Software Ecosystems and E-learning: recent developments and future prospects

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ABSTRACT
This paper presents an overview of commonly used E-learning systems and the way developers of such systems try to incorporate the notion of Software Ecosystems (SECOs) for design and deployment. Utilizing the power of crowds is a popular notion on today's web and many companies let others extend their core products and to generate profit from that. Is this process something that could applicable in the area of E-learning? This paper aims to serve as a stepping-stone for further work into this area by providing a survey into recent research in both E-learning and Software Ecosystems. The paper also surveys the already existing SECOs in E-learning and discusses current and future efforts in this field.

Categories and Subject Descriptors
K.3 [**Computers and Education**]

General Terms
Design, Standardization, Theory

Keywords
E-learning ecosystems, E-learning, Software Ecosystems

1. INTRODUCTION
Many tools used by teachers and students in the area of learning have undergone significant changes during the last two decades. Some authors suggest that various aspects of teaching are moving from a teacher-centric to a learner-centric approach with the help of these tools [1]. This shift can to some extent be attributed to the fact that the notion of knowledge is changing as part of the information society we are living in [13]. Companies like Blackboard, Desire2Learn and OpenText are all providing popular tools for flexible and collaborative learning. Open source projects have also gained major acceptance in the field with initiatives like Moodle, Sakai, dotLRN and OpenLMS. Another thing that recently has impacted E-learning is the move towards Web 2.0 applications, with a transition from a passive to an active web [17]. This transformation towards a more social and user centric web have also lead to some other interesting changes in the way content is generated and shared. Users suddenly are not only reviewing products, tweeting and writing blogs, but are also putting their development skills to good use in different projects to a whole new extent. This old, newfound willingness to contribute to various open source and other projects around the web have recently opened the door to a brave new world for many companies, the world of software ecosystems. But it is only recently that a lot of small and medium sized enterprises have started to realize the potential of having their users refining their products or concepts in this manner [4]. In the light of this brief introduction to the areas of E-learning and software ecosystems, the intended purpose of this article is to investigate if the most commonly used E-learning systems are incorporating the notion of SECOs in their development and to explore whether or not this approach could be beneficial for the field of e-learning systems. The paper is structured as follows; next section discusses the motivation and method used to carry out this research followed by a section that briefly presents the current research efforts in the field of software ecosystems. Thereafter, the following sections discuss some frequently standards used in E-learning and some common systems that employ them. A section discussing the stance these systems have taken towards reusability and software ecosystems follows this. The paper concludes with three sections including a discussion, overall conclusions and future directions in this field.

MEDES'09, October 27–30, 2009, Lyon, France.

2. MOTIVATION
The notion of taking an entity from a system and reuse it in another is something that sounds trivial in theory. This is in few cases practically possible with complex components however, especially with preserved context. The field of E-learning is not exempt from this latest fact. The importance of reusability of learning digital content is perhaps even greater in public schools and institutions where money is usually scarce. The need for customization and adaptation is something that affects software vendors as well and Software Ecosystems has proven to be a part of a viable remedy in that context [4]. This recent paradigm shift is one of the main motivations driving the study presented in this paper and has resulted in the following questions.

- *What common standards are currently in use in E-learning systems?*
- *How are the selections of E-learning systems handling the notions of reusability and ecosystems?*
- *Is there any possibility to apply recent findings from the field of Software Ecosystem to the field of E-learning?*

In order to answer these questions, a literature study in the fields of E-learning and Software Ecosystems was conducted aiming at identifying notable initiatives and novel approaches between these fields. This literature study was conducted by searching for for scientific articles in databases like ACM, IEEE Explore and

Google Scholar that contains relevant terms common to these two fields. The terms used were “E-learning reusability”, “M-learning”, “Software Ecosystems”, “E-learning ecosystems” and the like. References from some of the papers I found were also followed and used. In the next section, I elaborate on the main outcomes derived from the literature review regarding the field of Software Ecosystems.

3. SOFTWARE ECOSYSTEMS

Software Ecosystems (SECOs) derives, just like all ecosystem analogies, from the notion of variety and diversity. The term Software Ecosystem refers to the ecosystem of a piece of software whilst the term ecosystem can refer to anything with an ecosystem like content or social. A short and concise definition of the term ecosystem can be found at the Merriam-Webster dictionary: “a community of living organisms with air, water and other resources”. This view is suitable for Software Ecosystems since it highlights the community aspects of ecosystems in general, which is one of the biggest advantages of SECOs. By encapsulating core functionality and providing a friendlier interface to complex implementations, the end users ability to expand upon the existing system increases [14]. Figure 1 presents a taxonomy that organizes the different kinds of software ecosystems into a two-dimensional scheme. The different categories mean the different levels where ecosystems exist and the other dimension is popular areas of computer science. SECOs that surround operating systems and applications benefit immensely from the size of their ecosystems; it is in fact together with the ease of development the biggest factors in building a successful SECO for these areas. End-user programming differs, with its most important factor being the feeling of additional value added for an end-user. A good and effective way of sharing these artifacts is also crucial for the success of an end-user programming ecosystem [4]. This effective way of sharing artifacts and its importance seems like it is spilling over to other ecosystems as well and Apples “app store” is a concrete example to successfully illustrate this idea. Google, Microsoft, Nokia and others are all planning for similar projects.

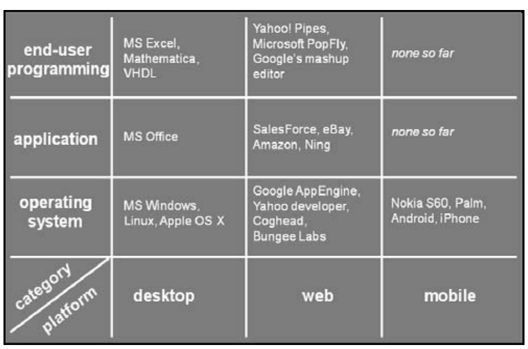

Figure 1: Software Ecosystem Taxonomy [4]

Jansen and colleagues have defined the boundaries into four categories; namely; market, technology, platform and firm [12]. They also detailed different ways a SECO can be viewed from: externally, internally and from organizational perspectives. The external characteristics can favorably be looked at to get a first glance on if a SECO is worth investing development time in. Among the most important external characteristics are recent developments in the field, recent fluctuations in customer base or in the developer base or if the keystone players are changing. Another thing that needs to be taken into consideration is the health of the SECO. A SECOs´ health is derived from a number of different factors like productivity, niche creation and its robustness [10]. Productivity refers to how much business is created, the value being added and how many new actors that are joining the SECO. Robustness refers to the notion of stability i.e., the way that the SECO can handle crises like large keystone players demising or new innovations challenge the SECOs market. The notions presented in this section have given some insights into the field of SECOs. The next section provides an overview of a number of commonly used systems in the field of E-learning and makes also an attempt to identify if some basic concepts from the field of SECOs can be applicable to E-learning systems in order to increase their quality.

4. CURRENT STANDARDS AND PRACTICES IN E-LEARNING

One way of fostering a SECO is to adhere to common standards used by a community of developers [3]. This section presents frequently used standards used in E-learning and a selection of common systems they are utilized in.

4.1 Learning Objects

A concept that has been around for a number of years in the E-learning community is the notion of Learning Objects (LO). The idea with learning objects is promote content granularity in order to avoid large blocks of content. These smaller blocks could then be independently put together and combined with the help of their metadata in order to create customized learning experiences. Initial efforts in this field can be found as early as 1990 with a database with reusable educational resources and courseware [16]. Recent developments in LO include solutions from the semantic web in order to aggregate the content in a more efficient way. This approach also may help to solve problems associated with the movement of objects, updating resources and to some extent the “one-size-fits-all” problem. This can be seen in projects like the Pinetree [19]. A few LMSs (Learning Management Systems) allow importing LOs by packaging them in a subset of the SCORM[2] (Sharable Content Object Reference Model) standard or utilizing the IMS-CC (common cartridge) standard. Critics towards learning objects have been addressed which simply states that the term learning object might be considered harmful since it implies something that simply isn’t true. That is, an object with its associated metadata can in no way guarantee that a cognitive learning process is automatically initiated by the receiver of the object. Something more elaborate was needed and IMS-LD and SCORM are both overlapping standards with different focuses. The next section will elaborate on the former.

4.2 Learning Design

Something more elaborate elaborated approach was required in order to ensure that cognitive learning processes can be supported. One of the notions that aim to remedy this process is learning design and I will elaborate upon this concept in this section. Learning design is a very broad area and can be defined as suggested by [7] as “*a range of activities associated with better describing, understanding, supporting and guiding pedagogic design practices and processes*”. This definition implies that learning is a complex process and designing it, is just as complex. Learning design also aims to support educators in creating new forms of teaching and learning that new technology can generate. The term learning design can refer to either the process of making learning activities or the actual artifacts produced by the process.

The capitalized version usually refers to a more technical approach that is taken in the IMS LD specification [7]. The technical side of this is the IMS LD, which is split up into three levels, A, B and C. A is the least complicated but implementing C means that the developer has implemented A and B as well [11]. There are currently many initiatives in the field of learning design where projects like RELOAD [15], Cloudworks & CompendiumLD [8], LAMS [9] and others. All these efforts provide both technical and soft tools for modeling, utilizing and running learning designs. The IMS LD standard is linked to several other standards like IMS-CP (Content Packaging). The IMS LD is often compared to SCORM, which is another standard for modeling learning. Researchers sometimes confuse these standards, but they have proven to be able to complement each other [20]. SCORM is a set of standards that was developed by the ADL (Advanced Distributed Learning) for the Department of Defense. The SCORM standard consists of different parts and these are the Content Aggregation Model (CAM), the Run-Time Environment (RTE) and the Sequencing and Navigation (SN). This set of standards enables SCORM to control content, packaging and the communication between any running Sharable Content and the hosting Learning Management System. This section aimed at partially answering to the first leading question presented in section two. It also tried to elaborate on the standards that are currently used in this area of research. The next section will depict how these standards are incorporated into the design and deployment of E-learning systems.

4.3 Commonly used E-learning systems

The first area to be analyzed is the one known as CMS (course management systems). The three specific applications presented in this section have been chosen since they are amongst the most prominent systems in the field. Moodle has a well-developed plug-in framework for extending the functionality of the core system. This plug-in framework has excellent documentation and guidelines. It also sports a portal for sharing these plug-ins, which consists of a list with links to the plug-ins. There have been efforts to make Moodle compatible with IMS-LD [6] and this work was planned to be included in Moodle 2.0 but due to the nature of open source projects, the effort has been put on ice due to lack of interest from developers[1]. It does however incorporate the IMS-CC standard for both importing and exporting learning content. Another open source project is Sakai, a Java based CMS. Sakai also sports a plug-in framework that enables developers to build their own applications on top of the Sakai framework. The Sakai development team is the only one who has not implemented support for IMS-CC yet and they claim the standards needs to be further matured before an implementation can be considered[2]. It does however have several players and creators for SCORM content. The engine in Sakai shows promise in being compatible with IMS-LD, but there seems to be a lack of interest in developing this[3]. Blackboard is the last of the three choices discussed in this paper and differs from the two others by being proprietary software, and quite a successful one in the educational market. Blackboard provides a plug-in framework called building blocks and a portal for sharing the artifacts created. The portal suffers from the same problems as Moodle does and it could be improved in many ways. All of these have support for IMS-LD level A via the LAMS plug-in. Most also have mobile support via either web pages or an iPhone application in Blackboards´ case.

The next level of analysis are the so called *learning activity systems*, which will be briefly summarized in the lines below. There are quite a few notable initiatives in this area but they are naturally more diverse than the ones in the area of CMSs. This is partly due to the fact that the term is much wider. Out of the systems supporting IMS-LD the most complete are Telos [18] and CopperCore[4]. Both support IMS-LD of all levels but CopperCore is due to its modular architecture more widely used in many projects as an engine. LAMS (Learning Activity Management System) is another effort in the same direction but with a more elaborate support for learning flows and collaboration with blogs, forums and chats. However, LAMS only supports level A. Tools for modeling IMS-LD include RELOAD and Telos. Telos, however, models its own language and exports it into IMS-LD on request. RELOAD also have editors for other standards like SCORM, IMS-CP and IEEE LOM (Learning Object Metadata). Another relevant effort is Cloudworks [8], which is a social network that deals with the problems of learning design and lets everybody share their designs and comment on others amongst other things. CompendiumLD is a tool developed in conjunction with Cloudworks and is meant to help teachers model their learning designs.

One question that needs still to be answered is what standards and practices are currently in use in E-learning. After this brief overview, a clear trend points out towards the establishment of IMC-CC and SCORM as carriers of content and all the CMSs support this together with other systems. Another trend that is quite clear is that the interest for IMD-LD seems to have declined. Activity systems thrive however and with recent development like Telos, IMS integration is full-fledged in a few systems. In the next section, I will depict the approaches taken by these systems to SECOs and reusability.

5. A SECO PERSPECTIVE ON E-LEARNING SYSTEMS

From the initial findings presented in this paper, a few prominent standards have emerged. These are the IMS-LD and SCORM, with IEEE LOM and other IMS standards showing future promise. These standards form a basis for an at least rudimentary reusability approach amongst the course management systems presented in the former section. All of the mentioned above systems have the ability to at least import and export basic learning objects and learning designs in the form of IMS-LD level A. Since IMS-LD level A is not very expressive and only supports the core elements of the standard, the interoperability is very crude. The issue might to some extent be moot however, since most of the systems offer conversion tools between the systems. As seen in Table 1 below, the IMS-LD support in the largest course management systems today is simply not implemented. In the case of Moodle and Sakai, the developers´ interest is not there and Blackboard has given no explanation. Support for IMS-CC is widespread which makes it a viable option for learning objects.

[1] http://moodle.org/mod/forum/discuss.php?d=128149&parent=561853 (last visited July 2009)

[2] http://confluence.sakaiproject.org/display/KERNDOC/IMS+CC (last visited July 2009)

[3] http://confluence.sakaiproject.org/display/PED/LD+in+Sakai (last visited July 2009)

[4] http://coppercore.sourceforge.net/ (last visited July 2009)

Table 1: Course Management Systems

FEATURE / CMS	Moodle	Sakai	Blackboard
Native IMS-LD level A export	planned	-	-
IMS-CC support	X	planned	X
LAMS support	X	X	X
SCORM support / player	X	X	X
Plug-in support	X	X	X
Developer support site	X	X	X

All of the systems also have support for LAMS via plug-in architectures and SCORM support. All of the projects also have developer communities where developers can share ideas and plug-ins via forums or similar means. These communities seem to be utilized but all of them could be greatly improved to further augment the usefulness for the developers. The interoperability between the surveyed systems seems to be limited to custom converters for each platform and IMC-CC or SCORM. Support for centralized plug-in and learning object repositories is also a popular notion. When considering the surveyed CMSs from a SECO perspective, it seems to be doing ok for the most part. The open source CMSs are easier to get survey and at a first glance they seem to be healthier than Blackboard. This might only be an illusion however due to the fact that Blackboard is a commercial company.

Compatibility between the LD systems is an entirely different story. The systems presented in this study are all compatible to some extent with IMS-LD but there are plenty of systems developed for "E-learning activities" out there in a plethora of projects that have no compatibility between each other. Relatively, successful projects like LAMS are only supporting IMS-LD level A and there seem to be difficulties to implement support for the higher tiers in systems like this. This field is not as mature as CMS and it is therefore harder to measure its performance. The ecosystems could be seen as centered on IMS-LD or SCORM but that is a bit misleading since they are not really competing standards [20]. The lack of central keystone organizations in this field is also a problem. The systems presented here tend to be motivated by academic goals and might lack monetization and commercial strategies. This is a good thing for innovation but it also makes it harder to get traction amongst developers since there usually is less monetary gain in these kinds of systems. This seems to limit the motivation to the personal interest of developers, academic achievements or teachers that extends the systems they are using in their projects.

When considering the measuring points presented in the third section for SECOs, the health of these SECOs is varying greatly. Some of these problems are associated with the typical bootstrap problem and are perhaps solved by more developers. Some significant problems in the orchestration, stability and entry barriers associated with the field of E-learning are still prominent. Based on the initial results presented in this paper, CMSs seem to be in a better position than the activity and learning design systems. To answer the third question presented in section two, it could be claimed that there are a few different approaches when handling the SECO and reusability aspects in these systems. The CMSs have a lot in common. All of them have rudimentary plug-in portals and at least plans for different kinds of repositories for learning content. There are also significant differences like how Moodle, LAMS and Sakai have a more open attitude towards developers. Finally, this section has offered some insight into the different e-learning platforms available and their approaches to reusability and SECO in general. The next section will discuss and conclude the findings from these previous sections.

6. DISCUSSION

Learning is a customized experience and this is one of the things that make systems for supporting it so challenging to construct. This customization issue is something that SECOs should be considered as a viable approach to solve these challenges. The bigger CMSs have already a healthy traction amongst developers but it would be a mistake to be contempt with that since very little research have been conducted in this area. Standardization is another issue and some authors [5] have come to the conclusion that there currently is no good way of authoring native IMS-LD objects due to the complexity of the C level of IMS. The Telos project is showing some significant progress here but will need further testing to validate its approach [18]. The project also acknowledges the difficulties in visualizing the higher tiers of IMS and completely sidesteps this by using their own data structures internally and converting the projects into IMS-LD at the time of export.

Table 2: Proposed adaptation for E-learning

End-user programming	Telos, RELOAD	None so far	None..
Application	CopperCore	Moodle, Sakai, Blackboard, lams	None..
Operating System	None so far	None so far	None..
	Desktop	**Web**	**Mobile**

Table 2 above shows a proposed initial adaptation of the taxonomy table proposed by [4]. All of the SECOs there can be improved upon however and some of them are in greater need of attention than others. This taxonomy is only a hint that may help to guide future research needs in this area, as to the best of this author's knowledge, very little formal research has been conducted here. The fact that teachers and student exists within the ecosystems makes the situation a bit different from regular ecosystems and SECOs, mainly due to the roles these actors impose. It would also be desirable to further research how reusability and development issues are handled in regular schools and further explore how to support and improve those. This paper has given an overview regarding the state of E-learning systems today but the field of mobile learning has somewhat been put aside, not ignored however. The issue with mobile aspect of today's E-learning today is that the SECOs are nonexistent. There are mobile clients for the larger E-learning systems however. This can partly be attributed to the fact that the field of mobile learning is still emerging. Another issue that effects the development of projects in this field is the fact that few mobile educational games or activities seldom adhere to standards or thinks about reusability aspects. The efforts in the Cloudworks project also suggest that something similar could be achieved for plug-ins for the different CMS and activity systems in development. Plug-ins that enable certain functionality could be attached to LDs and if a certain functionality is missing for a platform this would be a great way to identify the need to develop one. The outcomes of this paper also suggest that most systems explored in this study could largely benefit from the social and collaborative notions introduced with Web 2.0 applications. The last section will summarize the outcome of this paper and outline the future efforts that the findings suggest.

7. CONCLUSIONS AND FUTURE WORK

The initial findings presented in this paper indicate that a number of E-learning systems are starting to adopt some concepts related to SECOs when it comes to the on-going development of new software functionality and tools. However, those aspects related to the implementation of Learning Design /Activity Systems are still at early stages of development. Having these facts in mind, it could be said that further efforts exploring the formalization of Software Ecosystems concepts and applications in the field E-learning are needed. Up to date, little research has been conducted in the intersection of these two fields. Current efforts that combine some of the ideas from Software ecosystems in the field of E-learning show great promise. Cloudworks, Moodle and others are a few examples of such efforts. An additional line of future research efforts points out to carrying out more empirical research in order to find out how the ideas of software ecosystems (both content and software) are handled in regular schools where only limited technical support and knowledge is available. How is digital content reused, if at all? How can we encourage teachers to develop and to get involved in these developments? Cloudworks has shown that bringing some ideas from Web 2.0 applications into a specific content ecosystem can with some effort become successful. The emerging field of Software Ecosystems research and its application to E-learning systems could provide valuable answers to some of the questions above. In my coming research efforts, I will continue to explore how some of the ideas and concepts discussed in this paper can bring further value to the design and implementation of E-learning systems.

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