E-learning Materials Development: Applying and Implementing Software Reuse Principles and Granularity Levels in the Small

Nabil Arman[1]
Department of Mathematics and Computer Science
Palestine Polytechnic University
Hebron, Palestine
Email: narman@ppu.edu
[1]On a sabbatical leave at Palestine Ahliya University during 2009/2010

Abstract

E-learning materials development is typically acknowledged as an expensive, complicated, and lengthy process, often producing materials that are of low quality and difficult to adapt and maintain. It has always been a challenge to identify proper e-learning materials that can be reused at a reasonable cost and effort. In this paper, software engineering reuse principles are applied to e-learning materials development process. These principles are then applied and implemented in a prototype that is integrated with an open-source course management systems. The reuse of existing e-learning materials is beneficial in improving developers of e-learning materials productivity. E-learning material reuse is performed, in this research, based on construct's granularity rather than on unified constructs of one size.

Keywords: *Software engineering, software reuse, e-learning, granularity levels.*

1. Introduction

Developing appropriate e-learning materials is an expensive, complicated, and lengthy process. Therefore, the reuse of existing e-learning material is of great value. To reuse existing e-learning materials, one has to locate and sometimes adapt such materials. Many approaches have been suggested in the literature for reuse of existing e-learning materials, but these approaches are tailored for reuse in the large [1,2]. Some approaches advocate Advanced Distributed Learning (ADL) Sharable Content Object Reference Model (SCORM) - A suite of standards and specifications for online education that enables interoperability of learning content. SCORM implements a modular approach to online learning that aggregates discrete units of digital instruction called learning objects. Learning objects are self-contained and may be reused in multiple contexts and environments, including online courses, knowledge management systems, and performance support systems [3]. Despite SCORM's evident advantages, taking that into account proved to be expensive and beyond the capabilities of e-learning materials reuse initiatives in the small.

A three-layer e-learning course development model has been suggested in [2]. The model starts by decomposing the learning content into small chunks placed in a hierarchic structure of units, blocks, sub-blocks, …etc. Based on these small chunks learning objects (LO) are obtained. These LO are candidates for reuse.

In this paper, a new approach is presented for reuse of e-learning materials in the small. The new approach splits the e-learning material into smaller units that can be placed in a hierarchy consisting of large units at the top of the hierarchy and smaller units are placed at lower levels of the hierarchy allowing reuse of units at different granularity levels. These units can be re-used easily in a more productive manner. The new approach is implemented as a prototype that is integrated easily in an open-source course management system MOODLE as explained later.

2. Software reuse: benefits, problems and principles

Although software reuse has many evident benefits, it has also many problems. These benefits and problems can be summarized as follows [4,5]:

a. Increased dependability
b. Reduced process risk
c. Effective use of specialists
d. Standards compliance
e. Accelerated development
f. Improvements in productivity
g. Improvements in quality

The problems of software reuse can be summarized as follows [4]:

a. Increased maintenance costs
b. Lack of tool support
c. Not-invented-here syndrome
d. Creating and maintaining a component library
e. Finding, understanding and adapting reusable components

The benefits and problems of software reuse do apply for the reuse of e-learning materials. However, the effects of the problems may be minimized by concentrating on the most important aspects and attributes of e-learning units. The use of sound reuse principles can also minimize the effects of problems as explained later.

As for the software reuse principles, a set of candidate principles for software reuse is suggested in [6]:

1. Build a software domain architecture as a framework for reuse activities.
2. Use a software development process that promotes and controls reuse.
3. Reuse more than just code.
4. Practice domain engineering.
5. Integrate reuse into project management, quality management and software engineering activity.
6. Organize the enterprise to facilitate partnering to achieve reuse across product boundaries.
7. Use automation to support reuse.
8. Couple modern reuse theory and technology with natural, traditional organizational reuse practices.

These principles, where applicable, are adapted and utilized in the e-learning material development process that promotes reuse as explained later.

3. Reusable E-learning content/ materials

Before describing the reuse of e-learning materials for a new course, one has to determine the parts of the materials of the course that should be taken into account. These may include:

1. Syllabus: Although, parts of the syllabus can be reused like intended learning outcomes (ILOs) and the list of contents of a course, it does not represent a major construct in our suggested approach. There is not that much saving in reusing the syllabus and the time needed to prepare a syllabus is very short when compared to the time and effort needed to prepare the e-learning material itself.

2. Contents: The course contents consist of a number of chapters that are divided into modules. Modules, in turn, are divided into units. Units may also be divided into subunits, …etc. These small subunits may include text segments, exercises, questions, data, figures, keywords, project descriptions, and so on. Considering different levels of granularity, a complete chapter may be very large to be reused as a whole and a subunit may be considered too small. In addition, these components may be obtained from different sources. The components may be arranged in a whole-part UML aggregation that depicts special relationships between the components as shown in Figure 1.

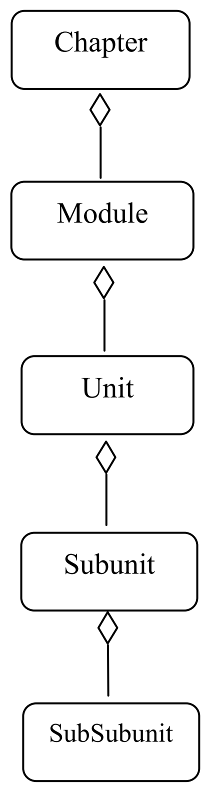


Figure 1. UML aggregation of e-learning constructs

As shown in Figure 1, an e-learning material developer should start looking at complete chapters as a reusable construct. If that is not possible, one should consider modules, then units, then subunits, …etc.

4. Reusable E-learning material development approach

A reusable construct should have a number of attributes that are essential in determining the appropriateness of this construct in the reuse process. These attributes, which are considered as metadata for the e-learning constructs, include:

ID: The identification number of the construct
Name: The name of the construct
Short Description: A short description of the construct
Learning Outcome: A brief description of the learning outcome
Language Used: The language used in the construct
Format: The format of the construct
Duration/Length: The time needed to complete the construct
Level: The intended level of the construct
URL: Uniform resource locator of the construct
Whole ID: The ID of the parent of the construct

Certain constructs may be reused from different sources. Therefore, these constructs may be arranged in a way to avoid any conflicts that may result from such a situation.
Similar to software reuse, e-learning materials reuse consists of processes such as: identifying reusable constructs, describing the constructs, retrieving reusable constructs, adapting retrieved constructs to specific needs, and integrating constructs into the e-learning material being developed [6]. In software reuse, these processes are complicated, made more complicated by large number of reusable components with which a software engineer must deal with. This doesn't apply in our case since we are dealing with e-learning material reuse in the small. This means that we are dealing with e-learning material reuse in a small organization like a university or a consortium of universities and academic institutions.

Based on the circumstances and the degree of similarity, based on the constructs between the e-learning material being developed and the existing e-learning material, a complete chapter may be reused as a whole and in other circumstances a subunit may be reused, based on the meta data associated with the e-learning constructs.

In developing a new e-learning course and after taking the syllabus of the course into account, one should start by considering the possibility of reusing a whole chapter. If that is not possible, consider reusing a module, then consider reusing a unit, and so and so forth. The larger the reused component the better the situation is.

In our approach, the principles of software reuse are taken into account. In the e-learning material development process, reuse is promoted by associating meta-data for all components (chapters, modules, units, subunits, …etc.). Another principle is domain engineering, which is defined as the entire process of reusing domain knowledge in the production of new software systems, is practiced in the development of reusable e-learning material. This is very beneficial since domain engineering is a key concept in systematic software reuse. A key idea in systematic software reuse is the application domain, a software area that contains systems sharing commonalities [8]. Taking domain engineering into account, one should consider reusing e-learning materials from the same domain, in terms of the subjects and the organizations.

As stated in the principles of software reuse, automation that supports e-learning material development is very beneficial especially in the process of listing the set of candidate e-learning constructs to be reused.

In addition, integrating reuse into quality management activity is very important, since reusable e-learning material is likely to be of high quality.

Using the meta-data for the e-learning constructs, one can manually identify the suitable e-learning constructs for reuse. As mentioned before, one should always strive to reuse larger constructs. Instead of performing adaptations for the larger constructs, one can proceed to smaller constructs.

5. Reusable E-learning material reuse implementation

Identifying the appropriate e-learning constructs manually is a lengthy, complicated, and error-prone process [9]. Therefore, in this research effort the automation of the process of e-learning material reuse is presented. Instead of searching for candidate reusable constructs manually, one can use an automated process (an algorithm) to identify the most appropriate reusable e-learning construct based on its meta data. In addition, a new approach for obtaining the input for such a tool from the e-learning platform is used. Getting such input from an open-source tool like MOODLE is easier since its backend database schema is easily accessible.

To benefit from our suggested approach for e-learning material development to promote reuse, as a major issue in e-learning material development, there is a need to keep information related to the courses and their components (on all levels of granularity) in the e-learning platform database. As mentioned before, most local universities are using MOODLE, which is an open-source platform. To achieve that, there are two approaches to be used:

1. Modifying the MOODLE database schema: This makes it extremely difficult for upgrading to newer versions/releases of MOODLE since the data can't be loaded easily into the database of the new version
2. Using external tables and views: This integrates easily with MOODLE backend database. One may add any external tables of almost any kind to handle what is needed.

An external table or a view should include one or more fields that corresponds to the primary keys of the main MOODLE tables so that views can be updatable. Since, the focus is on the courses, the primary key of this table should be included in the external table/view. Based on the meta data described in section 4, our external table/view named REUSE table has the schema:

Field Name	Data Type	Null?
ID	Number	No
Name	Varchar	No
ShortDesc	Varchar	No
LO	Varchar	Yes
LangUsed	Varchar	No
Format	Varchar	No
Duration	Number	Yes
Level	Varchar	Yes

URL	Varchar	No
WholeID	Number	Yes
mdlCourseID	Number	No

The names of the fields are self explanatory, except for two fields:

1. mdlCourseID: This field represents the primary key of the courses table of the MOODLE database schema, which is called mdlCourse. The field is used to link the REUSE table to this main table.
2. WholeID: This field represents the foreign key that references the field ID of the same table. Thus, REUSE table is a self- referencing table resulting from a recursive relationship type (association) as shown in the UML conceptual schema of Figure 2. Therefore, the largest level of granularity of a certain construct (e.g., a chapter) is the construct whose WholeID is null. Lower levels of granularity constructs have WholeIDs referencing higher levels of granularity constructs.

The mapping of this UML conceptual schema into the REUSE and MDLCOURSE tables is used.

The mdl_course table has a large number of fields (around 32 fields) of which only a few are used, the rest of them are for future use [10]. For our research, this table is treated as a read-only table which is used to retrieve the course enrolled by the student and for the information pertaining to a course. The main field used is the id which is an auto increment field and is used as the primary key for the mdlcourse table. It is of type unsigned int and ranges between 0 and 10.

Fullname is the name of the course which is of type varchar, the maximum size of it is 254 characters and cannot be null. The shortname is the call number of the course of type varchar, the maximum size of it is 15 characters and cannot be null. The summary is the description of the course which is of type text and this field can hold data up to 4 GB and cannot be null [10].

It is suggested that educators, who are adding new courses to the MOODLE course management system, complete a REUSE form containing the fields of the REUSE table as shown in Figure 3. The form can be completed at the level of courses, modules, units, subunits, …etc. The smaller the granularity levels provided, the greater the reuse will be.

In addition, educators who are developing new courses are advised to use a SEARCH form to identify potential reusable constructs as shown in Figure 4. The search is based on the keywords, which are compared with the short description and the learning outcomes. To narrow down the search, one may specify additional criteria, including the level of students, the language used, the format of the material, …etc.

These forms can be integrated with MOODLE systems easily. Similar to software engineering reuse, good documentation is very important. For example, an educator, who doesn't specify the learning outcomes of his course precisely, prevents other educators form reusing materials of this course. Therefore, this is a collaborative effort of all educators.

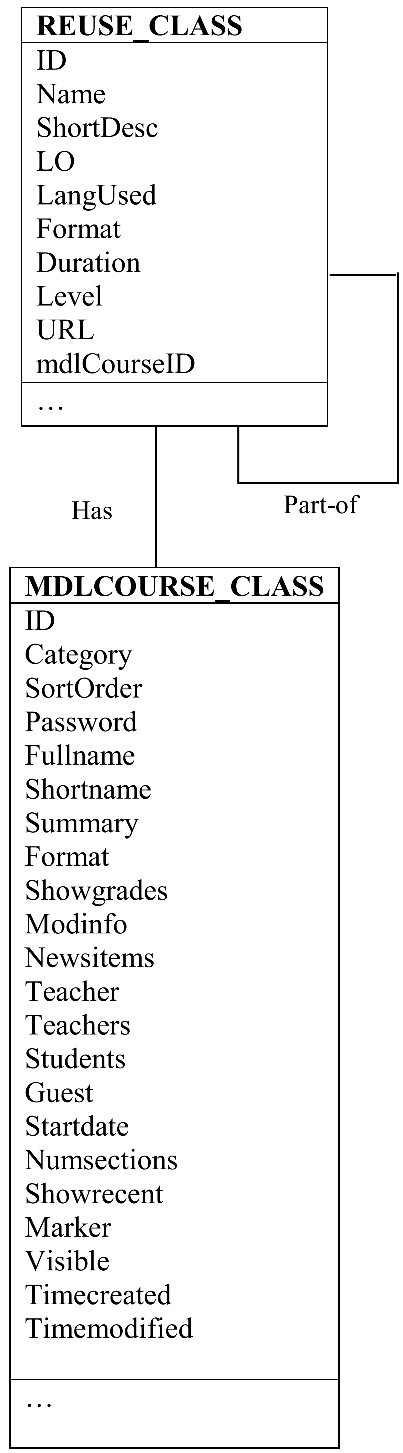


Figure 2. UML Conceptual Schema for REUSE_CLASS and MDLCOURSE_CLASS

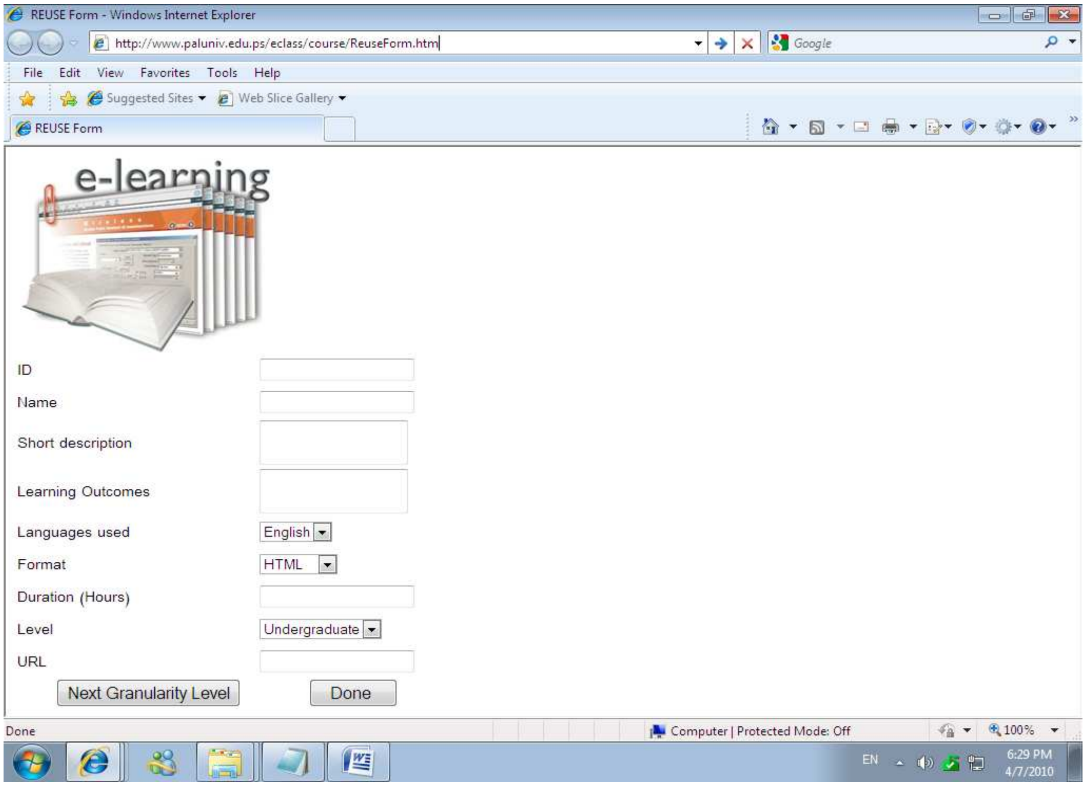


Figure 3. REUSE Form

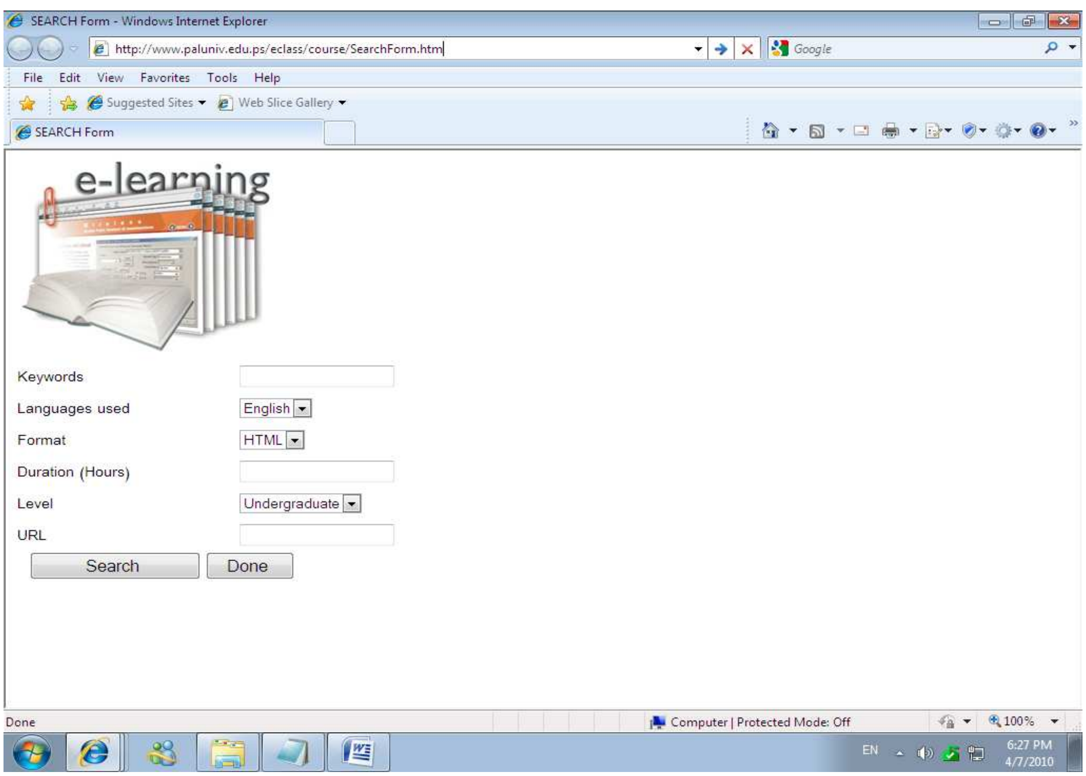


Figure 4. SEARCH Form

6. Case Study

A database systems course can be found in many information technology related programs like computer science, computer systems engineering, information technology and information systems. A typical set of topics to be covered in a computer science database systems course includes:

Chapter 1: Database Concepts and Architecture	1.1 Introduction 1.2 An Example 1.3 Characteristics of the Database Approach 1.4 Advantages of the Database Approach 1.5 Data Models, Schemas, and Instances 1.6 DBMS Architecture and data independence 1.7 Database Languages
Chapter 2: Data Modeling Using the Entity-Relationship Model	2.1 Conceptual Data Models 2.2 An Example Database Application 2.3 Entity Types, Attributes, Keys 2.4 Relationship Types and Constraints 2.5 Weak Entity Types 2.6 Data Modeling CASE/Diagramming Tools
Chapter 3: Normalization for Relational Databases	3.1 Informal Design Guidelines for Relation Schemas 3.2 Functional Dependencies 3.3 Normal Forms Definition 3.3.1 First Normal Form 3.3.2 Second Normal Form 3.3.3 Third Normal Form 3.3.4 Boyce-Code Normal Form 3.3.5 Fourth Normal Form 3.3.6 Fifth Normal Form 3.3.7 Domain Key Normal Form

A typical set of topics to be covered in an information systems database systems course includes:

Chapter 1: Database Concepts and Architecture	1.1 Introduction 1.2 An Example 1.3 Characteristics of the Database Approach 1.4 Advantages of the Database Approach 1.5 Data Models, Schemas, and Instances 1.6 DBMS Architecture and data independence 1.7 Database Languages
Chapter 2: Data Modeling Using the Entity-Relationship Model	2.1 Conceptual Data Models 2.2 An Example Database Application 2.3 Entity Types, Attributes, Keys 2.4 Relationship Types and Constraints 2.5 Weak Entity Types
Chapter 3: Normalization for Relational Databases	3.1 Informal Design Guidelines for Relation Schemas

	3.2 Functional Dependencies 3.3 Normal Forms Definition 3.3.1 First Normal Form 3.3.2 Second Normal Form 3.3.3 Third Normal Form 3.3.4 Boyce-Code Normal Form

If the computer science database systems course was prepared as a reusable e-learning material with meta-data associated to chapters, modules, units, and subunits as suggested in our approach, then preparing the e-learning material of the information systems database systems course can be accomplished as follows:

1. Chapter 1 from the computer science database systems course can be reused as a whole. The granularity of reuse here is a complete chapter.
2. Modules 2.1, 2.2, 2.3,2.4, and 2.5 from the computer science database systems course can be reused. However, module 2.6 is not reused. The granularity of reuse here is a module.
3. Modules 3.1 and 3.2 are reused. From module 3, units 3.3.1, 3.3.2, 3.3.3, and 3.3.4 are reused. The granularity of reuse here is a module and a unit.

Thus, instead of decomposing the e-learning material into learning object of small granularity, it is suggested in this research to decompose the e-learning material into learning constructs of different granularity levels and arrange these constructs in a UML-like aggregation to facilitate the reuse process and to improve e-learning materials developers' productivity. As mentioned in the principles of software reuse, this should be promoted in the e-learning development process itself.

The implementation of this case study is accomplished as follows:

1. When the educator completes the entry of a course, he will be prompted to complete the REUSE form.
2. If the educator chooses to complete the REUSE form, he will be presented with the form to fill in all fields. The completed form information will be stored as a tuple in the external table named REUSE table as part of the MOODLE backend database.
3. The first time completion of the REUSE form represents the information for the highest level of granularity construct (i.e., a chapter in our case). If the educator chooses to complete next level of granularity form, it will be for the next level of granularity construct (i.e., a module in our case) and so on and so forth.

To benefit from the information stored in the external table REUSE, an educator should search for potential reusable constructs by using the SEARCH form.

The search will be conducted based on the keywords provided by the educators and by checking the short description and the learning outcomes. To refine the search further, the educator can complete the rest of the fields. Completing the rest of the fields narrows down the potential reusable constructs. For example, if the language is specified, then all constructs that match the search criteria except the language will be excluded. Another approach for searching is using a subject taxonomy to narrow down the search space of potential reusable constructs. This is particularly useful when the REUSE table becomes extremely large. Based on the taxonomy, a set of major subjects are used. From these major subjects, sub-subjects are defined and so on. Before issuing a search request, educators are asked to choose the specific subject of their interest which speeds up the search process.

7. Conclusions

A new approach that utilizes principles of software reuse is applied to the development and implementation of e-learning materials is presented. The approach suggests reusing e-learning constructs of different granularity levels to improve e-learning material developers' productivity. A case study that demonstrates the benefits of this approach is presented. A prototype, that integrates easily with MOODLE course management system, to demonstrate the approach is also presented.

8. References

[1] Jancso, T., and Markus, B. "Reuse and Sharing of E-learning Materials Inside the EU," FIG Working Week 2007, Hong Kong SAR, China, 13-17 May, 2007.

[2] Schreurs, J. and Dalle, R. "Authoring Systems Delivering Reusable Learning Objects," iJET, Vol. 4, Special Issue 2, October 2009.

[3] Hersh, W. and Bhupatirajum R, "Adopting e-Learning Standards in Health Care: Competency-based Learning in the Medical Informatics Domain", AMIA Annual Symposium Proceedings, pp. 334–338, 2006.

[4] Sommerville, I. Software Engineering, 8th Edition, Addison-Wesley, 2008.

[5] Grabert, M. and Bridge, D. "Case-Based Reuse of Software Examplets," Journal of Universal Compter Science, Vol. 9, No. 7, pp. 627-640, 2003.

[6] James, M. "Fundamental Principles of Software Reuse," Eighth Annual Workshop on Institutionalizing Software Reuse (WISR), Ohio State University, Ohio, USA, March 23-26, 1997.

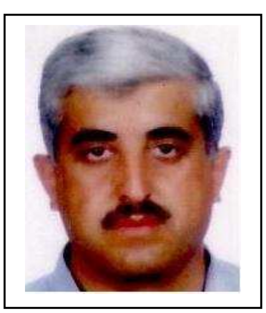
[7] Smolarova, M. and Navrat, P. "Software Reuse: Principles, Patterns, Prospects," Journal of Computing and Information Technology, Vol. 5, No. 1, pp. 33-49, 1997.

[8] Frakes, W. and Kang, K. , "Software Reuse Research: Status and Future", IEEE Transactions on Software Engineering, Vo. 31, No. 7, pp. 529-536, 2005.

[9] Arman, N. "E-learning Materials Development: Applying Software Reuse Principles and Granularity Levels in the Small", Proceedings of PICCIT 2010, Palestine Polytechnic University, 2010.

[10] Ramagiri, R. "Integrating the Moodle Course Management System into a Collaborative Virtual Environment", Master's in Computer Science Project, New Mexico State University, 2007.

Authors



Nabil Arman received his BS in computer science with high honors from Yarmouk University, Jordan in 1990, his MS in computer science from The American University of Washington DC, USA in 1997, and his PhD from the School of Information Technology and Engineering, George Mason University, Virginia, USA in 2000. Currently, he is an associate professor at Palestine Polytechnic University, Hebron, Palestine. His research interests include database and knowledge-base systems, algorithms, software engineering and e-learning.