Towards the Establishment of a Standard Process for Developing Educational Modules

Ellen Francine Barbosa
José Carlos Maldonado
University of São Paulo (ICMC/USP), Computer Science Department
São Carlos/SP, Brazil 13560-970 {francine, jcmaldon}@icmc.usp.br

Abstract – Educational modules, concise units of study capable of integrating theoretical/practical content and supporting tools, are relevant mechanisms to improve the learning process. Despite their relevance, none of the initiatives to address the problem of creating educational modules considers a systematic process for developing them. The establishment of a well-defined set of guidelines and supporting mechanisms should ease the distributed and cooperative work to create, reuse and evolve educational modules, taking also into account the impact on the learning process. In this work we present a standardized process we have established aiming at creating well-designed, highly flexible and configurable educational modules. Aspects of process specialization and instantiation have also been considered. Its application is illustrated by the development of a software testing educational module, which has been applied and preliminarily evaluated in terms of the learner’s attitude toward content, usability and navigational aspects. In general, we observed a positive attitude toward the flexibility provided by the produced educational module.

Index Terms – Educational modules, Instantiated and specialized process, Standard process, Supporting tools.

INTRODUCTION

Several initiatives on using new computing technologies have been investigated in order to facilitate the learning process in general [1]-[6]. The challenge is to provide ways to establish quality educational products, capable of motivating the students and effectively contribute to their knowledge construction process in active learning environments. Also, there is a need for a global education, capable of crossing international, cultural and social borders in order to prepare the students for the global market. Educational modules, which consist of concise units of study delivered to students by using technologies and computational resources [7], can be explored in this perspective. Besides that, educational modules themselves should be evolvable, reusable and adaptable to different learning scenarios and objectives.

Similar to software products, educational modules require the establishment of systematic development processes to produce reliable and quality products. None of the initiatives to address the problem of creating educational modules considers a systematic process for developing them. In short, the development of such modules can involve developers from different domains, working on multi-disciplinary and heterogeneous teams, geographically dispersed or not. They should cooperate, sharing data and information regarding the project. Furthermore, we should consider the adoption of supporting tools, which can be used either as part of the educational module under construction or as a mechanism to automate its development process.

In this paper we propose a Standard Process for Developing Educational Modules, based on ISO/IEC 12207, which takes into account issues of content modeling [8], practices from instructional design [9], and aspects of distributed and cooperative work [10]. Process specialization and instantiation have also been explored. The aim in the long-term is to provide a well-defined set of guidelines and supporting mechanisms to ease the cooperative work to create, adapt, reuse and evolve the underlying processes and products, taking also into account the impact on the learning process. At the very end, we intend to provide a context for “open learning materials”, which could facilitate the cooperation and use in different institutions and learning environments and effectively support new learning approaches.

We have applied and validated the feasibility of our process in the testing domain. The material produced has been applied and preliminarily evaluated in terms of the student’s attitude toward content, usability and navigational aspects. We consider the testing area since it is one of the most relevant activities regarding software development [11] but, at the same time, it is a difficult topic to learn or teach without the appropriate supporting mechanisms [12]-[14].

This paper is organized as follows. At first, we provide an overview on educational modules and summarize the relevance of the content modeling activity. Following, we present the Standard Process for Developing Educational Modules and discuss the issues of process specialization and instantiation. To illustrate these ideas we describe the development of a software testing educational module. Results from a preliminary evaluation on the effectiveness of this module are also presented. Finally, we summarize contributions and perspectives for further work.

EDUCATIONAL MODULES: AN OVERVIEW

Educational modules are concise units of study, composed by theoretical and practical content which can be delivered to learners by using technological and computational resources [7]. Figure 1 illustrates the main components of an educational module. For theoretical content, instructors use books, papers,
We summarize educational content I. IMA-CID: An Integrated Approach for Modeling preferences, learning goals and course length, among others. scenarios, according to the learner's profile, instructor's adaptable and reusable in different educational and training should be seen as independent units of study, subject to be need for adaptability and reusability – educational modules incorporated to the previously defined content. Also, there is a knowledge of testing techniques and criteria, which should be theoretical and experimental studies can result in new instance, practical activities involving the conduction of its dynamic and evolutionary aspect. In testing domain, for developing the software testing educational module. conceptual, instructional and didactic – in order to characterize the models for representing educational content. Then, we established a connection between the perspectives and requirements, which was the starting point for defining IMA-CID. The integrated modeling approach is composed by three models: (1) the conceptual model – corresponds to a high-level description of the knowledge domain, representing the main concepts and the relationships among them; (2) the instructional model – characterizes what kind of additional information (e.g., facts, principles, procedures, examples, and exercises) can be used to develop learning materials; and (3) the didactic model – characterizes the prerequisites and sequences of presentation among conceptual and instructional elements.

We have also introduced the idea of open specifications, which provide support for the definition of dynamic contexts of learning [7][15]. Depending on aspects such as audience, learning goals and course length, distinct ways for presenting and navigating through the same content can be required. An open specification allows representing all sequences of presentation in the same didactic model. So, from a single model, several versions of the same content can be generated according to different pedagogical aspects. Moreover, when an educational module is implemented based on an open specification (open implementation), its navigation paths can be defined by the user, in “execution time”, based on the learner’s understanding and feedback, for instance.

The development and application of educational modules should consider intrinsic characteristics of knowledge, such as its dynamic and evolutionary aspect. In testing domain, for instance, practical activities involving the conduction of theoretical and experimental studies can result in new knowledge of testing techniques and criteria, which should be incorporated to the previously defined content. Also, there is a need for adaptability and reusability – educational modules should be seen as independent units of study, subject to be adaptable and reusable in different educational and training scenarios, according to the learner’s profile, instructor’s preferences, learning goals and course length, among others.

I. IMA-CID: An Integrated Approach for Modeling Educational Content

We summarize IMA-CID (Integrated Modeling Approach – Conceptual, Instructional and Didactic), an integrated modeling approach we have defined in previous work [7][15], since we have used it in the instantiated process for developing the software testing educational module.

Content modeling plays a fundamental role into the development process of educational modules [8]. How the content is structured impacts on the reusability, evolvability and adaptability of the module. Despite its relevance, there are few approaches for modeling educational content, which considers different perspectives that are suitable for a given learning scenario, but inadequate for others.

Preceding the definition of IMA-CID we had proposed a preliminary set of modeling requirements: (1) concepts taxonomy; (2) concepts composition; (3) specific relationships; (4) hierarchical decomposition; (5) knowledge categories; (6) learning contexts; (7) pedagogical order; (8) history mechanisms; and (9) event propagation. We had also identified some modeling perspectives – conceptual, instructional and didactic – in order to characterize the models for representing educational content. Then, we established a connection between the perspectives and requirements, which was the starting point for defining IMA-CID. The integrated modeling approach is composed by three models: (1) the conceptual model – corresponds to a high-level description of the knowledge domain, representing the main concepts and the relationships among them; (2) the instructional model – characterizes what kind of additional information (e.g., facts, principles, procedures, examples, and exercises) can be used to develop learning materials; and (3) the didactic model – characterizes the prerequisites and sequences of presentation among conceptual and instructional elements.

The standard is based on ISO/IEC 12207, tailored to the context of educational modules by including aspects of content modeling [8], practices from instructional design [9], and issues of distributed and cooperative work [10]. Basically, a set of processes that can be employed to acquire, supply, develop, deliver, operate, and maintain educational modules is established. Three categories of processes are defined: (1) primary processes; (2) supporting processes; and (3) organizational processes. Figure 2 shows the general structure of the standard. In dashed rectangles are the processes adapted from the ISO/IEC 12207. In dotted rectangles are the processes adapted from the standard process for geographically dispersed working groups [10]. In white
rectangles are the processes specifically developed to the context of teaching and learning.

![Diagram of the ADDIE Model]

**FIGURE 2**

**Main Structure of the Standard Process for Educational Modules.**

In the establishment of the primary processes we have considered the main principles and practices from instructional design. In short, the goals of instructional design are achieved by means of five phases: Analysis, Design, Development, Implementation, and Evaluation. These phases correspond to the ADDIE Model, which serves as the basis for the majority of the existent approaches for instructional design [9]. These practices are spread out through the activities and tasks related to the primary processes. For instance, the Operation and Delivery processes address issues of the implementation phase of the ADDIE Model.

Particularly, in the case of the Development Process, besides the practices of instructional design, aspects from educational content modeling are explored [7][8][15]. The tasks of conceptual, instructional and didactic modeling of educational content are established as part of the design activity.

For the sake of illustration, consider the Delivery Process, which is specifically defined for the context of educational modules development. It establishes the activities and tasks that should be performed by the module’s instructor. The following activities are established: (1) initiation; (2) delivery; (3) monitoring and instructional support; and (4) identification of problems and improvements. For instance, the last one addresses the problems and difficulties found when using the module. Basically, they should be registered and sent to the Maintenance Process. Learning goals and objectives not achieved as well as the knowledge resulting from using the module should be identified, documented and published for future improvements. Cases of success and recommendations for future developments should also be reported.

Supporting and organizational processes are established in a similar way as the primary ones. In the case of supporting processes, we defined the Knowledge Management Process, responsible for managing and controlling all the underlying knowledge under which the module is based. In the case of organizational processes, we established the Copyright and License Process, responsible for addressing the intellectual property of the module and the details regarding to its utilization, modification and distribution.

The standard process is responsible for the establishment of a unique development structure to be adopted and followed by the entire organization [7]. However, changes in organizational procedures, educational paradigms and principles, learning requirements, development methods and strategies, as well as the size and complexity of the projects, among other aspects, impact the way an educational module is produced. To be used into particular projects, the processes should be defined case by case, taking into account the specific features of each project.

Process specialization and instantiation have also been explored in order to apply the standard process into specific learning environments and organizations. The definition of a process for developing a given educational module should consider its adequacy to: (1) the involved technologies, supporting mechanisms and economical resources; (2) the domain of the educational application; (3) the characteristics of the module; (4) the maturity level of the development team; and (5) the characteristics of the organization. As a result, processes into different levels of abstraction are defined.

**II. Specializing the Standard Process**

In the same line as the CMMI Model for software development [16], a capability maturity model for educational modules development – the CMMI/Educational – is proposed and used as a supporting mechanism to the standard process specialization [7]. The main goals are to guarantee that distributed projects can be developed with unlike maturity level teams and improve each working group capability.

The CMMI/Educational is adapted from CMMI for the context of teaching and learning. A capability maturity model for geographically dispersed software development [10] is also considered to establishing the tasks and practices related to the distributed and collaborative creation of the modules. Both continuous and staged representations are addressed.

Similar to the staged representation of CMMI, CMMI/Educational establishes five maturity levels [7]. Two new process areas (PAs) are included at Level 2: Distributed Knowledge Management and Distributed Infrastructure Management. At Level 3, three new PAs are established: Knowledge Evolution Management, Domain Experts Interaction and Distributed Monitoring and Management of Educational Modules Utilization. At Level 4, we include the PA of Quantitative Management of Educational Modules Utilization. Finally, at Level 5, we define a new practice – Change Management of Educational Paradigms and Principles –, included as part of the PA Organizational Innovation and Deployment. For instance, the PA of Knowledge Evolution Management is responsible for: (1) identifying, choosing and evaluating the new information
related to the subject knowledge domain; and (2) establishing and maintaining the supporting mechanisms to systematically integrate the new information into the module.

By determining the correspondence between the standard process aspects and the PAs of the capability maturity model, we can identify the process categories that would require more attention and generate the standard process specializations. The specialization of a given maturity level is generated by excluding the activities of higher levels. So, the specialization of the second level does not contain the activities of the third, fourth and fifth levels. Instead, it contains only the activities related to the PAs of Level 2.

III. Instantiating the Standard Process

An instance of a process should take into account the development and organizational environment; it may address specific features of a particular project. Process instantiation consists of the selection and allocation of development methods and techniques as well as human, technological and computational resources.

In order to illustrate the standard process instantiation we consider its application in a specific kind of educational projects. Basically, these projects should be conducted in a given academic institution, involving the development of educational modules to be used in traditional classes. The produced modules can be applied either as part of an one-semester course, at the academic institution itself; as a short-course, a tutorial or an invited talk, in scientific events; or as a training course, at industrial organizations.

We have defined, among others: (1) the human resources and their roles in the process; (2) the produced and consumed artifacts; (3) the life cycle model and development methods and techniques; and (4) the automated tools and supporting mechanisms for the process. In this section we focus on (3) and (4); the readers can find further details in [7].

As the life cycle model to be adopted through the projects we chose the ADDIE Model. It is specifically designed for the development of educational products, establishing mechanisms for the systematic application of practices and principles of instructional design [9]. For modeling the educational content, we chose the IMA-CID approach [7][15], previously discussed.

In terms of technological and computational resources, tools and mechanisms to automate and support the instantiated process should be selected according to the roles they would play in the context of each specific project. Two basic categories of tools should be analyzed: authoring and educational tools.

- Authoring tools support the creation of the educational content, taking into account representation, integration and management aspects of the subject knowledge domain. We consider as authoring tools: (1) tools for modeling the educational content; (2) tools for knowledge integration; and (3) tools for editing the content.
- Educational tools consist of the required infrastructure for integrating the learning materials and for delivering/publishing them to the learners. They are also responsible for providing support to perform practical tasks and evaluations. We consider as educational tools: (1) presentation tools, which support delivery of learning materials; (2) collaborative tools, which support collaborative work and augment communication and discussion among instructors and learners; (3) evaluative tools, which support the evaluation of learner’s performance; and (4) capture tools, which provide ways to transform the content of a traditional lecture into browsable, searchable and extensible digital media that serves both short- and long-term educational goals. In fact, capture tools can serve as one part of a rich and dynamic educational repository.

One essential activity during the instantiation process is the identification and analysis of supporting tools to the standard process. The results of this activity constitute the alternatives to instantiating the standard process. Table I shows the adequacy of the tools we have analyzed; for the complete references on the supporting tools see [7]. Notice that some of the supporting tools can be used either as mechanisms to automate the processes or as part of the educational module itself. For instance, collaborative tools, such as CoWeb [3], can be used as a communication and discussion mechanism both for the development team as well as for the learners and instructors.

Table I  Adequacy of Supporting Tools to the Standard Process.

<table>
<thead>
<tr>
<th>Categories of Tools</th>
<th>Examples of Tools</th>
<th>Standard Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Modeling</td>
<td>Inspiration, KMap, CMap, HLM</td>
<td>Development</td>
</tr>
<tr>
<td>Instructional and Didactic Modeling</td>
<td>HySCheats</td>
<td>Development, Quality Assurance, Verification, Validation</td>
</tr>
<tr>
<td>Knowledge Integration</td>
<td>Protégé, ObjectEditor, Ontolingua, ODed</td>
<td>Definition, Development, Maintenance, Knowledge Management</td>
</tr>
<tr>
<td>Editing</td>
<td>Word, PowerPoint, FrontPage, Visio, LaTeX, WebCT, AulaNet, HySCheats, web, PowerPoint</td>
<td>Development, Maintenance</td>
</tr>
<tr>
<td>Presentation</td>
<td>WebCT, AulaNet, HySCheats, web, PowerPoint</td>
<td>Delivery, Operation, Validation</td>
</tr>
<tr>
<td>Collaborative</td>
<td>e-mail, discussion forums, CoWeb, WebCT, AulaNet</td>
<td>Delivery, Operation, Validation, Publishing, Communication</td>
</tr>
<tr>
<td>Evaluative</td>
<td>HLM, CyberQ, WebCT, AulaNet</td>
<td>Delivery, Operation, Validation, Improvement</td>
</tr>
<tr>
<td>Capture</td>
<td>eClass</td>
<td>Delivery, Operation, Maintenance</td>
</tr>
</tbody>
</table>

It is important to highlight that each instance of the standard process establishes a specific set of automated tools and supporting mechanisms to be applied. As presentation tools, we adopted a specific tool – WebCT [4], and generic tools – web and PowerPoint (when the use of educational tools is not required). As a collaborative tool, we adopted CoWeb [3]. As the infrastructure for capturing the classes, we chose the eClass environment [5][6]. As a support for authoring the educational content, we adopted generic editing
tools: *Word*, *PowerPoint*, *FrontPage*, *Visio*, *LaTeX*. To support communication between the members of the development team we chose *electronic mail* and *CoWeb*.

Taking into account the supporting tools to the standard process (Table I) and the requirements of the project under development (software testing educational module for traditional classes) we then define the instantiated process to a particular project, since each project may require itself specific tools and related mechanisms. Notice that some constraints are to be considered. For instance, the *IMA-CID* models had to be manually developed since the existent modeling tools do not incorporate the extensions required to construct them. Thus, the development of automated tools for the *IMA-CID* models is one of the research lines we intend to further explore.

Additionally to the authoring and educational tools, specific tools for the subject knowledge domain of the educational module should also be considered. In the case of the testing module, we chose *Proteum* [17] as the testing tool to be adopted. The main goal is to enable the application of basic testing concepts in realistic situations, fostering training situations and promoting exchange of technology between industry and academia.

**APPLYING THE INSTANTIATED PROCESS IN THE SOFTWARE TESTING KNOWLEDGE DOMAIN**

The instance of the Standard Process for Educational Modules was applied in the development of a software testing educational module. Concepts, facts, principles, procedures, examples and exercises were modeled and implemented as a set of slides, integrated to HTML pages, text documents, learning environments and testing tools. Figure 3 shows the main components of the module and their integration.

I. Evaluation of the Software Testing Educational Module

To provide a preliminary evaluation on the effectiveness of the testing module, we applied it in a three-hour short-course on software testing for a group of about 60 undergraduate students with some previous knowledge of software engineering. We focused on theoretical aspects of testing, providing an introductory perspective on this subject. Practical aspects were illustrated but, due to time constraints, there was no direct participation by the audience on using any of the materials. The effects of our approach were informally evaluated by applying a voluntary survey to the students after they had finished the course.

The survey was composed by four sections, covering the students’ attitude toward: (1) content, regarding the concepts, additional information, examples and exercises used in the module; (2) usability, in terms of the interface of the module; (3) navigational aspects; and (4) general aspects about the module. Regarding the content, the students pointed out as positive aspects the way the module was structured and how it addresses the topics discussed. The connections between concepts were also highlighted and the examples and additional information seemed to be appropriate. In terms of the proposed exercises, we noticed some expectation for practical tasks where the students could actively participate.

Although practical exercises involving the use of testing tools had already been integrated to the module, the short time available to the course made them trackless. The results pointed to the need of more concise exercises, which can be explored in such particular kind of course.

In terms of usability, the adopted schema of colors, the distribution of information through the pages/slides and the representation of the interface functions (icons, links, and so on) were, in general, well accepted by the students. Specific comments, however, indicated some disappointment with respect to the size of fonts and figures. With respect to the navigational aspects, we observed a positive attitude toward the flexibility on choosing the sequences of presentation. In general, despite the large amount of information available, the students did not “get lost” in the module. Besides the specific characteristics of the module, aspects such as instructor’s energy, enthusiasm and objectiveness were also reported.

Instructor’s responses were observed by his comments after using the module. The possibility of having defined the sequences of navigation through the module during the “execution time”, based on the learner’s understanding and feedback, was a significant point highlighted.

The results obtained provide preliminary evidence on the practical use of the standard process as a supporting mechanism to the development of effective educational modules. However, it is important to conduct more systematic and controlled experiments to validate our ideas. Such experiments have already been planned for the next term, involving three different courses on software testing, offered to graduate and undergraduate students at ICMC-USP as well as to professionals from local industries. Furthermore, both students and instructors’ attitudes toward the module should be evaluated.

**FIGURE 3**

SOFTWARE TESTING EDUCATIONAL MODULE.
CONCLUSIONS AND FURTHER WORK

In this paper a Standard Process for Educational Modules was defined and supporting mechanisms for developing educational modules, based on ISO/IEC 12207, aspects of content modeling, practices and principles from instructional design and issues of distributed and cooperative work, were discussed. Process specialization and instantiation were also considered to apply the standard process into specific learning environments and organizations. These ideas have been applied to the development of a software testing educational module.

The main contribution of this paper is to motivate the use of systematic processes for creating well-designed, highly flexible and configurable educational modules, which would provide: (1) transferability to different institutions and learning environments; and (2) effectively supporting traditional learning approaches. As a further work, we intend to focus on the development of educational modules to be applied in non-traditional environments, motivating the transition from lecture-based to active learning. The input of students in the very early stages of the module development, similarly to the participative approach in software development, is another point to be further investigated.

Besides that, we intend to investigate the definition of supporting tools for the IMA-CID models. Specifically, we are interested in automated tools for helping the edition, interpretation and execution of didactic models, providing mechanisms to simulate and validate executable specifications of the content. Tools for automatic content generation, based on IMA-CID approach, should be explored and integrated in future instances of the standard process.

We are also motivated to keep evolving and evaluating the mechanisms we have proposed in future offerings of testing courses. We are now working on the development of an educational module for the integrated teaching of testing and programming foundations in introductory CS courses [14]. The educational module for integrating these knowledge domains has been designed and implemented according to the standard process and the IMA-CID models. Since the standard process can be applied to different domains, we are also interested in using it to develop and evaluate educational modules for other areas and broader projects.

At the very end, we intend to establish a culture for “open learning materials”, so that the use and evolution of them by a broader community would be better motivated and become a reality. The existence of a well-defined process to systematize the development of learning materials and, at the same time, flexible enough to be adaptable to different knowledge domains and maturity level development teams, is a relevant issue to be addressed in crossing international, cultural and social borders in order to prepare the students to be successful in a global market, with diverse groups of people. The establishment of “agile methodologies” for developing and evolving educational modules should also be further explored.

In spite of the increasing costs to initially develop an educational module based on the ideas discussed herein, the quality factors of the produced materials, such as evolvability, maintainability, reusability, among others, would increase the long-term benefits and decrease the overall costs.

ACKNOWLEDGMENT

The authors would like to thank the Brazilian funding agencies – FAPESP, CAPES and CNPq – for their support.

REFERENCES