concentrating the integration services and should be incorporated into EscolaNaNet.

![Figure 5 – Internal structure of SyncME Integration Library](image)

Figure 5 details the internal structure of SyncME integration library and identifies the three fundamental components, which are described in the following sections.

5.2.1. SyncME Core

This component provides integration services for use by the interface module and concentrates the logic for identification, information attribute differentiation, synchronization and transfer of information entities between the target systems. Within the core the operations are performed with entities in the interchange format, as presented in “4.3 - Information Architecture”. Thus the core is isolated from the details about information formats in Moodle or EscolaNaNet which aims for the portability objective stated in “1.3 - Objectives”. For the loosely coupling between the core and the target systems to be possible are necessary to implement components (Moodle Integrator and School Integrator) responsible for carrying out the data transformation and interact with target systems. These components must implement a well defined API to be used by SyncME core.

It is interesting to note that, similarly to what happens in Entity Name Server (see “3.1.2 - Information Transfer and Synchronization” integration is carried out in a logical manner don’t occurring any replication of information centrally persisted. SyncME presents some similarities with Entity Name server, being the main difference the fact that SyncME operate as exclusive communication channel between the target systems, rather than to what it happens in Entity Name Server which delegates on target systems the responsibility to transfer and synchronize the information.
The operations in SyncME Integration API used by the interface can be classified in three types:

- **Entity Browser** – For searching entities in the target systems. These services always return entities in the interchange formats. To achieve that, the core performs the necessary format conversion from the entities in local formats retrieved from the target systems, using the operations provided by corresponding integrator (Moodle or School) component.

- **Users Integration** – Services for performing the use cases described in “4.2.1 - Users”. Internally the operations at core are performed with entities in the interchange format. It is worth to highlight the operation to map users in EscolaNaNet with users in Moodle that correspond to the same real world entities. This mapping could be performed automatically due to matching algorithms that were implemented, in a similar fashion to what it occurs in Entity Management System at Project OKKAM (see “3.1.1 - Entity Identification”).

- **Course Integration** - Despite the enumeration of several use cases for course integration in “4.2.2 - Courses” the implementation only covers services for creating courses in Moodle from a set of class subjects enrolling the users accordingly.

The functionality and behavior of the core is configured by a few parameters allowing each educational establishment to define his preferences and apply his policies. This configuration addresses the flexibility objective stated in “1.3 - Objectives”.

5.2.2. Moodle Integrator

This component isolates the core from the details of a particular Moodle configuration, namely, from a particular version and from a database provider. It concentrates the tasks of transforming the information from the local format to the interchange format and of interacting with Moodle database for searching and manipulating information. Moodle integrator provides an API (called Moodle Integration API) to the core and adapting SyncME to a new configuration of Moodle corresponds to the development of a new component that knows how to handle the information in the new version and provides the same API. When several Moodle configurations are supported, it is possible to instruct the core for which Moodle integrator package to use.

5.2.3. School Integrator

This component plays a similar role than the component described in the previous section, but for EscolaNaNet, isolating the core from their information details. Despite the fact that SyncME have been primarily conceived to meet the integration needs between EscolaNaNet and Moodle, the solution was designed trying to capture the key and global concepts of school management systems. Thus it provides an API with integration services and data transformation defining an interaction model that facilitates future adaptation to new versions of EscolaNaNet or, ultimately, to different school management systems.

6. Conclusions

Although serving different purposes, school management systems and learning management systems deal with similar information and processes which bring integration opportunities to suppress potential inefficiencies in the use of both systems jointly by the actors at educational establishments. In the Portuguese educational panorama, Moodle is, by far, the most implemented and succeeded LMS and so their integration with EscolaNaNet offers great value to the latter. There were been identified several aspects to be addressed by the integration solution SyncME, however we concluded that the flow of information should not always be bidirectional and that Moodle is predominantly a passive element when synchronizing with EscolaNaNet.

Given the integration specificity and to overcome the limitations of the integration mechanisms offered by Moodle allowing the desired flexibility and leveraging the existing know-how, it was concluded that the best alternative to SyncME is the direct manipulation of Moodle database and the creation of an integration library that, also manipulating the data on EscolaNaNet, provides services to transfer, synchronize and map entities between these two systems for education.

The two major challenges faced were the heterogeneity of information between the systems and their constant which requires that the integration solution should be endowed with characteristics
that ensure its evolution and extensibility. To deal with the previous challenges it were specify interchange format entities over which the integration operations are made independently of the local formats. The logic of transformation and conversion between formats is also isolated in specific software packages.

It was concluded that any system for education and, consequently, any integration solution that addresses them is located at a very instable domain and must be endowed with characteristics to rapidly react to those constant changes. Besides, it can also be affected by internal policies at the educational establishments and so it must be highly flexible and configurable. The initial objectives stated were almost entirely met but without a school with an EscolaNaNet instance in production, SyncME could not be tested with real data.

References
2. Silva, Alberto; Estevens, Luís; Borrêga, Gonçalo; Azevedo, Rui. Rent@School – Sistema de Gestão de Ensino à Escala Nacional. Instituto Superior Técnico, INESC-ID. 2003