Marjanovic, O. (2005). Towards A Web-Based Handbook of Generic, Process-Oriented Learning Designs. *Educational Technology & Society*, 8 (2), 66-82.

Towards A Web-Based Handbook of Generic, Process-Oriented Learning Designs

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ABSTRACT

Process-oriented learning designs are innovative learning activities that include a set of inter-related learning tasks and are generic (could be used across disciplines). An example includes a problem-solving process widely used in problem-based learning today. Most of the existing process-oriented learning designs are not documented, let alone analysed, in any systematic way because they are tacit knowledge gained through years of experience and reflection.

The paper investigates the problems of creation, sharing and IT support of process-oriented learning designs and proposes a new type of process-oriented, knowledge management educational technology called the web-based handbook of learning designs. It is envisaged that this technology will enable teachers to assemble, share, reuse and execute process-oriented learning designs without any programming involved. To design this technology, the paper proposes a multidisciplinary framework that integrates research in six different areas: educational theories, educational technologies, knowledge management, software engineering, process management and web-services. The paper then uses this multidisciplinary framework to identify the main research challenges that need to be solved before this technology can be adopted on a larger scale.

Keywords

Process oriented learning designs, Innovative teaching practices, Educational technologies, Knowledge management, Web services

Introduction

One of the key challenges to innovative, computer-supported education today, is development of a framework based on sound pedagogical principles that will promote the *exchange and interoperability* of learning concepts, materials and teaching strategies (IMS Global Learning Consortium http://www.imsproject.org), (Oliver, Harper, Hedberg and Willis, 2002), (LOM Standard http://ltsc.ieee.org/wg12/index.html). The new term *learning design* has been proposed to describe, at the conceptual level, various components of learning experiences including, for example, teaching resources, tools and innovative teaching strategies. So far, learning designs have been mostly *resource-oriented*. Thus, the main emphasis has been on educational content and tools for content presentation, delivery and management.

In recent years, several standards have emerged (see for example (IMS Global Learning Consortium), (LOM Standard), (Learning technology standard committee)) to enable specification of various learning objects (again mainly content or resource oriented) so they could be easily exchanged among various educational tools and platforms. Furthermore, the latest educational technology standard SCORM (Sharable Content Object Reference Model) (ADL, 2004a) goes one step further and enables sequencing and dynamic presentation of learning content to suit the needs of a particular learner. However, sharing the innovative teaching practices and activities (not only content-based) among teachers is even more important, but yet to be adequately supported by the emerging standards and existing educational tools and platforms.

This paper concentrates on *process-oriented learning designs*, that are innovative *teaching/learning activities* that consist of a set of inter-related learning tasks and are *generic* (rather than discipline specific). In order to promote active learning individual tasks need to include collaboration, critical thinking, problem solving and authentic interactions with real-world problems. Therefore, process-oriented learning designs are at the core of socio-constructivist theory of learning (Bostock, 1997). It is important to note that they are not necessarily fully on-line activities and could incorporate both face-to-face as well as technology supported tasks. Consequently, they could be used both in the mixed (blended) mode of learning as well in e-learning.

Some process-oriented learning designs have became widely known and accepted across different disciplines, for example the problem-solving process that forms a foundation of problem-based learning. Although there are many variations of the problem-solving process, in essence, it includes tasks such as: identification of a problem, alternative evaluation and selection of the course of actions for the chosen alternative. There are many more processes, hidden within boundaries of individual disciplines, which could be generalised and used in other disciplines (e.g. the balanced scorecard method).

However, the analysis and implementation of process-oriented learning designs is very challenging because they are difficult to (1) *describe*, (2) *share* among teachers and consequently (3) *support* by information technology.

1. Difficulties in descriptions arise because the designs are in fact, *tacit* knowledge gained through years of practical experience of looking for the answers for a simple question: "How do I help my students to learn?" This is the main reason why, most of the existing process-oriented learning designs are not described or analysed in any systematic way.
2. Because process-oriented learning designs are hard to describe, they are very hard to share among teachers (especially across disciplinary boundaries). Benefits of this knowledge sharing are obvious (especially for the less experienced teachers) and even more important in the world where advanced information technologies open up new possibilities for innovative learning designs.
3. In order to support process-oriented learning designs by Information Technology (IT) (if such a support is required), it is necessary to have *process-oriented* educational technology. However, currently popular educational technologies are still quite limited when it comes to process support. If one ignores different "look and feel" of the leading commercial learning environments (for example WebCT and Blackboard), one can observe that they provide support for various aspects of course and student management, online quizzes in different forms, but in essence, they are still task-oriented rather than process-oriented. In order to support processes, in addition to communication and collaboration, it is necessary to adequately support coordination of different tasks.

The main objectives of this paper are to further analyse process-oriented learning designs in order to find out what type of IT support can be offered to teachers to create, share and reuse their innovative designs. More precisely, the paper aims to:

4. critically analyse the problems of description, sharing and support of process-oriented learning designs from six different perspectives (disciplines).
5. propose a multidisciplinary framework and use this framework to identify the main research challenges related to process-oriented learning designs
6. define the main requirements for a new type of knowledge-management, process-oriented educational technology called the *web-based handbook* of process-oriented learning designs. It is envisaged that this technology will be used by teachers to create, store, retrieve, modify, re-use and assemble process-oriented learning designs without any programming involved.

This paper argues that the creation, sharing and IT support of process-oriented learning designs is a complex, multidisciplinary research problem. The following sections analyse, in more details, the identified problems of *creation* of learning-designs, *knowledge sharing* and *possible IT support*. This analysis then leads to a multidisciplinary research framework that will be used to define the requirements for the web-based handbook.

Motivating examples

The following simplified examples illustrate typical process-oriented activities that many teachers are already using. Suppose that both teachers A and B are interested in implementing problem-based learning in an assignment they are about to give to their students. Recall that in problem-based learning going through the process is as important as the final outcome itself. Obviously, this has to be clearly stated within the learning objectives for this activity.

The first example comes from Oliver and Omari (2001) who used the following scenario to illustrate how technology can be used to support problem based learning: Teacher A posts an authentic problem on the course web site along with links to various learning resources and questions for self reflection. He also specifies the deadline for submission of a solution that students are required to post on the web site. In the next step students use web-based discussion tools (forum) to discuss a possible solution. Then, they post a short summary of their solution on the web by the given deadline. The teacher then marks each summary. Finally, all summaries are made available to all students on the course web site. A similar example of problem-based learning can be found in (Phillips, 2000) where the individual tasks of this process are supported by WebCT.

It is important to observe that in both examples, integration and coordination of individual tasks into a process are not supported by technology. This is because technology used (e.g. WebCT) is task-oriented rather than process-oriented.

In the second motivating example, suppose that teacher B is in charge of a postgraduate course. In this course, students are required to solve a complex unstructured problem for their assignment. This teacher is interested not only in the final solution but also in finding out how students work together to solve the given problem. In other words, she is interested not only in the outcome but in the steps students take to solve the given problem. To start their assignments, students need to register their groups (via e-mail) and allocate roles to individual members. Then, they are required to submit a project plan within two weeks from the day the assignment was issued. In order to complete the given assignment, students need to find and assemble the relevant learning resources (e.g. journal articles, web sites etc.) and share them within their own group. To support their work, students also have access to a number of communication and collaboration tools (e-mail, chat, forums etc.).

Furthermore, teacher B wants to implement a form of peer-review because she believes that students can also learn from reading and commenting on other completed assignments. So, after all assignments are submitted, the teacher marks each assignment. Then, for each assignment she allocates another group of students that will play the role of reviewers. The reviewers are not supposed to mark the allocated assignment but are required to comment on the proposed solution. After they complete their reviews and send back the allocated assignment, teacher B will give the reviewers additional marks based on the quality of their comments.

To support this particular process-oriented learning design by existing educational technologies is not as simple as it may appear. This is because the existing, widely available tools do not support the coordination aspect and do not provide simple integration of various tools and resources (especially across different software platforms). In terms of integration support, the exception is the latest standard SCORM. However, this standard is yet to become widely accepted and incorporated into the popular Learning Management Systems (LMS). Furthermore, teacher B will find it really hard to monitor students' progress especially in terms of problem solving stages. For example, she could analyse the messages students post on the topic forum but they may not correspond to the phases of students' progress.

In terms of knowledge sharing, unless these two teachers have a chance to exchange their experience related to the practical implementation of problem-based learning, their practices will stay within their individual subjects or disciplines. This means that it may never occur to teacher A to use peer-review in his course. Even if he decides to use it, A could also benefit from B's experience e.g. learn about difficulties in supporting this learning design with the existing educational technologies. The following sections will analyse creation, sharing and IT support for process-oriented designs from a multi-disciplinary perspective.

Creation and sharing of process-oriented learning designs

The problem of creation of process-oriented learning designs and their sharing can be analysed from the perspectives of educational theories as well as knowledge management, as described in this section.

Educational theories

It has been widely recognised that one of the most important skills that students should acquire during their university study today, is the ability to learn how to learn. To help students build these skills, it is necessary to engage them in carefully planned learning activities (i.e. processes) rather than isolated learning tasks. Learning activities should include the integrated learning tasks that promote active learning through collaboration, critical thinking, problem solving and authentic interactions with the real-world problems. Also to help students become more "self-regulated", reflective learners it is necessary to develop student's awareness of the process itself. Even more, in many cases, going through the process is equally important as the process outcome itself (for example in problem-based learning).

In order to describe process-oriented learning designs from the educational perspective, this paper adopts the *activity-centered approach* to design of student learning experience. This approach differs from both *resource-centered* and *technology-centered* approaches to instructional design. For example, when the resource-centered approach is adopted, the main emphasis is on learning resources. Consequently, student learning is organised around the available resources (e.g. around textbook's chapters, web resources etc.). On the other hand, in the technology-centered approach, the main emphasis is placed on the available technology (educational tools). This approach is best described by the following question: "How should I design student learning experience so I can use a particular tool"? (e.g. bulletin board, chat tool etc)

On the other hand, according to the activity-centered approach, the first step is to identify learning objectives (what students need to learn) and then design learning activities to help students meet those objectives. These activities will make use of the available resources and educational tools. Finally, it is necessary to design the assessment tasks that will measure the intended outcomes (how well the students have achieved the intended objectives).

The activity centered approach to learning complements the design framework described in (Oliver, Harper, Hedberg and Willis, 2002) and (Agostinho, Oliver, Harper, Hedberg and Wills, 2002). According to (Oliver et. al, 2002), a learning design comprises three key elements: the *task or activities* learners are required to perform; the *content* or resources learners interact with; and the *support mechanisms* provided to assist learners to engage with the tasks and resources.

In order to support process-oriented learning designs, it is necessary to extend this framework and introduce one more key element of a learning design - the *process*. Figure 1 illustrates the extended activity-centered approach proposed in this paper. This extension acknowledges that tasks are not performed in isolation and the actual process (e.g. in problem-based learning) is as important as the final outcome.

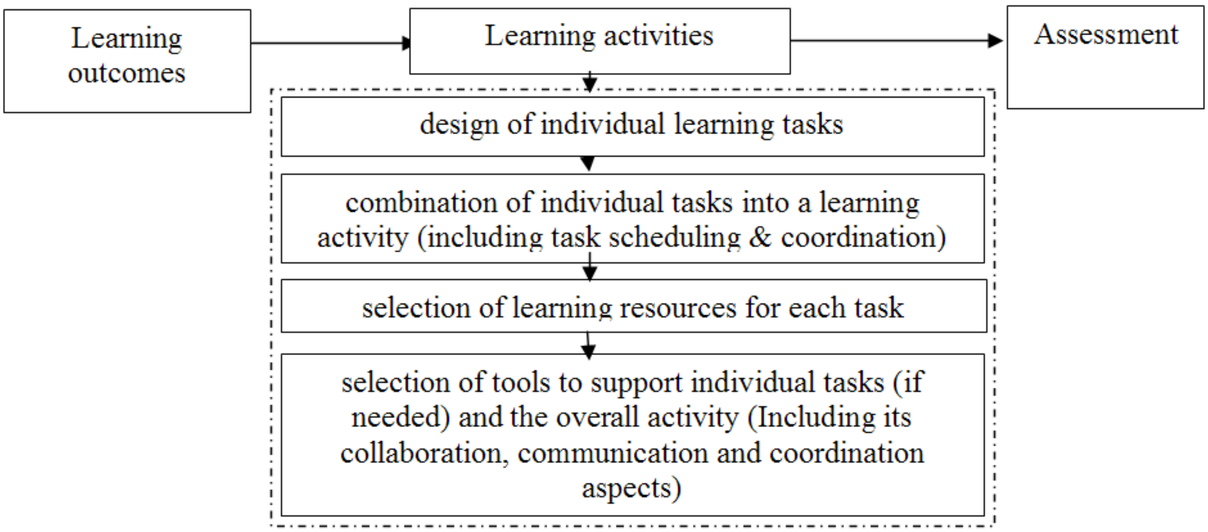

Figure 1. The proposed extension of the activity - centered approach to learning

Knowledge management

Design and sharing of process-oriented learning designs is also a knowledge-management challenge. This is because, learning designs are, in fact, tacit knowledge that is gained/invented by teachers and refined through years of practical experience and reflective practice. Therefore, they represent *experiental* rather than widely available *external* knowledge that can be easily shared. In fact, one could claim that process-oriented learning designs have a very long-history (probably as long as formal education) as teachers have always invented and used innovative learning activities to help their students to learn.

On the other hand, this type of knowledge sharing is becoming increasingly important not only to help the less experienced teachers. More and more teachers need to share their experiences simply to stay up-to-date with ever changing technologies as well as to meet higher student expectations. This is especially the case in the area of IS/IT/CS education where most students come to expect their teachers to use very sophisticated educational technology. Furthermore, some universities are in the process of implementing various institutional strategies to encourage knowledge sharing among teachers that should, over time, result in much better student learning experiences (see for example UNSW's teaching and learning guidelines (UNSW, 2004)).

The relevant literature in the area of knowledge management also confirms the need for research on knowledge management in educational systems. However, current research efforts in this area concentrate more on knowledge management from the learner's (student's) perspective rather than teacher's perspective. For example, (Kayama and Okamoto, 2001) define knowledge management in the educational context as the systematic process of finding, selecting, organising and presenting information in a way that improves learner's comprehension and/or ability to fulfill his/her current learning objectives. This paper argues that knowledge management is relevant for both teachers and learners. In fact, better knowledge management support on teacher's side should, in turn, result in a better learning experience on student's side.

In order to offer better knowledge management support to teachers, it is necessary to better understand the *knowledge processes* they are involved in when dealing with process-oriented learning designs. In this respect, we see the universities as organisational "knowledge systems" (where the term "system" refers to human and organizational capital rather than technology systems) and adopt the framework developed by Alavi and Leinder (2002). According to this framework, organizations as knowledge systems consist of four sets of socially enacted "knowledge processes": (1) creation (also referred to as construction) of knowledge, (2) storage/retrieval, (3) transfer and (4) application of knowledge. Alavi & Leinder's view of organizations as knowledge systems represents both the cognitive and social nature of organisational knowledge and its embodiment in the individual's cognition and practices as well as the collective (i.e. organizational) practices and culture.

Also relevant for the knowledge management perspective are the well-known educational projects such as MERLOT (http://www.merlot.org/Home.po) and ARIADNE (http://www.ariadne-eu.org/). These projects concentrate on sharing of various static educational resources and providing tools for teachers to search and create educational content (such as lecture notes, curriculum design etc.). Another example of a similar static repository of educational resources is the educational clearinghouse called ERIC (http://ericeece.org/) that was recently closed after 36 years of existence.

From the current experience with MERLOT project, one can observe that teachers are willing to share their learning resources. However, sharing of static resources is only one, very limited aspect of knowledge management that in some cases can easily lead to resource-centered teaching. Certainly, a more challenging problem is sharing and exchange of teaching strategies and innovative practices. In terms of knowledge management, this problem requires support for: creation, storage/retrieval, transfer and application of knowledge as identified by Alavi and Leinder' framework.

One of the objectives of this paper is to investigate how to use technology to support all four knowledge processes and enable teachers to create new process-oriented learning designs, store them, share and apply within their own discipline and learning setting. The following section describes in more details what is currently available and, more importantly, what is required to create such technology.

Supporting process-oriented learning designs with IT

Educational technologies

To support composition, storage and execution of process-oriented learning designs, it is critical to have process-oriented educational technology that is capable to support the coordination component of a process (that is scheduling and coordination of individual tasks). However, as already pointed out, currently popular educational technologies (such as WebCT, Blackboard et.) are still quite limited when it comes to coordination support.

At this point, it is also important to mention the growing number of educational technology standards such as Learning Object Model (LOM) etc. As more and more researchers and practitioners are adopting the emerging standards in this area, there is a growing number of learning objects (e.g. educational resources) that could be shared across different educational platforms. At the same time, currently available modeling languages, invented and used to specify various, interoperable learning designs are far too complex for the non-IT specialists (e.g. XML based). This is not surprising, as these standards were not invented to enable teachers to model and share learning designs, but to enable exchange and reuse of educational materials by different educational environments (software packages). These languages are intended for software engineers who are developing educational tools and environments.

Furthermore, the emerging standards mostly concentrate on static resources (educational materials). An exception is certainly the latest version of SCORM (see ADL, 2004a). SCORM supports the notion of learning content composed from relatively small, reusable content objects aggregated together to form units of instruction such as courses, modules, chapters etc. Thus, a learning management system (LMS) based on SCORM standard, offers a set of functionalities designed to deliver, track, report and manage learning content as the learner moves through the assigned content. This dynamic presentation of learning content is based on learner needs and is enabled by the "Sequencing and Navigation Model" (see ADL, 2004b). Here, sequencing rules and navigation behaviour are specified independently from the content objects by the instructional designer. Finally, SCORM standard aims to enable interoperability of reusable, sharable objects (instructional components).

Compared to other standards, SCORM goes one step further towards process support. It enables sequencing of a learning content in a form of so called "activity tree" to suit the needs of a particular learner. However, it is important to note that in many aspects this process support is very similar to what is already available in the field of process technologies (as explained in the next session). Nevertheless, sequencing of content further confirms the need to support process-oriented learning activities by educational technology.

Process-Management Technologies

As already pointed out, process-oriented learning designs require technologies that are capable to support processes rather than individual tasks. In the area of business technologies, such support is already available in the form of workflow technology that has been widely recognized as the leading process-oriented technology (WFMS). In essence, workflows are designed to specify, execute, manage, monitor and streamline business processes by allocating the right task to the right person at the right point of time along with the resources needed to perform the assigned task. Workflow technology enables coordination of different tasks as well as integration of tools and technologies used to support individual tasks. Because of these features, workflow is considered to be the leading coordination and integration technology (WFMS).

Workflow models are designed by workflow analysts and stored in a workflow repository during design (or build) time. Then, during run-time, a *process instance* is created and enacted (executed) based on the stored, pre-defined model. The actual enactment of different tasks and their coordination are performed by the workflow engine on the basis of different events (e.g. task completion event). For example, when one task is completed for a particular instance, workflow engine will "read" the corresponding workflow model and activate the subsequent tasks if their activation conditions are satisfied.

At this point, it is important to draw parallels between SCORM's Sequencing and Navigation model on one side and workflow models and workflow engine on the other side. Although they are designed for different domains (education vs. business), in terms of their *coordination* (sequencing) mechanism they offer very similar functionality. From the modeling perspective, workflow models are much richer models in terms of coordination and sequencing constructs and options. Therefore, they could be used to express a relatively simple sequencing structure as in SCORM. In this case, sequencing and navigation could be achieved through workflow engine that could activate individual tasks through an event (e.g. completion of a learning module). In fact, a similar project was described by (Marjanovic, Orlowska, 2000). The result of this project was a proprietary, workflow-based, flexible-learning environment called Flex-eL. In Flex-eL, a single workflow model was designed for a course (as depicted by Figure 2) to include a number of content modules and corresponding fully supervised quizzes. Then workflow engine was used for sequencing and navigation through a set of learning modules. The main objective of this system was to make the right module available to the right student at the right point of time along with the required educational resources and tools. It is important to note that a workflow model was designed by a workflow analyst (not end-user). Also one process instance was created for each individual student enabling them to progress through the content in a variety of ways. For example, after completing Module 1, student could do Modules 2 and 3 (and the corresponding quizzes) in any order. Then after completing the first three modules, a student could progress through the remaining modules in any preferred order e.g. complete Module 8 and the assignment, then Modules 6 and 7 and Quiz 4 and finish off with Modules 4 and 5 and Quiz 3. A student had to complete all modules and quizzes before attempting the final exam. This model also contained the associate temporal constraints making sure that all components are completed by the required deadlines.

Another example of process-oriented educational technology can be found in (Van der Veen, Jones and Collis, 1998) where they use workflow technology to track and manage student projects. It is important to observe that both projects use a *single* process model, predefined by a workflow analyst and imbedded into the workflow system. The same model is then executed many times, once for each student. The same limitation of a pre-defined model applies to SCORM (this will be discussed in more details in later sections of this paper).

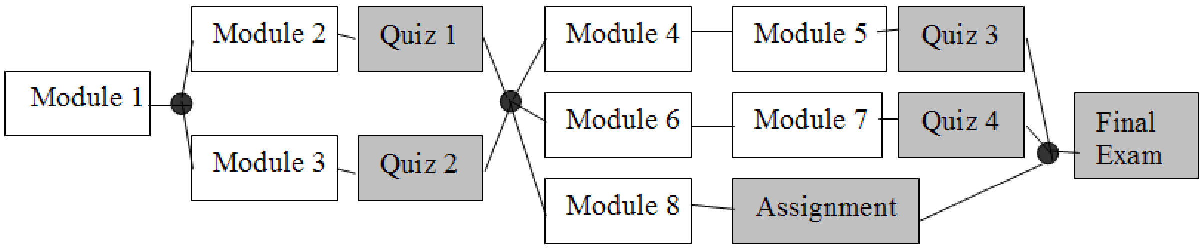

Figure 2. A workflow model in Flex-eL by (Marjanovic and Orlowska, 2000)

However, in spite of its process-orientation, workflow technology is not directly applicable to process-oriented learning designs for several reasons. It is primarily business rather than educational technology and therefore, its main objective is to improve *process efficiency* through task coordination. Models of business processes are very different from process-oriented designs. Among other things, it is easier to create models of business processes than process-oriented learning designs because the standard descriptions of various business process models are becoming widely available and accepted. In fact MIT's handbook of organisational processes already exists (see Malone, 1999) and is available to users to store and review models of common organisational business processes. The purpose of MIT's handbook is not to provide a repository of executable models but to enable users to see the benchmark examples of various business process models that they may adopt in their organizations. As already pointed out, such a collection of models of process-oriented learning designs does not exist due to the fact that process-oriented learning designs are tacit (experiential) rather than explicit (widely available and documented) knowledge. Furthermore, while business process models (as the ones used in workflows) are designed by expert process analysts, it is envisaged that modeling of process-oriented learning designs should be done by domain experts - teachers. Therefore, they will require different type of support than workflow specialists.

Finally, models of process-oriented learning designs need to be much more flexible than the currently available workflow models as well as activity models in SCORM. For example, some learning designs even evolve (emerge) during the learning experience (unstructured problem-solving processes is one such example). Support of emergent processes is a very recent research area of process management and technologies and modeling frameworks are currently under investigation and not yet widely available (Marjanovic, 2005), (Carsen and Jorgensen, 1998).

Software Engineering

Another area related to design and possible IT support of process-oriented learning designs is software engineering. Thus, when analysed from the software engineering perspective, learning designs are related to the work on patterns. For more details on patterns see (Hillside Patterns Home at http://hillside.net/patterns/). In general, patterns are used to describe various repetitive activities at a very high level so they could be reused. There are several different categories of patterns that are applicable to different modeling and implementation levels such as design patterns, software architecture patterns etc. It is important to observe that the use of the pattern theory in educational systems is still limited to design of educational software rather than learning experience. For example, (DiGiano and Roscelle 2000) use software architecture pattern to create so called componentware for education. However, they do not consider learning processes at all and concentrate on stand-alone learning tasks.

Furthermore, (Crista and Garzotto, 2004) focus on design patters for adaptive/adaptable educational hypermedia (AEH). AEH are designed to provide learning experiences that are dynamically tuned according to learner's characteristics. Although, AEH patterns are not directly applicable to research presented in this paper (at least at this stage), they nevertheless illustrate the growing importance of patterns and their reuse in educational technologies.

Another special category of patterns also related to process-oriented learning designs are the so called *pedagogical patterns* (http://www.pedagogicalpatterns.org). These are high-level (natural language) descriptions of various educational experiences, components and activities (where some of them represent examples of learning activities) designed by software engineering community interested in teaching software engineering concepts.

Although this high-level specification is not precise enough to be used as a model of process-oriented learning designs, nevertheless it provides an excellent collection of examples of various learning tasks and activities that can be further generalised.

Enabling new process-oriented learning designs

The latest developments in IT open new possibilities for more flexible process support as well as integration and coordination of individual tasks and education tools. We argue that IT can be used not only to *support* the existing process-oriented learning designs (partially or in full) but also to *enable* new learning designs never before possible. This section gives a brief overview of web services – an emerging technology that can be used to enable more flexible process-oriented learning designs.

Web services are Internet-based, modular applications, possibly offered by different providers that have standard interface to enable efficient integration of business applications across organisational boundaries. Recent reports by various leading industry analysts and practitioners claim that web-services will revolutionise the existing IT applications as they enable easy integration of different platforms, tools and resources (Zhang, L-J, 2004), (Yang, 2003). Web-services are platform-neutral and they enable building of composite services by using the existing elementary or complex services. So far, web services have been developed mainly for various business applications, while in the education domain their wide application is yet to be seen (especially beyond simple integration of service infrastructure). Currently, there are several exemplary projects that deal with web service support for learning processes at the technical level (see IEEE Learning Technology Newsletter, 2004). These projects use the term "learning process" to describe a model of a composite web-service. (Note that the same term is used in educational theories to denote cognitive processes of human learning rather than learning activities).

We argue that it is necessary to take the top-down approach i.e. to design (model) learning activities to achieve the intended learning objectives and then map the conceptual design into a composite service. From the educational perspective this approach follows the activity-centered approach to learning where composite web services are used for integration of tasks, tools and resources into a process (learning activity) at the technical level. However, modeling of a composite service at the conceptual level (by non-specialists) is a real research challenge. In fact, the current experience with conceptual modeling of a composite service in the business domain illustrates that, as technologies and infrastructures are becoming available, the gap is widening between the available technology and our current understanding of process modeling, verification, orchestration and monitoring. In other words, modeling of the process (made of composite web services) and its context are currently the major research problem in the area of web-services (Zhang, L-J, 2004), (Marjanovic, 2004).

A web-based handbook of process-oriented learning designs

As already pointed out, it is important to start from understanding and modeling of learning designs – not by IT experts, but by the domain experts – teachers – who are involved in creation and sharing of learning design in their everyday work. Consequently, knowledge management processes (creation, sharing, transferring, application and modification of learning designs) are not happening in IT labs. They occur while teaching is in progress and while teachers are looking for the best way to help their students to achieve the intended learning objectives at that particular point in time.

A multidisciplinary framework for design of a web-based handbook

In order to design a web-based handbook, it is necessary to integrate the expertise in innovative teaching on one side, and currently available and emerging technologies and standards on the other side, in a much better way than what is currently offered by the commercial learning management systems.

To address this integration challenge, this paper proposes a new type of knowledge-management, process-oriented educational technology called the *web-based handbook* of process-oriented learning designs. The main motivation behind development of this technology is to enable teachers to retrieve, modify, re-use, share and assemble the executable components to support their learning designs. These components are self-contained modules used to implement one or more process tasks. By combining individual components, teachers can create and implement various process-oriented learning designs without any programming involved. Recall that these technology-supported tasks could be also combined with various tasks not supported by technology (e.g. face-to-face activities).

Design and implementation of the web-based handbook is a complex multidisciplinary research and development problem that requires integration of knowledge, tools and methods from several different disciplines (as depicted by Figure 3).

In terms of Alavi and Leinder's framework (2000), the proposed web-based handbook of learning designs represents a knowledge repository that will enable teachers to perform all four knowledge processes:

- create learning designs by assembling different executable components
- store them in, and retrieve from the knowledge repository
- transfer their knowledge and experience to other teachers and
- apply this knowledge within their own teaching discipline to further improve their teaching practices.

Obviously, it would be unrealistic to expect teachers to implement (develop code for) their own executable components. Instead, teachers' role is to create a process-oriented learning design and select and assemble the most appropriate executable components that could support parts of, or the complete process. However, in order to enable development of the new executable components and provide ongoing support, it is necessary to establish a feedback loop (knowledge sharing) between domain experts (teachers) and IT specialists (knowledge engineers) as described in the next section.

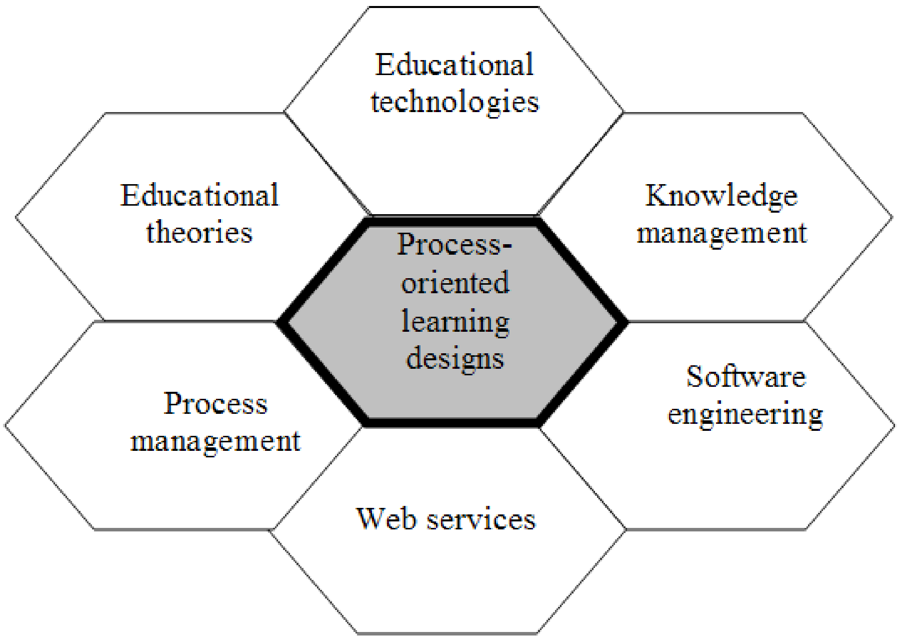

Figure 3. Process-oriented, generic learning designs – a multidisciplinary framework

Web-based handbook – basic functionality

In terms of its functionality, the web-based handbook provides a knowledge repository (used to store executable components, process models and instances) and a set of tools for its main users: teachers and knowledge engineers. Before the handbook can be made available to teachers it is necessary to populate the knowledge repository with executable components designed and developed by knowledge engineers. The system development lifecycle of the *new* executable components involve the following steps:

(1) Externalisation of tacit knowledge
This step starts from understanding of the intended process-related learning designs. Thus, teacher's role here is to describe the intended learning design to a knowledge engineer by using the activity-centered approach (as depicted by Figure 1). This means that they need to start from the intended learning objectives and then describe the series of inter-related learning tasks designed to achieve these objectives along with educational resources and tools that could be made available to students.

(2) Modeling of innovative practices
In this step, knowledge engineers document the described learning design in a more formal way, by using a process-modeling language. The formal model enables capturing of the details of individual tasks as well as the intended coordination mechanisms and process constraints (e.g. how long does it take to complete the given process).

(3) Identification of possible generic patterns
In order to identify possible generic patterns that could be turned into executable components, knowledge engineers need to analyse and compare the available process models. This highly creative task requires a very good understanding of the capabilities of the existing educational technologies and standards as well as the ability to identify new components that could be created to support individual tasks. Formal models provide consistency in process description that, in turn, enables easier comparison of different models and detection of possible similarities and patterns.

(4) Design and development of executable components
The identified patters are then used to design and implement new executable components. When completed and tested these components are then stored in the knowledge repository and made available to teachers.

(5) Ongoing management (maintenance) of the knowledge repository
After they develop the initial set of components, knowledge engineers will be involved in ongoing management (maintenance) of the knowledge repository. This involves storage and retrieval of executable components and possible improvement (modification) of the existing components. Note that, in addition to individual components, the knowledge repository could also store complete or incomplete models pre-assembled and used by other teachers.

When components are made available, teachers can use the web-based handbook to perform the following process-related activities:

(1) Selection and configuration of components and process models
Again starting from the intended learning objectives and activities designed to meet these objectives, teachers can select the executable components to support individual tasks, parts of a process or a complete process. The real challenge here is to decide which part of the intended process can and should be supported by technology and then find the most appropriate components to support it. However, the match between the individual learning tasks and executable components is not one to one, as a single task may require more than one component to support it and vice versa. Therefore, especially for non-IT teachers, it is necessary to involve knowledge engineers to help with possible selection of the most appropriate components. It is envisaged that over the time, as teachers gain more and more experience this help will be less and less required. Individual components should be configured (i.e. different values assigned to different parameters) to make sure they fit the intended process and comply with process constraints. As the knowledge repository also contains process models, teachers should be able to retrieve and configure complete models rather than individual components.

(2) Composition, verification and simulation of process models
When the individual components are selected, the next step is to assemble the selected components into a process model (learning activity). This involves specification of the various process constraints including both temporal and structural constraints. This process model is also stored in the knowledge repository and will be used during run-time for activation of process instances. Again, teachers may need help from knowledge engineers to compose a process model and decide how to coordinate the selected components. In addition to individual components, teachers should be able to reuse a pre-assembled process that had been composed and tested by other teachers. Note that all process components may not be identified in advance. Therefore, teachers should be able to add or remove components during the actual execution of the process. Finally, before the assembled process could be used it is necessary to verify its consistency and validity. For example, teachers should be able to check if it is possible to complete the whole process within the required time (e.g. within 6 weeks) based on the duration of individual components and well as to verify if the components are assembled in the right logical order (e.g. peer marking comes after assignment submission). Recall that the assembled process could also include specification of non-IT tasks (face-to-face discussion) and these tasks should also be included in the process model so it can be properly verified.

(3) Initiation and monitoring of process instances
After the process model has been verified, it is ready to be used by the teacher and his/her students. The same process model can be reused many times. The actual execution of the given model is called a *process instance*. A

process instance is initiated by an event (e.g. teacher's action, deadline constraint etc.). In general, a single process instance is designed for a single course (subject) and shared by all people in that course (teachers and their students). However, different courses can reuse the same learning design (model) at the same time. In that case, they will have separate process instances. Obviously, the same student enrolled in two different courses may participate in more than one instance of the same process at the same time. Obviously, these process instances will have separate contexts.

The key component here is the coordination support that can be implemented via to-do lists in shared and private workspaces. In essence, as teachers and students progress through a particular process instance, new tasks will appear on their to-do lists and the required tools will be available in their shared and private workspaces at the right point of time. For example, once the assignment is ready for peer review, the task will appear on the to do list of the student that has been selected to peer review the assignment. Once all reviews are completed a message will appear on teacher's to do list to inform him/her that this particular task has been completed. Although, in most cases, process instances will follow the corresponding process model, teachers should be able to change the pre-defined model and add new components or add and remove the selected ones during run-time. However, this flexibility cannot be adequately provided by the existing workflow technology. The same problem remains if coordination is implemented though SCORM's navigation and sequencing mechanism. (ADL, 2004b).

Finally, it is important to observe that the instances of the running and completed processes are also stored in the knowledge repository. This enables reuse of the same experience (model) by the same or different teachers and learning from completed instances.

(4) Analysis of the accumulated knowledge and experience
In addition to the process models and experiences, teachers should be able to store their experience with the particular model in the form of comments or their own personal reflections. This should be made available to other teachers so they could learn from the accumulated experience to create better process models or avoid repeating the same mistakes.

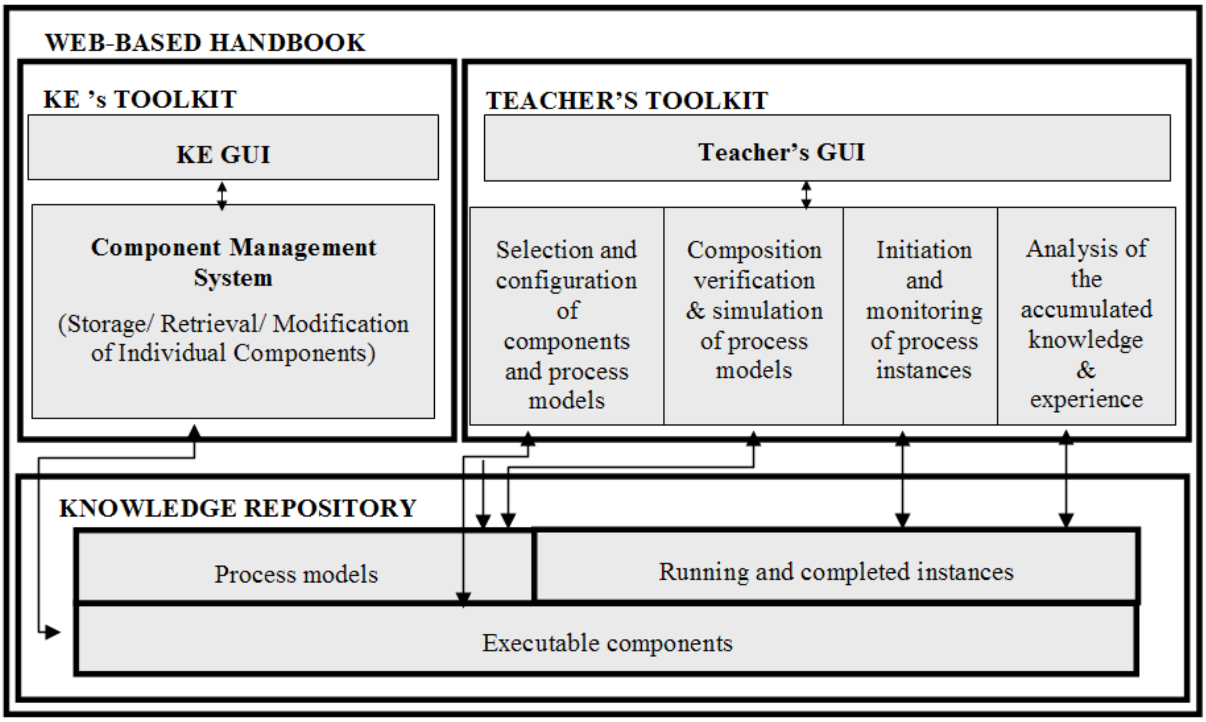

Figure 4. Web-based handbook – the architecture

A high-level architecture of the web-based handbook is depicted by Figure 4. Development of its prototype is currently in progress. The current version of the prototype is implemented in Java programming language combined with Oracle DBMS. This proprietary system is based on a client-server architecture that uses the Model View Controller (MVC) design pattern. Knowledge repository is stored in Oracle database. At the moment, it contains a small number of components for problem based learning along with process models (assembled out of these components) and their corresponding instances. The *Model tier* is designed to encapsulate all processing logic and knowledge repository maintenance. This level also integrates a special purpose coordination mechanism that is designed to handle declarative models of learning designs (also invented for the purposes of this project). The core software within the model tier has been implemented in Java. The *View tier* encapsulates the interface modules enabling two different categories of users (teachers and knowledge engineers) to use the system. This tier has been implemented using Java Server Pages (JSP). The *Controller tier* manages the communication between model and view tiers. It has been implemented by using Java servlets. The initial version of the prototype has been developed to test the underlying theoretical concepts and frameworks. It is envisaged that the next version of the prototype will adopt the web service architecture where individual components will be implemented as web services. This solution should provide much better flexibility and interoperability between components than what is currently the case. At the same time, the objective is to move from the proprietary system to a system that will be compliant with the emerging educational technology standards to the extent that is possible without limiting its required flexibility.

Using the web-based handbook

Going back to the motivating examples introduced previously in this paper, suppose that both teachers A and B are given access to the web-based handbook. The following are some examples of the possible components that could be stored in the knowledge repository:

- *Problem registration* – This component enables teachers to post the assignment on the web. Students will be automatically notified that the assignment is ready via e-mails. This will also generate a temporal constraint (submission deadline) that is used for verification purposes during model composition as well as process instance.

- *Registration of groups* – When this component is used, students will receive an invitation to register their groups by the given date. If configured in that way by the teacher, this component may, for example, automatically form groups of all students who fail to register by the deadline.

- *Problem-solving component* – For example this component may include a number of subcomponents both generic and subject specific such as electronic brainstorming, mind-mapping, alternative analysis or collaborative design of ER diagrams.

- *Assignment submission component* – This component can be designed to work similarly to conference paper submission system or simply to remind the students of the approaching deadline and issue a confirmation that the assignment has been submitted.

- *Peer-review component* – This component could be configured by the teacher in a variety of ways to support different roles and coordinate tasks accordingly. For example, the same item can be marked only by the lecturer or by two different groups of students or even by an external marker.

Note that when stored in the knowledge repository these components are not pre-ordered in any way (e.g. in a form of a activity tree). Therefore, they could be selected independently as required by a particular learning design.

Even with this small number of components teachers can create several different combinations of learning designs. For example, teacher B may assemble all the above components into a process, giving her students a choice between various problem-solving subcomponents. At the same time teacher A may decide to use only “problem registration” and “assignment submission” components and supplement them with traditional face-to-face problem solving activities. Teacher C may request development of a new problem-solving component that will simulate De Bono’s “Six thinking hats” activity (De Bono, 2001). Teacher D may decide to use electronic debate instead of the electronic brainstorming tool etc.

Furthermore, when creating learning designs some teachers may decide to assemble a complete model during design phase and then use it without any changes. Others may decide to use semi-structured or unstructured models and then complete these models during run-time depending on students’ progress.

In essence, as these teachers gain more and more experience in using the web-based handbook, they will be able to invent further components and delegate their implementation to knowledge engineers. Once components are developed and stored in the repository, all users (with valid access privileges) will be able to share and reuse the stored components, process models as well as process-related experience.

Web-based handbook and SCORM Standard

The main purpose of this section is to discuss a possible relationship between the web-based handbook as new educational technology and SCORM as an emerging educational technology standard. More precisely, this section explains to what extend the web-based handbook can benefit from the current developments in SCORM. It also defines new research and development challenges that are yet to be addressed by this or other emerging standards. For more details on SCORM see (ADL, 2004a and 2004b).

A possible relationship between the web-based handbook and SCORM can be analysed along several important dimensions as follows:

- *Instructional design approach*

Although the term "content" may have different broad interpretations, SCORM standard may be more suitable for a Learning Management System designed to support the "resource (or content) – centered" approach to instructional design. SCORM enables a content to be dynamically sequenced for each learner. Learners are then monitored as they progress though the content. A learning activity designed for each student is also content-based. Moreover, learning objectives are narrowly defined and based on student's progress though the assigned unit of content.

On the other hand the web-based handbook technology adopts the activity-centered approach to instructional design. Recall that design of a process-oriented learning design starts from the intended learning objectives. Here, learning objectives are defined for the whole process. However, in many instances, they may not be directly associated with student's progress through the assigned content and therefore, cannot be easily monitored and measured by technology.

- *Mode of learning*

SCORM standard is designed primarily for an e-learning environment. On the other hand, the web-based handbook incorporates process-oriented learning designs that have both technology supported tasks as well as the tasks that could be, but are not necessarily supported by technology (face-to-face discussion, lecture presentation etc.).

- *Modeling of a learning activity*

In SCORM, a conceptual structure of a learning activity for each learner is called an activity tree. The current model of an activity tree is not flexible enough to support the requirements of the web-based handbook. When designing process-oriented learning designs, teachers need more flexibility as they could change the sequence during run-time as well as introduce new tasks or skip some of the existing tasks. In this way, teachers should be allowed to interact with the model to make sure that students are using the available tools and resources in the best possible way and more importantly that they are meeting the intended learning objectives. Furthermore, the nature of individual tasks may vary. They may not be directly linked to the content and completion of a content module (as in SCORM).

An activity tree in SCORM is designed for individual learners. In the web-based handbook, models are designed and components selected for a cohort of students as well as their teachers. Students may progress through some tasks individually and as a group through the other tasks. To enable collaborative work in some instances, students have to be *aware* of each other's tasks. Then, some tasks are designed for teachers too. Students' and teacher's activities are then coordinated to achieve the intended objective.

- *Navigation and sequencing (coordination mechanism)*

As already pointed out, navigation and sequencing mechanism provided by SCORM could be, to larger extent, provided also by workflows. Therefore, compared to workflows, the main advantage of the current version of SCORM is not in the functionality of its sequencing mechanism. Rather, it is in its semantic richness as it is designed for the educational domain.

However, both workflow and SCORM based navigation and sequencing are not flexible enough for the requirements of the web-based handbook. The current version of the web-based handbook is using a special-purpose, component-based, declarative model of a process model and proprietary component-based coordination engine that is more flexible than traditional workflow engine. In the future, a more flexible solution could be provided by web services.

➢ *Integration*

In terms of integration, SCORM enables integration and reusability of instruction components. For the purposes of the web-based handbook it is necessary to consider integration at several different levels. At the technical level, it is necessary to ensure integration of content as well as various existing applications and tools. Both SCORM standard and web services deal with integration issues. However, it is more important to enable integration at the conceptual level (including non-IT tasks) to enable consistent, well-designed and educationally sound process-oriented learning design.

Finally, design of the web-based handbook supports the vision that the real value of this new type of educational technology is not in coordination and interoperability mechanisms that support a particular process at the technical level. Rather, the real value is in the wealth of externalised models of tacit knowledge stored in the knowledge repository in a form of models of process-related learning designs and their enabling components. Therefore, the main objective of the web-based handbook is to enable teachers and capture, store, share and reuse learning experiences.

Web-based handbook – the main research challenges

Design and implementation of the web-based handbook is a complex research and development problem that cannot be solved by a simple integration of the existing methods and tools available in the identified related disciplines. This section describes how design and implementation of the web-based handbook creates a set of new interesting challenges for all related disciplines used in the framework.

➢ *Educational theories:*

The main research challenge here is how to create an instructionally sound model of process-oriented learning designs that will match the identified learning objectives. Then, once the model is created, the next challenge is to support teachers to identify/select, configure and assemble a set of executable components that will support/ enable the intended learning design. These research challenges are likely to result in further extensions of the activity-centered approach to design of student experience.

Another equally important educational challenge is related to evaluation of process-oriented learning designs. Therefore, it is necessary to design new instruments that will evaluate the proposed learning designs to make sure they meet the intended learning objectives. Furthermore, it is also necessary to design evaluation instruments to evaluate the use of the web-based handbook by teachers and consequently possible effects of improved knowledge sharing on student learning.

➢ *Educational technology:*

When designing and implementing the web-based handbook, in addition to content integration, it is necessary to integrate the existing tools and applications (for example collaboration tools such as chat and bulletin board) as they could be used in individual tasks. As already pointed out, the integration problem has been solved to some extend by the emerging SCORM standard (ADL, 2004a) that enables integration of content as well as web services that enable integration of applications and tools. However, web services need to be designed to comply with the existing educational standards. This, in turn, may require a possible extension of the existing web service standards (such as Web Service Description Language WSDL) or creation of new cross-disciplinary standards (between web services and educational technologies).

In order to support more flexible learning designs it is necessary to extend SCORM even further than what is currently possible. In that respect, some important lessons could be taken from the field of process-related technologies. There are more than 100 commercial workflow products, each using a workflow engine to enable scheduling and coordination of tasks in a much more complex way that what is currently possible with SCORM.

Yet, more than decade of research and practical use of this technology has proven that this technology has been successful only when applied to highly structured, repetitive processes. One of the current challenges in this area is a possible support for highly flexible emergent processes. On the other hand, SCORM's navigation and sequencing mechanism, at least at this stage, appears to be very similar in terms of its functionality. Consequently, it may prove to be as inflexible as workflow models and their coordination mechanism.

Most importantly, when designing learning designs it is important to concentrate on their instructional value rather than technology and coordination mechanism. Obviously, the emerging standards are important in order to create solid and stable technical infrastructure, however their adoption could easily result in the technology-centered learning. "…Unless all learning specification turn the focus from infrastructure to pedagogical soundness, they are in danger of becoming instructionally irrelevant…Despite the progress being made on the interoperability front, that doesn't necessarily guarantee that what actually runs on SCORM systems will be worthwhile instructionally."(Welsch, 2004, pg. 2).

Teaching is highly creative process and should not be restricted by inflexible technology. At the same time, capturing of this creativity could be made possible, to some extend, with the help of new educational technology such as the web-based handbook. But at the same time, another standards body should emerge that would create e-learning instructional standards separately from basic e-learning infrastructure standard (Merill as cited by Welsh, 2004).

- *Knowledge-management:*

The main research challenge here is to design a simple methodology that will enable teachers (helped by knowledge engineers) to externalise their tacit knowledge and create process-oriented learning designs in a form that could be stored, shared, combined and reused. This also includes mapping between the process model and executable components. Ultimately, this transfer of domain knowledge is necessary for the on-going development of new executable components.

Another interesting knowledge management challenge relates to various organisational strategies that need to be developed to encourage sharing of learning designs between practitioners (teachers). The current body of knowledge in the area of professional communities of practice could also benefit from this research on sharing of best innovative practices among teachers.

- *Software Engineering:*

The main research challenges here are related to component-based software engineering methods especially in the area of specification and verification of re-useable (process-oriented) components in the educational domain. What makes this challenge very interesting is the fact that the end-users, helped by knowledge engineers, should be able to select, assemble and verify components as well as execute (enact) the resulting processes without any programming involved.

- *Process management and process-oriented technologies:*

Recall that in the existing process-oriented technologies (such as workflows), process-specialists are in charge of process modeling. In the case of the web-based handbook, the main process-related research challenges are: end-user process modeling and support for emergent processes. To tackle the first challenge, it is necessary to design methodologies and tools for end-user support (e.g. the simulation and verification of process designs). So far, process-related technologies do not adequately support end-user modeling as tools are designed for professional process analysts.

Another equally challenging research problem includes support for emergent learning designs. These are process-oriented learning designs that evolve with experience (for example in the case of problem-based learning). Currently available solutions in the area of emergent business processes are still immature. However, design of technology support for emergent learning designs is, in many aspects, much more challenging than support for emergent business processes. The main emphasis is not on process effectiveness as in business but on student learning.

➢ *Web-services:*

The area of web service research and implementation is currently emerging with many standards, models and methodologies yet to be widely adopted. So far, the main driver as well as the application domain has been business rather than education.

However, the needs of these two domains are very different. Before this promising technology can be adopted more effectively in education, further investigation of the issues related to web service composition and deployment in the educational domain is required. This includes the educational, technical, organisational and social implications of offering learning designs as web services. At the same time, exchange of ideas between web service and educational technology communities should be further encouraged as they are many concepts related to process support that could be shared.

Conclusions and future work

"Process-oriented learning designs" is a new term used to describe innovative learning activities that include a set of inter-related learning tasks (thus, they are process-oriented) and are generic (can be used across different educational disciplines). Process-oriented learning designs are at the core of socio-constructivist theory of learning and there is strong evidence that students learn more then they are actively involved in a process rather than isolated learning tasks. Consequently, there is a need to create and share process-oriented learning designs among teachers, especially in the world where information technologies constantly change what is possible.

The paper investigates the problems of creation, sharing and IT support of process-oriented learning designs and proposes a new type of process-oriented, knowledge management educational technology called the web-based handbook. It is envisaged that this technology will enable teachers to assemble, share, reuse and execute process-oriented learning designs. Design of this technology is based on the multidisciplinary research framework that integrates up-to-date research in six different area of research: the existing educational theories, educational technologies, knowledge management, software engineering, process management and web services. The paper then uses this multidisciplinary framework to identify the main research challenges that need to be solved before this technology can be adopted on a larger scale.

In summary, the web-based handbook enables teachers to: (i) reuse not only educational resources but innovative teaching practices; (ii) combine the same components in different ways (where possible) and create different learning experiences for their students (iii) share their experience with other teachers and learn from their successful and less successful experiences.

Current and future work in this area includes further investigation of the identified research challenges related to both implementation and deployment of this new type of educational technology.

Acknowledgement

This research was partially supported by the UNSW Vice-Chancellor (Education)'s Innovative Teaching and Educational Technology Fellowship, ITET4, 2003.

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