Technology-Supported Management of Collaborative Learning Processes

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Abstract: This article deals with collaborative learning processes in a technology-enhanced learning environment and claims that a fully-fledged technological support for management of such processes is still missing. To back up that claim the article introduces an analysis framework for the evaluation of the state-of-the-art in technology-supported management of learning processes. This evaluation clearly reveals deficiencies in such a support and points out possible approaches for resolving the identified problems and drawbacks. As one of such approaches the paper discusses possibilities of using the Business Process Management technology for the management of collaborative learning processes.

Keywords: Learning Process, Collaboration, Learning Processes Management, Business Process Management

1. Introduction

Although the process-oriented nature of collaborative learning in traditional settings is indisputable, both E-Learning in general and collaborative E-Learning in particular commonly neglect this fact. Typically, E-Learning adopts one of the following learning modelling approaches: the content-oriented, the tool-oriented, or the task-oriented approach (Marjanovic, 2005). Commonly, these approaches are discrete and independent and they are rarely used simultaneously in E-learning:

Content-oriented approach is mainly concerned with management of learning content in E-Learning systems by supporting authoring, structuring, delivering, sharing, re-using, and querying of the content. Additionally, an extensive tool support for the students in their daily work with the learning content is commonly provided. For example, this support includes collaborative tools for enriching the learning content by writing comments and annotations, tools for tracking the student progress with the content, or tools for adapting the content to the students' preferences (Barron, 1998; Collis and Strijker, 2003; Barker, 2004).

Tool-oriented approach is based on the underlying technological infrastructure. Learning sessions which follow this approach are organised around the use of a particular collaborative tool and thus only reflect the technology. For example, moderated discussions or online conferencing sessions are typical uses of a discussion forum or a chat tool, respectively (Mioduser et al., 2000).

Task-oriented approach deals with learning tasks or learning activities which the students need to perform in their learning sessions. Those tasks are typically structured in very simple learning sequences that the students need to pass in a sequential mode. Commonly, learning tasks include reading, writing, or commenting tasks and are typically associated with a specific learning content (Agostinho et al., 2002; Oliver and Herrington, 2003; Collis and Margaryan, 2004).

The main goals of this article are first to show that none of these approaches deals with the learning process itself, but addresses only certain parts of such a process; second, that this situation can be seen as a major drawback in E-Learning; and third, to discuss possible solutions and future developments that might provide remedy for these problems. To achieve these goals the article focuses on an analytical survey of the current situation, trends, standardisation efforts, and systems for technology-supported management of collaborative learning processes. The data for this study was collected over the last 5 years in a number of European-wide research, commercial, and university E-Learning projects (Pfahl et al., 2004; Helic et al., 2004; Helic et al., 2005). For the purposes of this analysis the article introduces a generic technology-aware analysis framework for collaborative learning processes. In the next step, the state-of-the-art in the field is compared with this framework to infer its weaknesses, drawbacks, problems, and possible strengths. Finally, the results of this analysis are used to propose remedies to the identified problems and drawbacks.

2. Technology-Aware Framework for Collaborative Learning Processes

A significant work has been done on learning processes (McIlrath and Huitt, 1995) in general and collaborative learning processes (Reinmann-Rothmeier and Mandl, 1999; Resnick, 1989) in particular. Summarizing, collaborative learning processes are such learning processes where learning tasks are based on real-life tasks or authentic situations and typically require and motivate the co-operation or collaboration (co-construction and exchange of knowledge) of learners in a group. In addition, collaborative learning processes realise central features of a "learning community", i.e. they promote the development of both individual and socially shared knowledge; support and instruct the learning group on how to reflect their individual and collective experiences, identify their learning needs, and continually evaluate their knowledge and experience development (promotion of meta-cognitive processes); initiate the sharing and negotiation of knowledge by developing of a positive learning culture; take care that the group members are structurally interrelated and remain open-minded to external knowledge resources; and strive to support the development of a group-oriented identity.

In technology-enhanced learning field there are number of initiatives to develop various tools for collaborative learning (Althoff et al., 2002). For example, one of such projects was the project called CORONET (Corporate Software Engineering Knowledge Networks for Improved Training of the Work Force) that was funded by the European Commission (IST-1999-11634). The main purpose of the project was to analyse, implement and evaluate a number of tools for support of collaborative knowledge transfer processes. Each of such tools utilised the current and advanced Web technology to facilitate and speed the flow of knowledge from people possessing that knowledge to people who need to acquire it by following a particular collaborative didactical approach in a process-oriented manner. Thus, processes such as Web-based tutoring, Web-based knowledge mining, Web-based collaborative writing, and collaborative project-oriented learning have been supported. The evaluation of the project results in respect to the increase of learning effectiveness by knowledge sharing and collaborative learning generally indicated improved learning effectiveness (Pfahl et al., 2004; Helic et al., 2004; Helic et al., 2005).

The previous research and development suggests that the collaborative learning processes in an E-Learning environment contained the following five components: learning content, learning procedure, communication and collaboration facilities, technological infrastructure, and run-time execution procedure (see Figure 1):

Learning content in technology-enhanced collaborative learning comes in various electronic formats. The formats include courseware structured according to the latest E-Learning standards such as Sharable Content Object Reference Model (SCORM), text and media-enriched documents in different formats (Baudry et al., 2005), external Web documents including discussion board contributions, various blogs (Avram et al., 2004), or wiki-like contributions (Fuchs-Kittowski et al., 2004). Sometimes the content is not directly available in electronic form and needs first to be converted into that form. For example, a lot of learning content is still available only in text books, or is simply a part of knowledge that different participants in the learning process possess. Before such learning content might become a direct component of the learning process it needs to be extracted from the people and transformed into electronic form (Oliveira and de Souza, 2004). This, in turn, is typically achieved through communication and collaboration with other participants in the learning process (Maybury, 2002).

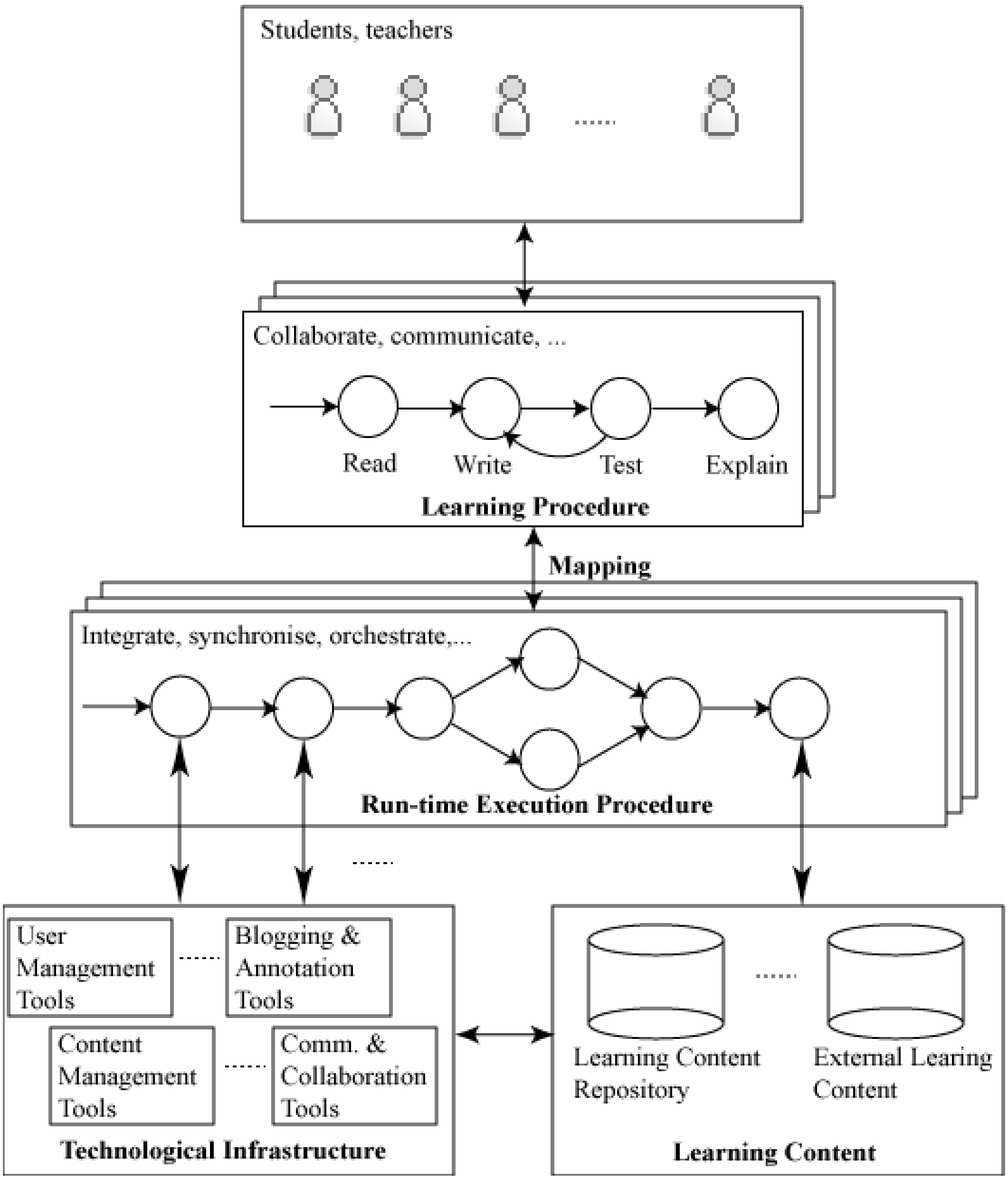

Figure 1: Generic Learning Processes Framework

Learning procedure is a structured rule-based sequence of learning activities or learning tasks; those need to be executed by different participants in the learning process in order to achieve a particular learning goal (Sampson and Karampiperis, 2006). The rules which govern the execution of such a learning sequence typically follow a particular didactic approach (Schroeder and Spannagel, 2006). For example, for the above-mentioned collaborative project-oriented learning process applied to teaching software development the following learning procedure can be defined. First, the students need to read about different software development methods. Second, the students develop collaboratively a particular software system by following an iterative software development method including analysis, design, implementation and test phases. After each of these activities the teacher provides feedback for the students. One of the sequencing rules requires the students to repeat a particular step if the teacher's feedback is negative (Helic et al., 2005).

Communication and collaboration between participants is one of the most important aspects of the learning process. Nowadays, learning is essentially a social process where the possibility of establishing a contact with other people, discussing, exchanging, and brainstorming ideas with the peers, or learning and working together with others is of primary importance (Repman et al., 2004; Hawkes, 2001; Rico, 2003; George, 2004). Huge success stories of so-called social software applications, such as blog applications, shared bookmarks, or wiki-based encyclopaedias are typical examples of the importance of the role which communication and collaboration play in technology-enhanced learning today.

Technological infrastructure and tools support different aspects of the learning process. This infrastructure includes but is not limited to user management tools, access right management tools, content management systems, content presentation tools, synchronous and asynchronous communication tools, as well as collaboration tools such as version control systems, shared content structuring and management systems, or annotation tools (Shih, 2002).

Run-time execution procedure is obtained by mapping the learning procedure onto the available tools and the technological infrastructure. Such an execution procedure typically defines composition, communication, and orchestration rules which are needed to successfully integrate and control the tools that are required to support high-level learning activities and the rules governing them (Junzhou et al., 2006; Torres et al., 2005; Lin et al., 2001). For example, for the above mentioned project-oriented learning process (Helic et al., 2005) the execution procedure would include tools such as user and access right management system (for controlling who can do what), content viewer (for the reading of the learning content), discussion forum (for a general discussion of all issues related to the learning process), upload tool (for the uploading of the course results), feedback, annotation and e-mail tool (for providing feedback and writing comments on the students' work). In addition, a number of execution rules should be defined inn order to control the way how different tools communicate and work together. For example, one rule might state that a student needs to be automatically notified by e-mail whenever the teacher provides feedback for that student; another rule provides automatic tool support for the student to repeat certain steps in the learning process if that feedback was negative (see Figure 2).

The most significant deficiencies of the E-Learning modelling approaches mentioned above, i.e., the content, task, and tool-oriented approach when compared with this framework can be summarized as follows:

- Lack of possibility to formally define a particular learning goal, which the students need to achieve, as well as a lack of possibility to automatically check the students' success in achieving that goal. Currently, the learning goal can be defined informally, e.g. by describing it within the learning content or within a discussion forum contribution. Obviously, checking of the students' success can only be accomplished by the users.
- Lack of possibility to define the learning procedure, i.e., the set of learning activities structured by means of certain pedagogical rules that lead students to achieving the learning goal (Marjanovic, 2005). For example, these learning procedures might reflect such sophisticated pedagogical approaches as problem-based learning, collaborative writing, or project-based learning. It is important to note here the

difference between such learning procedures and simple sequences of learning activities from the task-oriented approach.

- Lack of possibility to automatically map the learning procedure onto the available tools and the underlying technological infrastructure.

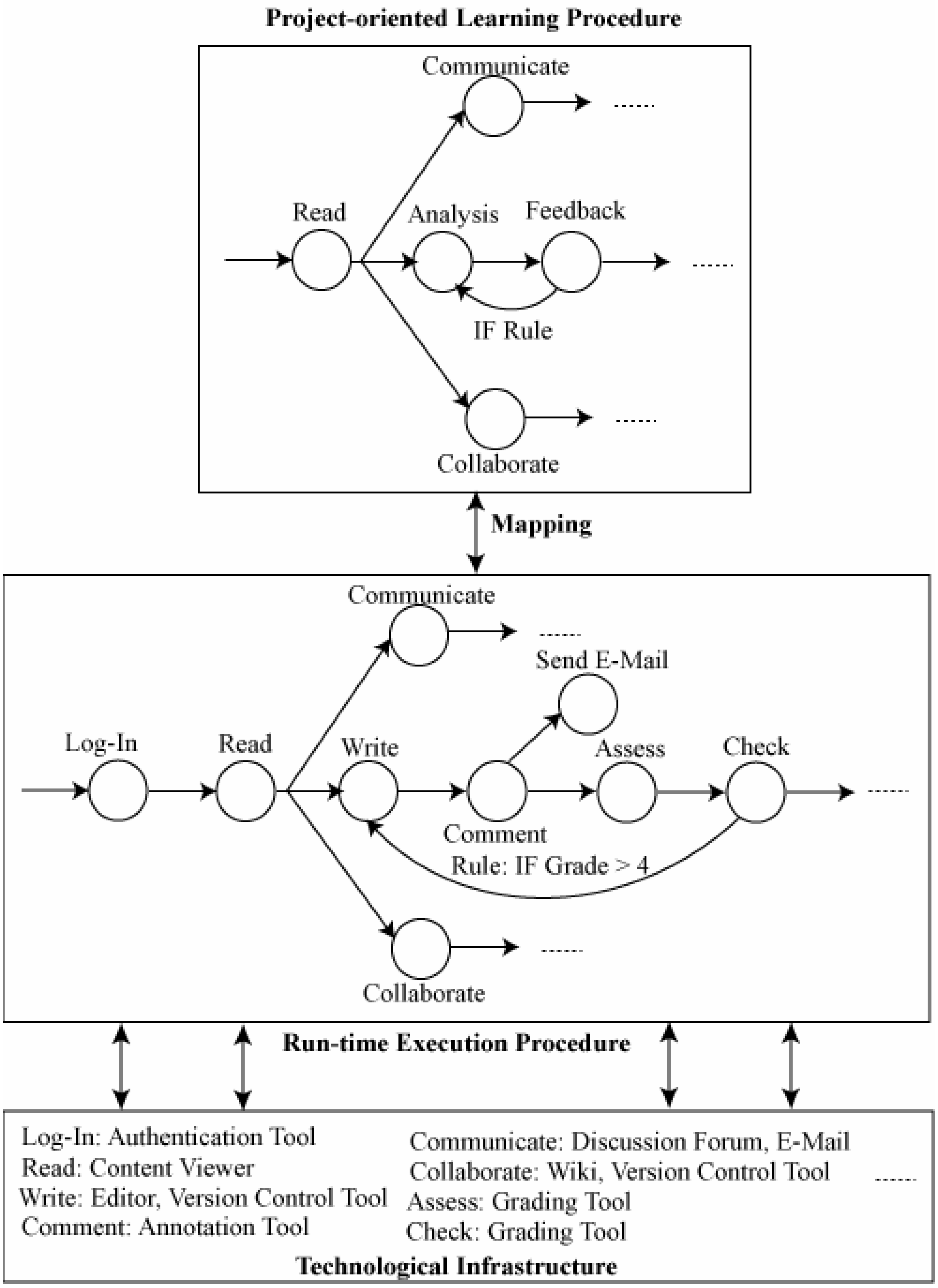

Figure 2: Learning Process for Project-Oriented Learning

The final issue which the developed analysis framework takes into account is the fact that collaborative learning processes exhibit a very dynamic nature in practice (Pfahl et al., 2004; Helic et al., 2004). First of all, there exist a wide range of external factors which influence the way of how learning processes and their components are developed or executed – a small change in these external factors leads to changes in the learning process. Also, learning processes are typically repeated by new students and therefore they are typically closely observed for their further modifications and improvements. Table 1 summarizes some of the typical changes in external factors and how these changes affect learning processes.

External Factors	**Influence on Learning Process Components**
Changes in knowledge and skill level	Learning content needs to be adapted Learning and run-time execution procedures need to be customised
Changes in organisation structure (e.g. when a team member leaves a team)	Communication and collaboration practices are changed
Improvements in didactical approach (e.g. when a learning process is repeated with new students)	Run-time execution procedure needs to be adjusted Increased communication to explain the new approach
New external learning content appears (e.g. through a blog or a wiki system)	Communication and collaboration practices might change Learning and run-time execution procedures might require customisation
Changes in technological infrastructure (e.g. a new software releases)	Run-time execution procedure needs to be adapted

Table 1: Dynamics of Collaborative Learning Processes

3. State-of-the-art in Management of Collaborative Learning Processes

In the university settings teachers commonly design, develop and publish their learning content using a standard E-Learning system such as *Blackboard* or *WebCT*. However, these modern E-Learning systems do not deal with learning processes per se, that is those systems support the learning process only partially. Typically, it is not possible to define the learning procedure or the pedagogical rules that will govern the learning process. Rather the teachers need to monitor the students and impose the pedagogical rules manually in order to lead the students to a particular learning goal. Apart from increased teacher workload this situation has another drawback. Basically, it is very difficult to improve the learning process for subsequent executions since the only modifications that can be made by the teachers are at the level of the learning content and not at the level of the learning procedure. This means that a subsequent execution of the same process requires that the teachers repeat their monitoring work since the system does not offer a possibility for modelling and improving of the learning procedure.

Recently, some standardisation, research, and development efforts have been undertaken that take into account process-oriented nature of technology-enhanced learning. Among these efforts there are two standardisation initiatives - SCORM Sequencing and Navigation and IMS Learning Design, as well as an innovative E-Learning system - Learning Activity Management System.

SCORM Sequencing and Navigation emerged from the IMS Simple Sequencing specification. This specification defines a standardised way of sequencing the learning content and learning activities for a particular student. Basically, it provides means for specifying so-called learning paths, which can branch according to the current learning situation. However, learning activities that occur along such a personalised and adaptive learning path are typically only reading or discussion activities. Essentially, SCORM Sequencing and Navigation might be seen only as an improved way of structuring the learning content to match the current learning situation, i.e. it can be hardly comprehended as a specification that supports management of collaborative learning processes (Kwang-Hoon et al., 2005; Yang et al., 2004).

IMS Learning Design (IMS-LD) provides a formalized way of describing activity-based learning scenarios and expressing different pedagogical concepts in the form of so-called Units-of-Learning. Units-of-Learning can be exchanged between different E-Learning systems for execution. For example, the above mentioned project-oriented learning process might be developed as an IMS-LD Unit-of-Learning that includes and structures all the learning activities such as reading, testing, analysing, designing, and implementing. Moreover, IMS-LD defines a number of formal constructs which might be used to apply certain pedagogical rules on the top of the learning activities. Thus, IMS-LD might be seen as a formal language to specify learning procedures. Additionally, IMS-LD Units-of-Learning might refer to the external learning content (e.g., by linking the content via Web addresses) or might refer to the tools and services available in an E-Learning system (Koper and Burgos, 2005). However, in the current version of IMS-LD those tools and services are restricted only to four simple services such as e-mail and discussion forum. Also, IMS-LD totally lacks possibilities to map the learning procedure onto the execution procedure, or to model the execution procedure. This means that this part of the learning process is basically unsupported by IMS-LD and it is up to the implementers of the IMS-LD specification how such a mapping and modelling can be accomplished. This represents a serious drawback of IMS-LD (Leo et al., 2004, Torres et al., 2005).

Learning Activity Management System (LAMS) is an E-Learning system implemented around a concept that E-Learning is as an activity-centric and workflow-based undertaking (Dalziel, 2003). The LAMS system was strongly inspired by the IMS-LD approach of modelling learning procedures in the form of Units-of-Learning. Later on, the implementation concentrated more on management of reusable learning activities, and the core functionality of E-Learning systems such as learning content management. LAMS proves to be very successful for supporting collaborative, experiential, self-initiated, and activity-oriented learning (Voerman and Phillip, 2005). Currently, LAMS is a fully-fledged E-Learning system and its learning process management functionality cannot be used without the rest of the system. Recently, LAMS has been extended to make it possible to integrate LAMS and its learning process modules into other external E-Learning systems and tools. Nevertheless, this integration support is provided only at the level of user authentication facilities, i.e. a single-sign-on procedure is provided which authenticates a user in both LAMS and an external E-Learning system. There are no possibilities whatsoever to sequence, structure, control, or orchestrate the external system by executing learning activities in LAMS. Basically, this means that to make use of management of learning processes by LAMS, the users need to abandon their E-Learning systems and move over to LAMS, which is typically not possible.

Thus, this short overview of the state-of-the-art in technology-supported management of learning processes shows that a fully-fledged support is still missing.

4. Supporting Learning Processes through Business Process Management

To successfully cope with the complexity of the collaborative learning process and its dynamics one of the most important requirements for the next generation of technology-enhanced learning is to facilitate technology-supported management of the collaborative learning process in its entirety. Such a technological support must include tools that provide fully-fledged support for all components of the process, as well as possibilities to smoothly manage changes in that process. In particular, such a support must include and integrate: learning content management component based on the recent E-Learning standards and principles; the basic and advanced E-Learning and collaborative tools; a modelling and authoring component for the creation of sophisticated collaborative learning procedures; an automatic or semi-automatic mechanism for mapping learning procedures onto the underlying technological infrastructure (i.e., onto run-time execution procedures); components for monitoring and analysing the students and their progress within a particular learning process; and finally facilities for altering, updating, and improving processes to be able to cope with their dynamics.

One possible approach to providing such a support might be a reuse of the experiences, practices and principles from technology-supported management and automation of business processes in organisations. There are close connections between collaborative learning processes and business processes at a number of levels. For example, at *the communication and collaboration level* human participants in both processes try to achieve a certain goal (i.e., a business or a learning goal) by working closely together with other people in a particular social context. Further, at *the procedural level*, both the business process and the learning process deal with tasks and activities structured in a certain way and executed by following a set of rules, i.e. business rules or pedagogical rules (the learning procedure) respectively. Also, at *the content level* both of the processes work with standardised and interoperable content in electronic form – the learning content or business documents. Finally, at *the run-time execution and technological infrastructure level* both processes rely on software systems and tools that need to be integrated, orchestrated, and synchronised by means of execution rules.

Let us now look more closely at the technological solutions for the management of business processes. Recently, such solutions are typically referred to as Business Process Management (BPM) technology. BPM evolved from the workflow technology and the Web technology. Workflow is typically defined as the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules (Hollingsworth, 1995). The automation is achieved through a so-called workflow management system that manages and executes workflows represented in a machine-understandable way. Participants of a workflow can be either humans or software systems that execute tasks defined in the workflow in order to achieve a particular business goal. Thereby, the humans work with the so-called worklist (i.e., a list of tasks to be executed) to achieve their goal. Currently, architectural principles such as Service-Oriented Architecture (SOA) and its particular implementation in the form of Web services are adopted by the workflow technology to achieve integration between Web-based software systems operating across the organizational boundaries. Additionally, the current workflow technology is based extensively on Web standards such as Extensible Markup Language (XML) to facilitate document and data exchange, to create definitions of service interfaces or to manage interoperable representations of workflows (Hollingsworth, 2004). For example, today workflows are typically defined using an XML-based language called Business Processes Execution Language (BPEL).

Obviously, basing management of collaborative learning processes on the BPM technology will bootstrap its development. Nevertheless, there are a few very important research and development steps which need to be realised for a successful application of BPM in learning process management. Those development steps take a top-down approach to supporting the whole management cycle for learning processes, i.e., first, facilities for creating and modelling of collaborative learning processes are addressed; second, mechanisms for automatic mapping, deploying, and executing of learning processes within the available technological infrastructure are taken into account; and finally, integration with existing user-interfaces are considered:

Step 1: Authoring and modelling of collaborative learning processes should be supported. Business processes are typically defined using a graphical notation, such as Business Process Modelling Notation (BPMN) or Unified Modelling Language (UML). To simplify authoring of learning processes a similar graphical notation should be taken as the authoring basis. For example, a learning process authoring tool might support a graphical notation for defining learning processes including learning tasks, activities, procedural pedagogical rules, participants and their roles. Since notations such as BPMN are meta-modelling notations, i.e. such notations introduce only abstract modelling elements such as task, activity, participant, role or rule; a pedagogy-specific vocabulary based on these abstract elements should be constructed. For example, learning tasks such as reading, writing, testing or reflecting might be introduced. Similarly, participant roles such as teacher, tutor, or student should also become a part of this pedagogical vocabulary.

Step 2: Mechanism for the mapping of conceptual learning process onto their executable counterparts should be introduced. Such a mapping must be possible with minimal user intervention, automatically or semi-automatically. Allowedly, this is a very difficult task, but a reasonable remedy can be found in template-based authoring, where the teacher specifies only a couple of parameters for a common template, for which an executable model (e.g. in BPEL) already exists.

Step 3: Seamless integration of run-time execution procedures and a general E-Learning system must be achieved. For example, E-Learning functionality might be exposed as a collection of interoperable and through open standards accessible functionality, e.g. in the form of Web services. Prior to that, a specification of interfaces for these Web services should be made. For example, suppose that a run-time learning process requires upload functionality to store student contributions. Typically, the E-Learning system offers upload functionality by means of a graphical user interface that communicates with a Web server. However, to integrate it with run-time learning processes upload functionality must be made available through a Web service with a clearly specified interface. Typically, the created Web service will operate only as a mediator between the specified interface and the concrete interface of the E-Learning system.

Step 4: Seamless integration of worklist user interface with the existing user interface of an E-Learning system must be achieved. For example, user interface of the worklist could follow the hypertext interface paradigm, e.g. different tasks might be represented as hyperlinks. By clicking on a particular task-related link users access the associated learning environment, i.e. a system tool associated with the task and the learning content needed to accomplish the task.

By following these steps the following generic architecture of a Learning Process Manager (LPM) might be inferred (see Figure 3).

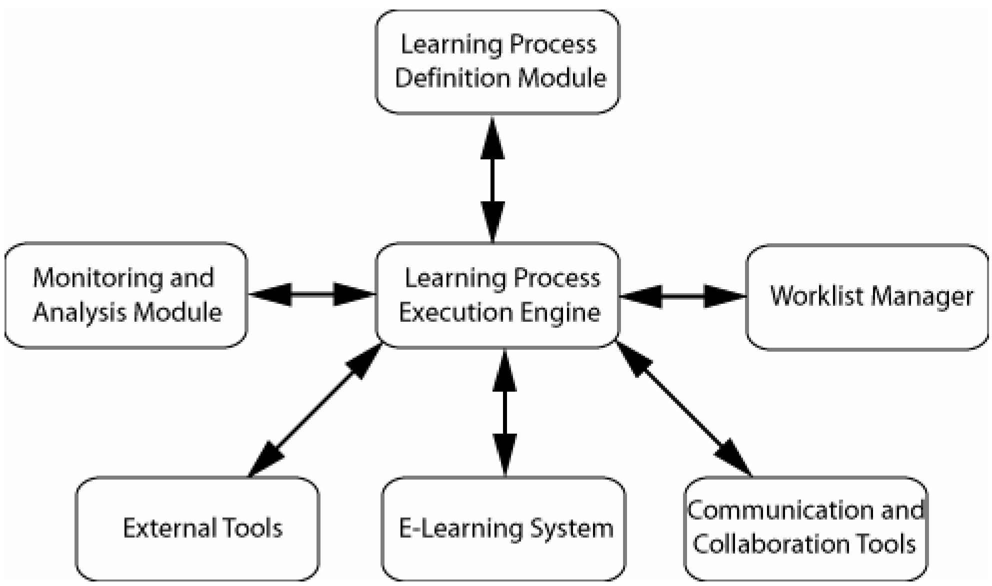

Figure 3: LPM Manager Architecture

Learning Process Execution Engine is the main component of LPM. The execution engine is responsible for the concurrent execution of a number of learning processes, which are typically called active learning processes. Each active learning process is an instance of a learning process definition (processes are defined using BPEL specification), which is associated with a unique execution context. Such an execution context keeps all the necessary information that is needed to, for example, identify the process instance, associate it with a unique user (e.g., a unique student), exchange data between the process and the external tools, provide learning and working tasks for users, store the current process state, or make execution sequencing decisions according to the execution rules. Thus, the execution engine leads the students through the learning sequence by creating the learning tasks and sending those tasks to the worklist manager, one task at a time.

Learning Process Definition Module is based on the defined pedagogical vocabulary. This vocabulary defines a number of typical collaborative learning activities such as reading, discussing, writing, testing, communicating, or brainstorming, as well as a number of typical user roles such as teacher, student, or tutor. On top of this vocabulary a number of learning process templates are prepared. These templates reflect typical collaborative learning processes such as project-oriented learning or collaborative writing. Each template is defined through the learning procedure and a corresponding execution procedure. For example, collaborative writing template defines the following learning procedure. First, the students need to read a document that explains important concepts from the subject domain. Second, the students are informed about the topic of their written work. Third, the students discuss the topic. Fourth, the students write in collaboration a document about their topic. In parallel, they discuss their work and all other relevant issues. The corresponding execution procedure maps the learning activities from the learning procedure on the execution steps and connects them with the appropriate tools. For example, the discussion activity is mapped onto a discussion forum, the collaborative writing activity is mapped onto an upload tool associated with a version control system, and the whole process is connected to a user authentication system. Thus, the authoring process is based on selecting an appropriate template and defining a number of parameters to obtain a particular process definition. Typically, this process only involves associating of the learning activities from the learning procedure with the learning content. For example, to obtain a process definition instance for the collaborative writing template the teacher needs to supply two documents (or Web addresses of two documents). The first document is related to the first reading activity and explains the concepts from the subject domain. The second document is related to the second reading activity and describes the topic about which the students need to write their documents.

Worklist Manager keeps track about learning and working tasks for all users and for all running processes. Also, it provides an interface for retrieving all completed and all active activities for a particular user and a particular process. The worklist manager interface might also be used to set learning activities as completed. Additionally, a call-back mechanism provides a possibility to inform the execution engine about the completion of learning and working activities.

Monitoring and Analysis Module provides a graphical user interface that allows the teachers to investigate all properties of a running learning process. For example, the time needed to execute a particular learning activity, or to branch and sequence learning activities can be easily observed.

External Tools, E-Learning System, and Communication and Collaboration Tools expose their functionality in form of Web services to facilitate communication and interaction with the execution engine. Obviously, the exposed functionality closely reflects the learning activities that are defined in the pedagogical vocabulary. For example, to support the test learning activity, the E-Learning system has a Web service to retrieve the test results for a particular student or to set test results for a particular student. The latter functionality is needed whenever the teacher revises a student's test, and the former functionality is needed whenever the execution engine needs the test results to make a sequencing decision.

Currently, the process execution engine, the worklist manager, and the monitoring and analysis modules are available as the standard components of any BPM product. Therefore, the main research and development focus will be on development of the learning processes definition module, i.e., the *pedagogical vocabulary*, and the learning procedure templates that can be *automatically mapped onto executable processes*. Additionally, development of standardised interfaces for the *E-Learning functionality* and the *user-interface modules* should be carried out, in order to integrate both of them into the BPM process execution engine and the worklist manager, respectively.

5. Conclusion

This article analysed the state-of-the-art in technology-supported management of collaborative learning processes by comparing the current trends and developments in this field with a generic analysis framework for such processes. The analysis identified the problems, drawbacks, and weaknesses of such a support. The critical components that are still missing include facilities for formally modelling and defining of sophisticated learning procedures with clearly defined pedagogical rules and a learning goal, as well as an automatic or semi-automatic mechanism for the mapping of such procedures onto the available technological infrastructure of an organisation.

Therefore, there exists a necessity for a new generation of standards, architectures, and system implementations that will take into account these missing components. As a first step in that direction this article considered an application of Business Processes Management technology for the management of collaborative learning processes. The main reason for this proposal is the fact that close connections between collaborative learning processes and business processes can be established. For example, in both cases users, by closely working and learning together, try to achieve a certain business or learning goal by following a number of rules. Furthermore, in both cases users are supposed to work with a number of tools and the content in electronic form.

Additionally, four important areas for further research and development have been identified that address the issues related to the *modelling* and *automatic mapping* of collaborative learning processes onto the available technological infrastructure, as well as their integration into available E-Learning systems at the *functional* and *user-interface* level.

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