Potential deployment of Java web-based learning objects from the public domain into mobile learning environments

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Abstract
Due to the large number of learning objects (LOs) freely available in the public web-based domain, and the desire of many learners to access such learning materials or LOs on their mobile phones/devices, there is a strong motivation to be able to convert web-based LOs into mobile LOs for reuse on different mobile technologies. We are very interested in the teaching and learning of computing and, more specifically, the Java programming language. Therefore, we conducted an online investigation where we searched and collected information relating to those university computing departments in the English-speaking world offering computing LOs for educational purposes, in order to gather all Java LOs written in the English-language from the public domain. A large number and diverse set of Java LOs was revealed which can be reused for effective educational purposes in web-based environments. Additionally, we examined how web-based LOs can be deployed on different mobile technologies for effective mobile learning.

Keywords: *Java, learning objects, mobile learning objects, reusability*

Introduction

Learning Objects (LOs) have been defined as "*any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning*" [1]. Advantages of LOs were noted by Kay [2] which include the following "*LOs are readily accessible over the Internet … because of their limited size and focus, LOs are relatively easy to learn and use … reusability permits LOs to be useful for a large audience … many LOs are interactive tools that support exploration, investigation, constructing solutions, and manipulating parameters instead of memorizing and retaining a series of facts… A number of LOs have a graphical component that helps make abstract concepts more concrete … [some] LOs allow students to explore higher level concepts by reducing cognitive load. They act as perceptual and cognitive supports, permitting students to examine more complex and interesting relationships*."

The Java programming language is a popular object-oriented programming language taught at university level throughout the world. In the past decade, a large number of LOs have been created and placed online by practitioners for the purpose of reuse by others, in order to save time and effort, and in order to reduce the production of the same or similar learning materials. LOs have been deployed primarily in web-based learning environments by both instructors for teaching and students for learning. Such LOs can be modified and adapted for individual use. Increasingly, consideration has been given to LOs as to whether they can be fully utilized on handheld devices for effective mobile learning (m-learning) i.e. learning using mobile technologies. A number of studies have demonstrated that it is possible for desktop-based LOs to be converted into ones that are suitable for effective learning on mobile devices i.e. mobile LOs (e.g. in [3], [4], [5], [6], [7], [8], [9]).

LOs have been more widely used in web-based learning environments than in m-learning environments, due to the nature of these learning materials already being in the form of reusable web-based LOs and the ease of implementing them. Additionally, web-based learning applications have existed longer than m-learning applications, and the development of LOs for e-learning is simpler than for m-learning given the technological constraints of mobile de-

vices such as screen size, input, memory and power constraints [3], [6]. As part of a web-based learning environment, Adamchik & Gunawardena [10] have designed web-based LOs in the form of core material, programming code examples, supplementary notes, and review questions/assessments as well as an *Adaptive Book* which is a system for putting together LOs (such as add and edit LOs) as a course for different students, and the system is able to customize the course for each learner. Similarly, web-based programming LOs at undergraduate level have been developed by Brennan [11], and Dumbraveanu and Balmus [12] have created a science module consisting of web-based LOs for teaching Wave Optics.

Bradley *et al*. [5] developed firstly multimedia LOs for desktop computers and for the PDA. Then they focused their development of LOs for mobile phones because they believed that "*short, bite-sized resources are most effective*" for students 'learning on the move', and since the majority of students nowadays have a mobile phone and they carry them with them most of the time. They noted that "*such [LOs on their mobile phones] can easily be used by the student whenever they have the desire or opportunity to engage in some learning, wherever they are, taking advantage of this "always there, always on" technology*" [6]. The authors had designed, developed and evaluated a series of 4 prototypes in light of student use and feedback. The learning content was study skills such as how to reference a book, a journal and a website and is in the form of tutorials, and multiple choice questions with feedback and tips. The subjects of evaluation by student participants comprised usability testing including navigation though the LOs, and some personal preferences such as how useful participants had found being able to access learning materials via their phones and how much they enjoyed using their mobile phones for learning.

There are a number of open unanswered research questions relating to this study in which we are interested. For example, *is it better in terms of the learners' learning effectiveness if mobile LOs were designed from scratch taking into consideration mobile technological constraints?* And *would the conversion from web-based LOs into mobile LOs compromise the pedagogical integrity of the original LOs?* These questions cannot be answered without having designed and evaluated a large number of mobile LOs from scratch and conducted time-intensive longitudinal studies to compare the learning effectiveness of learners who utilized mobile LOs designed from scratch and those who used mobile LOs which had been converted from web-based LOs. Additionally, we wanted to assemble the Java LOs which are currently in the public domain utilized by practitioners around the world into initially a list, then a website where those LOs are aggregated for others to utilize.

In this paper, the first research question our study addresses is: *Which Java LOs are available in the public domain?* Particularly, we determine whether existing Java LOs in the public domain can really be reused successfully and effectively in terms of learning pedagogy. We then discuss the second research question: *Whether and how can these LOs be deployed on different mobile technologies by m-learning environments/applications effectively?*

This paper is organized as follows. In section 2, related work on some qualitative studies of learners' feedback of their experiences and attitudes of using LOs is described. In section 3, our research methodology and study results obtained for Java LOs from the public domain in the English-speaking world are presented. In section 4, we discuss how web-based LOs can be potentially converted into effective mobile LOs and how different mobile LOs can be deployed on different mobile technologies. In section 5, we present our conclusions.

2 Related work

An exhaustive list of all programming LOs that are available in the public domain did not exist at the time of investigation and this motivated us to conduct this study to locate available ones which can be used and reused, rather than building new ones from scratch. Other survey studies have been conducted to determine whether LOs can be utilized as educational materi-

als and to evaluate the learning effectiveness of students having deployed web-based or mobile LOs for learning, as follows.

- A survey on the utilization of LOs as instructional materials in higher education (40 learning institutions in the US) was conducted by Griffith *et al*. [13] in which subsequently they presented recommendations for creating and sharing LOs in the future. Some of their findings included LOs should be used *"dependent upon the instructor, not the environment; whether learning online or in the face-to-face environment; [LOs] can be a part of the teaching/learning experience*." At the time of the study, they found that the disciplines using LOs are in the natural and physical sciences, computer sciences, and medical sciences including nursing. A minority set of institutions reported not using Los and stated their reasons being that LOs could not be "*shared across disciplines due to [the] lack of indexing, storage or network planning*".
- Limited research and studies relating to the impact of LOs in learning in comparison with traditional or other learning materials has been conducted. A study by Kay and Knaack [14] analysed the use and effect of LOs in secondary school mathematics classrooms. 11 teachers and 298 students participated in the study. Positive attitudes were received from these teachers regarding quality, engagement and the learning value of LOs. There were varying attitudes from these students towards the usage of LOs, however, their learning performance generally increased. The authors concluded that with the appropriate goals and strategies, LOs are viable teaching tools. Similarly, a study concerning the usefulness of a multimedia learning materials repository was conducted by Namuth *et al*. [15] who found that educational, animated LOs could be "*effective and sustainable means of meeting a wide array of educator needs*".
- A questionnaire survey of 143 responses was conducted by Edmonds and Barron [16] which included the participants' usage of learning technologies in their institutions. These included *mobile/wireless technologies, streaming-video platforms, satellite-based virtual classrooms/synchronous eLearning platforms, LO/e-learning content authoring tools, learning content management systems/ learning management systems, vendor-hosted eLearning platforms,* and *off-the-shelf e-learning content*. The majority of their responses perceived LOs for the purposes of 1) quick modification of content, 2) being simplified authoring tools, 3) having the ability to match content to learner needs, and 4) having the ability to manage content in modular format to be highly beneficial. Six early adopters of LOs were presented including Autodesk (computer-aided-design software maker), Washington National Guard, Shell Exploration, UK Improvement and Development Agency, Rabobank (cooperative bank offering commercial services), and Cisco Systems.

3 Online Investigation

In this section, our research methodology is described in 3.1. The study results are presented in 3.2 – with the computing departments containing computing LOs and the availability of Java LOs in 3.2.1 and 3.2.2 respectively.

3.1 Research Methodology

Our aim was to gather an exhaustive list of Java LOs in the English language from around the world. Our research methodology included a web search of the following to determine all potential LOs developed by institutions in the English-speaking world. This study was conducted from February to May 2009.

1. A list of institutions in the English-speaking world was created. These countries include UK, USA, Canada, Australia, New Zealand, Hong Kong, Singapore, India, Sri Lanka, South Africa, and some countries in the Middle East such as UAE. The institu-

tions include all universities, polytechnic institutions and any other which offer higher degrees including diplomas, bachelors and master degrees. Our aim was to investigate potential LOs that may be used as part of these degrees in these institutions.

2. We searched through the institutions' websites to determine whether they had a computing (or related such as software engineering, business computing, mathematical computing, information technology, digital multimedia, web-scripting and so on) course. A total 1567 institutions were found to contain a computing department and the names of the departments were noted in which these computing courses were offered. The different names of computing departments include Dept/College/School of Technology, Engineering, Science and Technology, Maths and Computer Science, Information Technology, Information Systems, Informatics, Computing, Computer Science, Computational Sciences, Business Studies and so on. 2633 institutions were filtered out because they did not contain any computing courses, and 17 Canadian institutions which provided instruction in French were also omitted.
3. Each of the 1567 institutions' internal search engines were searched using the term "learning object". Note that the Google search engine was used, where institutions did not have an internal search engine. In such cases, the terms "<name of institution>" and "learning object" were used for searching. A total of 895 institutions returned relevant hits, while 672 produced no relevant hits with the term "learning objects", respectively. Next, those 895 institutions were searched through again with relevant hits using the term "learning object". Only 7 of these institutions had a LO repository or had developed more than one LO for instructional purposes.

Note that there are also other institutions which contain computing departments. However, these are not included in this list because of the following reason(s) – 1) a login is required to view their LOs, 2) their LOs are copyrighted, 3) there are no metadata attached to the LOs or 4) their LOs do not actually contain learning materials.

3.2 STUDY RESULTS

In 3.2.1, a list of the departments containing computing LOs is presented. In 3.2.2, a list of the availability of Java LOs is presented.

3.2.1 Departments containing computing LOs

The institutions which contain LO or LO repositories which contain computing-related LOs are as follows:

1. Dept of Computer Science, Rice University, USA - cnx.org/
2. Dept of Computer Science, Furman University, USA - cs.furman.edu/~kabernet/cte/
3. Dept of Computer Science, University of Manitoba, Canada - https://mspace.lib.umanitoba.ca/
4. JORUM ("a JISC-funded service in development in UK Further and Higher Education, to collect and share learning and teaching materials") - www.jorum.ac.uk/
5. Faculty of Computing, London Metropolitan University, UK www.londonmet.ac.uk/ltri/learningobjects/objects/
6. Dept of Computer Science and Engineering, Hong Kong University of Science and Technology, Hong Kong - www.cse.ust.hk/learning_objects/
7. University of Applied Sciences, Tampere Polytechnic developed a LOR that contains programming LOs named Codewitz – for better programming skills - www.codewitz.net/

3.2.2 Availability of Java LOs

We further investigated the above list of institutions containing computing-related LOs. A variety of LOs in different computing or programming topics were found relating to the Java

programming language and other object-oriented programming languages such as C++ and VC++, and additionally graphical programming languages such as LabVIEW. Other topics found included software engineering, programming methodologies, simulation software tutorials, integrated development environments, software testing, open source software and web-scripting languages such as JavaScript, HTML. The topics of LOs are listed below under each of the institutions (as presented above) and the number in brackets indicates the number of LOs available on that particular webpage relevant to that topic.

1. Dept of Computer Science, Rice University, USA –
    a. LOs for inheritance in Java - cnx.org/content/m31249/latest/ (9)
    b. LOs for constructors in Java - cnx.org/content/m31248/latest/ (8)
    c. LOs for methods in Java - cnx.org/content/m31247/latest/ (9)
    d. LOs for arrays in Java - cnx.org/content/m31245/latest/ (9)
    e. LOs for control structures in Java cnx.org/content/m31246/latest/ (9)
    f. VC++ tutorial for beginners – cnx.org/content/m14425/latest/ (1)
    g. Software engineering - cnx.org/content/m14618/latest/ (3)
    h. LabVIEW graphical programming - cnx.org/content/m14634/latest/ (4)
    i. C++ programming fundamentals - cnx.org/content/m22453/latest/ (8)
    j. Simulation software tutorial - cnx.org/content/m14269/latest/ (1)
    k. Object-oriented programming - cnx.org/content/m22188/latest/ (1)
    l. Integrated development environment - cnx.org/content/m18920/latest/ (1)
    m. Software testing - cnx.org/content/m28939/latest/ (1)
    n. Open source software - cnx.org/content/m12403/latest/ (1)
2. Dept of Computer Science, Furman University, USA –
    a. Javascript - cs.furman.edu/~kabernet/cte/javascript/index.htm (4)
    b. HTML - cs.furman.edu/~kabernet/cte/web_authoring/html_intro/html_intro_lesson.htm (17)
3. Dept of Computer Science, University of Manitoba, Canada
    a. What is plagiarism? - https://mspace.lib.umanitoba.ca/handle/1993/253 (1)
4. JORUM –
    a. Computer science concepts – (languages and grammar, prolog, strings and languages) - open.jorum.ac.uk/xmlui/handle/123456789/1229 (9)
    b. Java server pages, Java beans and Java servlets - open.jorum.ac.uk/xmlui/handle/123456789/1319 (10)
    c. Introduction to OOP in Java (classes and arithmetic, creating classes, generic lists, inheritance – extending classes, AWT, making decisions, menu and switch, mobile phone case study, searching software quality and testing) - open.jorum.ac.uk/xmlui/handle/123456789/1986 (86)
    d. Object-oriented software design (building GUI in Java & Design patterns, class design & testing, classes and objects, Java object serialization, inheritance and polymorphism, OO design process) - open.jorum.ac.uk/xmlui/handle/123456789/1712 (36)
    e. Rapid application development - open.jorum.ac.uk/xmlui/handle/123456789/1764 (79)
    f. Web design and objects - open.jorum.ac.uk/xmlui/handle/123456789/2325 (16)
5. Faculty of Computing, London Metropolitan University, UK - While loops, if-statements, arrays in Java, and library of classes - www.londonmet.ac.uk/ltri/learningobjects/objects/ (4)

6. Dept of Computer Science and Engineering, Hong Kong University of Science and Technology, Hong Kong - www.cse.ust.hk/learning_objects/
    a. Arrays - www.cse.ust.hk/learning_objects/array (8)
    b. Creating wikis, podcasts, and blogs -www.csus.edu/atcs/tools/learning-objects/ (3)
7. Codewitz programming learning objects including Java, C++ - www.codewitz.net/ (202)

Through the investigation of this study, we gathered 540 LOs which relate to programming languages. The complete list of LOs that are computing-related totals 1607. The number of LOs is quite low considering the large number of English-speaking institutions containing a computing department that we located. Although many educators might be aware that they should develop LOs for the reuse of other students or learners, it often requires too much effort and time to put this into practice. The development of LOs is usually voluntary and the researcher/educator does not receive financial or other benefits, and it is a time-consuming task to convert ordinary learning materials into reusable LOs free of contexts (i.e. can be used and applied in different topics of learning). For example, a LO which teaches about the drop of an apple to illustrate gravity, can be used by students learning about physics or mechanics, among other subjects. Therefore, we were not surprised about the results of this investigation.

Nevertheless, 540 was a considerable and sufficient number to generate a collection of Java LOs for a web resource in which we located the links to all of these LOs for ease of reference and reuse. More specifically, the web resource that we had developed was a PHP-enabled prototype, which stores the LOs discovered in this study including their titles, URLs and keywords in MySQL tables. It allows the user to search for LOs based on one or two keywords taken from the set of keywords occurring in the LO metadata. Data relating to the interactions of users, including their perceptions about whether the search results were as expected and whether the LOs returned were useful are recorded by the resource.

4. From web-based to mobile LOs

In this section, we discuss how web-based LOs can be converted into mobile LOs with consideration to *metadata*, and different *mobile devices* in 4.1 and 4.2 respectively. We also present *an example of deployed LOs in an m-learning application* in 4.2.

4.1 Facilitating MLOs using Mobile LO Metadata

A proposal of an extension to Learning Object Metadata (LOM) and IMS Learner Information Profile (LIP) Standards has been set out by Chan *et al*. [17] to cover mobile and informal learning scenarios, called Mobile Learning Metadata (MLM). The necessity for this proposal was to include these forms of learning in the current usage of LOM and other standards alike, as these had previously been aimed at web-based learning using desktop and/or laptop computers. MLM comprises three top level classifications – *Learning Object, Learner* and *Setting*s (describes the context state of the learning environment such as the location of the learner or learning object). The Learner classification is divided into two sub-categories – *Learner Profile* (contains static information about the learner and their preferences) and *Learner Model* (contains dynamic information relating to the learner's knowledge and learning history). Conceptually, the relevant LO is located by the recommendation engine of an m-learning system using the information provided by the Learner and Setting classifications by accessing the metadata of the LO. Information within the Setting classification is generated dynamically to describe the current values of the m-learning context information.

Nakabayashi and Hoshide [18] have extended the SCORM 2004 specification to enable offline learning materials to be viewed using mobile phones and the sharing of course structure and learner tracking information for learning activities using both personal computers and mobile phones. Due to the varying application-programming environment of mobile phones from different makes and models, they specified a common content format for the learning

content delivered to the different browsers. In order to retrieve content for use on mobile phones, one possibility is to use a built-in mobile phone browser. Another way is to "*implement learning content using an application program downloaded and run on the mobile phone*" [18]. A third possible way is to install a general-purpose content browser on the mobile phone. Similarly, Alkouz [4] proposed a generator which allows web-based LOs to be used on m-learning applications on different devices.

4.2 Facilitating MLOs to be used on different mobile devices

A case study by Gkatzidou and Pearson [19] examined how existing web-based LOs can be accessed on different mobile devices. In particular, the first part of their investigation involved an analysis of the award-winning programming web-based LOs developed by the Learning Technology Research Institute in the London Metropolitan University. The analysis focused on "*navigation, interactivity, design and content issues, to establish the limitations to accessibility and adaptability to different devices*". The web-based version of these LOs had been evaluated by over 600 first year computing students. The PDA version of these LOs has also been evaluated by a number of students and positive feedback regarding the multimedia components, interactivity and flexibility of the resources. Based on these positive results concerning the usage of LOs on PDAs, the authors adapted them for use on MP3 players specifically the iPod. 4 types of categories of adaptation for conversion of LOs between different mobile devices were considered including the following:

1) Design adaptations – screen layout, removal of navigation buttons, and reposition of progress indicator.
2) Pedagogical adaptations – removal of interactive elements and interactive quiz (for audio MP3 players only).
3) Technical adaptations – file format conversion (such as from video to audio).

A *Web Services Oriented Rendering Architecture* (WSORA) [4] is an example of an m-learning system which deploys LOs. It was designed and developed to combine the LOM editor with any web browser or services available on different mobile devices. Its aim is to generate device-independent LOs because various devices have different sizes of screens, availability of memory, and may be using different bandwidth and there are possible constraints within each of these. WSORA attempts to tackle two current challenges: a) mobile web browsers display web pages in their entirety regardless that these were not designed for small screen displays, which also burdens the limited bandwidth of devices, and b) to compensate for (a), LO producers may be required to construct specific LOs for each mobile device, for example, WML and CHTML versions of HTML. This is a time-consuming process, which is impractical and uneconomical. WSORA includes a *Device-independent LO Generator* (DLOG) and a web server (which acts as a proxy server between mobile devices and the DLOG. Via HTTP requests, the client mobile device can communicate with the WSORA server to retrieve some LOs. The server a) detects the device type via the data sent in the HTTP requests, b) checks if the requested LO format is available in their learning object repository and if so, selects to client device , and c) if not, the desired LO format is generated on-the-fly and sent to the client device.

5. Conclusions

In this paper, we have presented the results of our online investigation; the main contribution being the compiled list of Java LOs from institutions in the English-speaking world which are freely available in the public domain and are of good quality. They can be incorporated into web-based learning environments for use as well as in m-learning environments. The compiled list of Java LOs can be used by educators to develop personalized Java programming courses for individual learners in both web-based and m-learning applications/environments.

Acknowledgements

This work was funded by the UK Higher Education Academy Subject Centre for Information and Computer Sciences.

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