

Service-Oriented Coordination Platform for Technology-Enhanced Learning

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Abstract. It is currently difficult to coordinate learning processes, not only because multiple stakeholders are involved (such as students, teachers, administrative staff, technical staff), but also because these processes are driven by sophisticated rules (such as rules on how to provide learning material, rules on how to assess students' progress, rules on how to share educational responsibilities). This is one of the reasons for the slow progress in technology-enhanced learning. Consequently, there is a clear demand for technological facilitation of the coordination of learning processes. In this work, we suggest some solution directions that are based on SOA (Service-Oriented Architecture). In particular, we propose a coordination service pattern consistent with SOA and based on requirements that follow from an analysis of both learning processes and potentially useful support technologies. We present the service pattern considering both functional and non-functional issues, and we address policy enforcement as well. Finally, we complement our proposed architecture-level solution directions with an example. The example illustrates our ideas and is also used to identify: (i) a short list of educational IT services; (ii) related non-functional concerns; they will be considered in future work.

Keywords. e-Learning, Service-oriented architecture, ICT architecture, Coordination.

1 Introduction

The Web is currently a preferred medium for distance learning and the learning practice in this context is referred to as technology-enhanced learning or *e-learning*, for short [8]. We claim that actual e-learning challenges are: (i) Reinforcing the links between individual and organizational learning, and between learning and creativity - it is challenging to embed learning, embracing knowledge, competency, and talent as well as collaborative innovation and process workflows; (ii) Establishing and sustaining interdisciplinary networks on emerging trends; (iii) Allowing context-awareness and real-time adaptability in learning activities.

These challenges seem hard to resolve when taking into account the current state of the art in e-learning that rarely reaches much farther than the distribution of *.ppt* and

.pdf files (even sophisticated environments that support learning, such as Blackboard [2,3] are argued to be mainly content-driven and thus insufficiently powerful in terms of collaborativeness, knowledge co-creation, and context-awareness). We claim that this is partially due to the lack of instrumentation to adequately address the coordination-related needs associated with a learning process.

Coordinating learning processes is currently difficult, not only because multiple stakeholders are involved (such as students, teachers, administrative staff, technical staff), but also because these processes are driven by sophisticated rules (such as rules on how to provide learning material, rules on how to assess students' progress, rules on how to share educational responsibilities). This is one of the reasons for the slow progress in e-learning. Consequently, there is a clear demand for technological facilitation of the coordination of learning processes.

In this work, we suggest some solution directions that are based on *SOA - Service-Oriented Architecture* [1,13,20,21]. In particular, we propose a coordination service pattern consistent with SOA and based on requirements that follow from an analysis of both learning processes and potentially useful support technologies. We present the service pattern considering both functional and non-functional issues, and we address policy enforcement as well. Finally, we complement our proposed architecture-level solution directions with an example. The example illustrates our ideas and is also used to identify: (i) a short list of educational IT services; (ii) related non-functional concerns; they will be considered in future work.

The outline of the remaining of this paper is as follows: In Section 2, we introduce the Service-Oriented Architecture – SOA and we outline some of its strengths that are relevant to e-learning. In Section 3, we analyze the complex learning process and identify SOA-relevant requirements for an advanced ICT coordination system. Then, in Section 4 we propose architecture-level solution directions that relate to some of the identified requirements and are partially illustrated in Section 5 by the means of an example. Finally, in Section 6, we analyze related work and present our conclusions.

2 SOA for e-Learning

In this section, we briefly recall the principles that underlie service-oriented approaches and subsequently discuss the potential beneficial implications of these principles for the e-learning domain.

SOA Principles. The main objective of SOA is to be able to create new applications from existing services, independently of who provides these services, where they are provided, and how they are implemented. Although this ideal is hard to realize to a full extent given practical business requirements, SOA provides a sound architectural foundation [6] and supportive technologies are currently available to test service-oriented approaches in practice [11].

A 'service' is a self-standing piece of functionality offered to the outside world. To access this functionality, a service user interacts with the service interface, using messages and a basic message exchange pattern defined by the interface. The service interface is independent from the service implementation. For example, a legacy

application may expose its functionality through a service, thus allowing external use without disruptive measures for internal users. The technologies supporting these principles are WSDL, for the definition of web service interfaces, and SOAP, for the exchange of messages based on standard Internet protocols.

Service providers can store information on their services, called service descriptions, in public (or closed community) repositories, enabling users to discover services that fulfill their requirements. These repositories can be organized in much the same way as telephone directories, with white pages, yellow pages and green pages, to facilitate different search strategies. For example, a repository's 'green pages' provide information on how to interact with a service by giving a pointer to the corresponding interface (WSDL) definition. The functionality of a repository for storing and organizing service information and enabling discovery of services can be provided as yet another service. The technology supporting this is UDDI.

Often real-life collaborations require coordination between partners which cannot be enforced by the simple message exchange patterns defined by a service interface. Therefore, service behaviors have to be defined that capture required orderings and dependencies. There are two perspectives on service behavior. The first perspective, called choreography, is concerned with the exchange of messages between two or more partner processes. The second perspective, or orchestration, considers a message exchange from the point of view of one partner process. A technology for defining choreographies is WS-CDL. Frameworks for specific types of coordination are also available, such as WS-Transaction. Orchestrations can be defined with WS-BPEL.

Choreography is essentially a public process or protocol that tells a partner how to behave in order to take part in a collaboration. On the other hand, an orchestration is a private process which specifies interactions with external services. An orchestration can therefore be used to define a composition of services. The result of this composition can again be exposed as a service. This composite service has a richer functionality or targets a more specialized community of users compared to the composed, or atomic, services. Since composite services may again be used in compositions, a hierarchical organization and composition is possible. Advanced discovery and composition algorithms allow rapid service creation and even dynamic service composition at run time. In the latter case, a service request is resolved by a suitable service composition (in case no match exists between the request and an individual service) based on the services found in the services registry. OWL-WS is a technology that allows the composition of services in a workflow using semantic information.

For an overview structure of SOA-related standards, we like to refer the reader to Figure 4 in [20].

Benefits for e-Learning. Being able to abstract from technological details and create reusable components (i.e., services) brings several potential benefits to enterprises, including those involved in education. Here, we will focus on the benefits from the e-learning perspective.

First of all, SOA allows institutions to continue to use legacy applications in new systems. This is the case since services are described independently from any implementation technology, and are accessed through standard WSDL interfaces. It is important to realize the relevance of this principle for the e-learning domain. Educational institutions must integrate processes and provide services for many

different people: those involved in the primary process, such as teachers, students, and assistants; those involved in providing educational resources, such as librarians; those involved in administrative support; those involved in planning, designing and maintaining educational material, systems, facilities and so on. Because of the varying needs of these people, educational institutions typically use various IT systems, legacy as well as new, which have to share data in order to support the enterprise processes.

SOA allows to mix and match legacy applications exposed as services with new application components to form composite applications. Moreover, 3rd party applications may be used as well, provided they are exposed as services. In this way, an e-learning system may be assembled by choosing required functionalities from the Web, if not available in-house, instead of building them from scratch or buying packages that have to be installed and integrated in the existing environment. Again, this can be of great benefit to educational institutions, since each of them has developed components (course material, course delivery systems, searchable repositories of learning objects and so on) which are potentially useful to other institutions.

Hence, SOA brings greater flexibility to (re-)use applications and to develop new applications and systems. Development may be much faster, and more cost-effective, also because services of 3rd party applications can be incorporated in new systems. Maintenance may also be easier, as implementations of services can be replaced without affecting functionality, and functionality may be changed or extended according to new requirements by changing or extending the composition of services. In addition, focus can be on domain aspects such as learning, processes and experience, instead of on technology.

The modular approach supported by SOA also allows educational institutions to offer diversity and apply different pedagogical methods according to purpose, audience and circumstances. Furthermore, e-learning may become more learner-centric and personalized, with high learner-empowerment and personalized learning pathways, thanks to the greater flexibility offered by SOA. Two parallel technological developments related to SOA are relevant here: dynamic service composition and context-aware services.

Dynamic service composition refers to the possibility to have runtime discovery, selection and composition of services based on a user request, followed by the delivery of the resulting composite service to the user who submitted the request. This technology is still in an early stage, based on syntactic matching of input and output messages of atomic (request-response) services. However, it is expected that advances in this area will allow semantic discovery and matching of services with more complex behaviors. A future scenario could be that a learner formulates requirements in terms of learning objectives, topics and timing, and that a service discovery and composition engine subsequently proposes possible services bundles which can be scheduled for delivery.

Context-aware services concern applications that take the context of the user into account when delivering their services to that user. User context comprises a range of dynamic properties that reveal something about the person who is also the potential user of a service [15]. Examples are the geographical location, local weather or environmental conditions (temperature, humidity, pollution, toxic gases), physical activity (sleeping, exercising), and bodily position (standing, sitting, lying). User

context data is unobtrusively gathered by sensors, and converted into useful context information for the application through a process of aggregation and inference. The application then adapts its service based on the context information, which is correlated to perceived personal needs of the user. Context-aware technologies have been developed in several research projects, but design methods that can systematically derive useful context-aware services and scalable supportive mechanisms are still lacking. Nonetheless, the relevance of context-awareness for e-learning is not hard to imagine. A future scenario could be that the e-learning system uses context (as well as stored preferences and historical data) of individual learners to adapt its services in order increase effectiveness and efficiency of learning.

3 Implications from the Perspective of Learning

A typical learning process is driven by the necessity of educating the student [10]. It requires also considering the one helping students in acquiring knowledge, namely the teacher. Student and Teacher are hence two *essential roles* in any learning process. Besides teaching and learning, some other activities to be taken into account, especially in modern society, are: (i) student selection (**examiners** usually conduct an entrance selection); (ii) controlling the learning process (**administrators** usually execute control over teachers on the learning content; it is necessary clarifying that by administrators we do not mean the administrative staff responsible for gathering and processing some administrative information but those who control the courses with respect to fitness in the overall educational program). We claim that a student-teacher-examiner-administrator model can be considered as a valid although simplified model of any learning process (the model is in fact simplified because we ignore, for the sake of brevity, some issues including: *a*) another responsibility of examiners, namely to evaluate students (through exams); *b*) another responsibility of teachers, namely to specify the prerequisites for their courses and also the entrance criteria for the exam (e.g. some practical assignment may have to be completed and approved before entrance to an examination is allowed) while checking such prerequisites and criteria is usually responsibility of administrators). We thus consider Examiner and Administrator as two other essential roles in a typical learning process. In order to identify requirements, we hence need to structure this as an initial step in describing and analyzing the learning process in general.

Figure 1 shows the student-teacher-examiner-administrator model using a diagrammatic technique derived from DEMO [5,18,19]. The identified entities (reflecting corresponding roles) are presented in named boxes – these are Student (S), Teacher (T), Examiner (E), and Administrator (A), while the small grey boxes, one at an end of each connection, indicate the *executor* role of the connected entities. The connections indicate the need for interactions between entities, in order to fulfill the goal of educating; with each connection, we associate a single interaction, $i_1 - i_3$, as follows: S-E (i_1), S-T (i_2), T-A (i_3). As for the delimitation, S is positioned in the environment of the education system – ES, and E, T, and A together form the ES system. Through i_1 and i_2 , ES is related to its environment (represented by S).

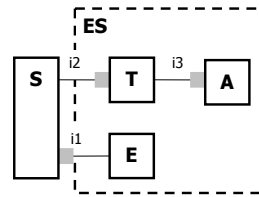


Fig. 1. A simplified business entity model for an education system.

In order to be part of the learning process, a student would have had fulfilled the entrance criteria, by passing some kind of entrance exam ($i1$ represents this with the student in an executor role since the student has to deliver). Once the student is in a position to participate in a learning process, a teacher is to deliver some kind of learning service ($i2$) however only under the condition that this has been approved by the controlling administration ($i3$).

This essential business model needs to be fulfilled by a realization no matter if it is technology-driven or not. Since we are mainly interested in service-oriented IT solutions, we analyze further the possible reflection of the model in that direction (it is to be stated nevertheless that much of the following concerns at the same time the business/institutional level). Further, we take an idealistic view, assuming that the possibility to transfer credits among some institutions is acceptable in general – said otherwise, a Student from University A can follow a course from University B and use the result for credits at University A. We make this assumption because we believe that the current globalization of education would lead to this. It might be even possible (in the near future) for students from universities which are not very prestigious, to attend courses in more prestigious universities. If this is the case nevertheless, such ‘external’ students would have to follow special ‘versions’ of these courses, adequate to their level and giving them less credit than to the ‘local’ students. As for the gap between what we want and what is available, we have mostly an ‘institutional’ gap and a coordination gap. This is because currently, sufficient technology exists, in our opinion, whose use is restricted however by university regulations, national regulations, and other regulations, and also by the lack of all-encompassing coordination mechanisms. Our proposed solution directions (that concern an open service platform) are not supposed to overcome the ‘institutional’ gap, being only directed to the coordination issue – this is considered to be the added value of what we propose in the current paper. It is to be mentioned as well that we do not consider a university as an isolated entity – we consider universities as global collaborative players, such that everybody can produce and consume global educational services, driven nevertheless by some underlying rules. We can therefore ‘draw’ on the basis of this initial information (presented above), a high-level view on what such a platform is to be:

- S-T *SEARCH* (ES should facilitate students in finding the most appropriate teachers for their needs and vice versa; we would however consider students to be in general foremost interested in the content (topic, learning material, course set-up) and only then look for the best or most suitable teacher);
- S-T *MATCH-MAKING* (ES should adequately connect a student(teacher) only to those teachers(students) who match properly for collaboration, which

includes for example matching students' demands and teachers' qualifications);

- S-E *EXAMINE* (ES should facilitate students in their finding the appropriate entrance exams and go for on-line selection with regard to the course(s) they would like to enroll in);
- A-T *REGULATE* (ES should support administrators to regulate teachers' work, by enforcing some compulsory rules through the platform);
- S-T *RANKING* (ES should help monitoring teachers' qualification, contribution and reputation, and storing such information for the purpose of ranking teachers);
- T-T *CO-CREATION* (ES should facilitate teachers in their co-creating courses, supported by course templates, collaboration tools as well as by wizards).

Based on the above analysis and motivated proposal, we firstly define some GENERAL REQUIREMENTS (demands) that are relevant to our suggested platform: (i) possibility of easy and flexible use minimum burdened by the underlying technology; (ii) process alignment (it is crucial that all ES-related processes are appropriately aligned and synchronized so that adequate coordination can take place); (iii) hierarchy of complex rules underlying the platform as a way to enforce the desired functionality guaranteeing that all users will be properly served.

Taking these high-level demands that relate to the technological perspective, we combine them with the domain details, considered in this section, concluding that the platform must be capable of enabling and facilitating an innovative methodology on how to conduct education. From this objective, some REQUIREMENTS ELABORATION can be derived upfront:

- it should be possible to mix and match learning modules offered by different organizations on geographically distributed nodes using diverse technologies;
- the mixing and matching is typically prepared and constrained by a program, by defining learning profiles, learning paths and learning policies that are generally useful with regard to a goal;
- the mixing and matching should be completed by the student, such that (s)he can tailor the learning content, method and plan according to personal needs and preferences given the constraints imposed by a learning program;
- it should be easy to add, remove and update learning modules so as to keep pace with changes in knowledge/skill demands and to profit from the availability of new or improved learning modules;
- it should be possible for students to transfer their experience and expertise to other students by contributing to or co-creating the content of certain learning modules;
- the delivery of learning content should be automatically adaptable to personal conditions, such as availability, place and device characteristics, using context sensors and context reasoning;
- teachers should have the possibility to be informed about the learning modules that are successfully completed by their students so as to compare realized and required knowledge/skill levels relevant for the considered education goals;
- students should have the possibility of knowing their knowledge/skill level (based on learning modules successfully completed) and as well how to improve it.

We discuss in the following section solution directions that relate to some of the requirements already defined.

4 Solution Directions

Elaborating further on how IT services can usefully support education goals, we will consider in this section: (i) the composition of IT services for education; (ii) related cross-cutting concerns; (iii) resolution of conflicting business processes.

Composition of IT Services for Education. The demands mentioned in the previous section provide a starting point to create education services. We need to take into account also the following:

- the *education services* may be supported in terms of *IT services* which in turn are provided by *generic education service components*;
- *business processes* need to be analyzed in order to adequately determine orchestration (coordination) with regard to the use of IT services.

We illustrate this view in Figure 2:

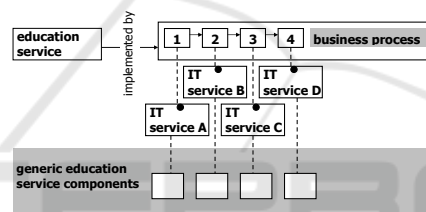


Fig. 2. Composition of IT services for education.

As shown in the figure, a business process implements an education service, as a way to underlie the desired functionality that corresponds to a customer (end-user) need. The business process needs to be analyzed in order to define adequately a data and control flow in which the supporting IT services are called in the right order and with the right parameters. Thus the IT services point to service components that are in general not especially developed for the application under consideration (for example, education resource manager, examiner, regulator), although they are specific for the education domain. They need to be configured (instantiated with the proper parameter values) in order to lead to the realization of IT services that relate to business process actions.

It is as well seen that (i) the upper part of the figure is about business activities unrestricted by technology (the education service is implemented by a business process that in turn consists of actions performed by humans (or at least controlled by humans)); (ii) the lower part of the figure concerns IT services which are realized by ICT components. We hence should address the 'IT level' with more attention because much at the 'business level' is driven by organizational and/or societal rules, human relations, intuitive human decisions, and so on, which need to be analyzed, simplified and reflected in the 'intelligence' of the IT system. The coordination (orchestration) of business actions is pushed by human intelligence; with regard to the coordination

of IT services nevertheless, we need to actually make decisions about it at design time. In considering technology-enhanced learning, we propose a single point of coordination because of the following reasons: (i) unlike in solving supply-chain-related mediation, for example, in supporting learning, we would not often have the case of hundreds of users being served simultaneously and therefore sophisticated coordination would add little value; (ii) mixing and matching learning modules (as required – consider Section 3) adequately would usually demand one point of coordination (otherwise, too complex facilities for prioritization would have to be considered); (iii) the domain of education is dynamic in a sense that often new rules/regulations appear, which means that the system design would have to be easily updateable, and with a single point of coordination updates would obviously be easier than in cases of complex coordination.

In the remaining of this paper, by *service* we mean only *IT service*.

Hence we introduce a service coordinator which in SOA terms should be a *service that can be invoked to coordinate other services* (we label such a service *coordination service*). In taking care of this nevertheless, the coordination service would deal inevitably with exchange of information concerning many issues, and this information would need hence to be stored and managed. We introduce thus a *service that can store information and allow other services to find information* (we label such a service *information service*). Such services (coordination-related and information-related) are claimed to be central for approaching problems that concern technology-enhanced learning in a service-oriented way. Figure 3 gives a general view on this.

The figure depicts 5 layers that are widely considered in discussing service-oriented reference architectures – ICT components can operate on top of an operational system, in their delivering services which in turn are developed for the purpose of supporting particular goals concerning some business processes, which goals appear with regard to needs of customers [7]. The layer that is explicitly considered in this work is the ‘Services’ layer and we thus elaborate there our proposed solution directions. As it can be seen from the figure, the coordination service and the information service are of crucial importance since they support the deliveries of all other services – the coordination service orchestrates the overall work of the system, invoking other services at the right moment and offering them also the right input; as for the relation between the coordination service and the information service, it is not trivial since the coordination service would need support from the information service on most of the service invocations, hence this complex relation is indicated by the dashed line between the coordination service and the information service. What is also shown in Figure 3 is that all other services operate through the mediation of the coordination service.

In the following section, we will identify through an illustrative example, a short list of IT services that have relevance to technology-enhanced learning. It should be noted that all that has been discussed so far with regard to IT services concerns the functional perspective and in order to be more exhaustive in presenting our proposal, we consider briefly in the below paragraphs crosscutting non-functional concerns.

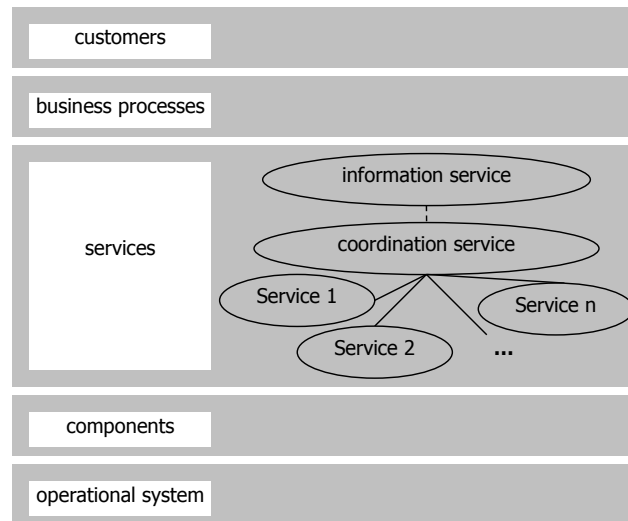


Fig. 3. A service-oriented solution direction for technology-enhanced learning.

Crosscutting Concerns. The architectural view already presented in the current section focuses on the desired primary functionality. Nevertheless, it appears that some concerns can not be easily localized and specified in individual architectural components, as researched by [22]. Similar to practice in aspect-oriented software development, we call such concerns *crosscutting concerns* [23,4]. Since crosscutting concerns are inherent, it is claimed that these cannot be undone simply by redefining the software architecture using conventional architectural abstractions. Explicit mechanisms are thus needed to identify, specify and evaluate such concerns at the architecture level. For the sake of brevity, we are not going to discuss this in further detail and will limit ourselves to only mentioning several such crosscutting concerns, especially ones that we claim to have relevance to the service-oriented IT support to technology-enhanced learning, as considered in the current paper: *synchronization*, *distribution*, *security*, *privacy*, and *logging* (illustrated in Figure 4):

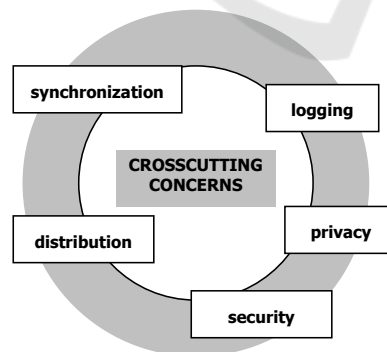


Fig. 4. Identified crosscutting concerns.

Although they are not specific to any particular process/component (with respect to the delivery of IT services for supporting technology-enhanced learning), these crosscutting concerns are still claimed to have huge importance for the adequacy of the platform, because:

- all processes that concern students and teachers are to be synchronized among each other and with respect to the overall program so that it is avoided for example that an exam is appointed for a date on which the examiner has also other obligations [**synchronization**];
- it is essential to offer support for distribution with regard to the need for courseware co-creation by teachers who are in different locations [**distribution**];
- high levels of security are necessary for adequately controlling numerous copyright-protected resources and personal data [**security**];
- privacy-sensitivity is essential in guaranteeing that for example, only the education-related data concerning students will be accessible to their teachers [**privacy**];
- it is also necessary keeping track of events that may later play a role in presenting proof of what actually happened [**logging**].

We have presented in both functional perspective and non-functional perspective our proposed views with respect to SOA-related supporting of activities that concern technology enhanced learning, and we will discuss in the remaining paragraphs of this section some complementary policy-related issues.

Policies. As already mentioned in this section, some corresponding business processes need to be analyzed in order to define adequately a data and control flow in which the supporting IT services are called in the right order and with the right parameters; this is needed in order to properly specify the coordination service which is responsible for invoking other services.

Hence, we need to consider *policies* in specifying the coordination service. This would often point a (standard) procedure that may be defined by rules (e.g., a service at a library often points to the following business process: Student makes selection of books, Librarian announces the maximum possible period of holding (each of) the books, Student takes the books). There could nevertheless be conflicting actions (in a business process) or even conflicting business processes [14]: let's assume, for example, that the education service 'Assessment' is implemented by a sequence of activities as follows: Examination, Evaluation, Announcement (the teacher should conduct the exam first, then make a review and put mark, and finally – announce the mark to the student); it may be that in cases of external teachers examining, there is a requirement for an approval (by a local teacher) of the evaluation output. We are thus facing a conflict that concerns both semantics and pragmatics [16].

Figure 5 illustrates this:

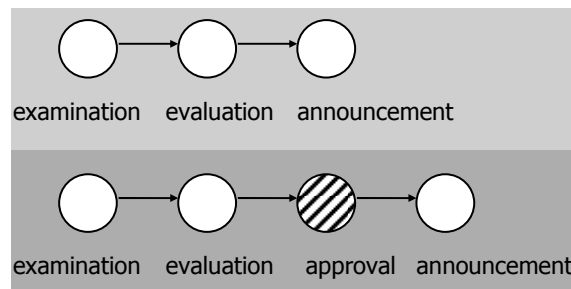


Fig. 5. A semantic conflict concerning an education service.

Based on previous work [17], we claim that Organizational Semiotics (OS) in general and the Norm Analysis Method – NAM [9], in particular can be of use in resolving such semantic conflicts and enforcing policies, taking into account not only the rules-related strengths of NAM but also its sound semantics-related OS theoretical roots.

Norms, which include formal and informal rules and regulations, define the dynamic conditions of the pattern of behavior existing in a community and govern how its members (agents) behave, think, make judgments and perceive the world.

Norms are developed through practical experiences of agents in a community, and in turn have functions of directing, coordinating and controlling their actions within the community. When modeling agents and their actions, which may reveal the repertoire of available behaviors of agents, norms will supply rationale for actions. Norms will also provide guidance for members to determine whether certain patterns of behavior are legal or acceptable within a given context. An individual member in the community, having learned the norms, will be able to use the knowledge to guide his or her actions, though he or she may decide to take either a norm-conforming or a norm-breaking action. When the norms of an organization are learned, it will be possible for one to expect and predict behavior and to collaborate with others in performing coordinated actions. Once the norms are understood, captured and represented in, for example, the form of deontic logic, it will serve as a basis for programming intelligent agents to perform many regular activities [9].

The long established classification of norms distinguishes between perceptual, evaluative, cognitive and behavioral norms; each governing human behavior from different aspects. However, in business process modeling, most rules and regulations fall into the category of behavioral norms. These norms prescribe what people must, may, and must not do, which are equivalent to three deontic operators “of obligation”, “of permission”, and “of prohibition”. Hence, the following format is considered suitable for specification of behavioral norms:

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whenever <condition>
if <state>
then <agent>
is <deontic operator>
to <action>

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The condition describes a matching situation where the norm is to be applied, and sometimes further specified with a state-clause (this clause is optional). The actor-

clause specifies the responsible actor for the action. The actor can be a staff member, or a customer, or a computer system if the right of decision-making is delegated to it. As for the next clause, it quantifies a deontic state and usually expresses in one of the three operators - permitted, forbidden and obliged. For the next clause, it defines the consequence of the norm. The consequence possibly leads to an action or to the generation of information for others to act [9].

Norms can be specified in both a natural language and a formal language. For example, adopting the format given above for specification of behavioral norms, a credit card company may state norms governing interest charges as:

whenever an amount of outstanding credit
if more than 25 days after posting
then the card holder
is obliged
to pay the interest.

We hence claim that underlying (hierarchies of) norms can play a useful role in enforcing policies with regard to the coordination service, as depicted in Figure 6, where the importance of enforcing policies in each service invocation is explicitly shown as well as our proposed use of a hierarchy of semiotic norms for that goal (a possible norm hierarchy is illustrated abstractly in the figure); the dashed line between the coordination service and the norms indicates the need for the service to be aware of the norms which it should enforce in invoking services.

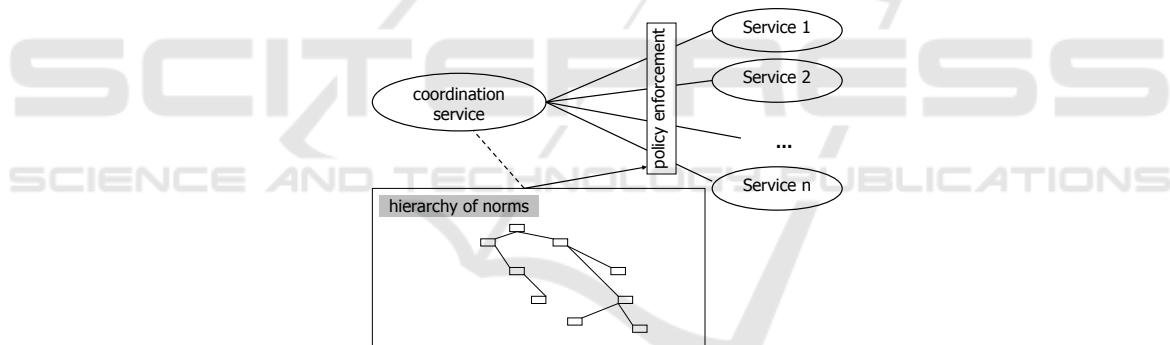


Fig. 6. Norm-driven policy enforcement.

After having introduced our proposed solution directions with regard to a service-oriented coordination platform for education, we will present in the following section partial illustration concerning nevertheless only some business-processes-related issues, and in particular the reflection of business processes in application functionalities as a bridge between the education services and the IT services supporting them.

5 Illustrating Example

We start from the simplified business model that is depicted in Figure 1 in order to illustrate partially how IT services can be methodologically reflected in a model, which reflection is driven by analyses concerning not only the corresponding business processes but also the demanded ICT support. We in particular derive the Education Mediator (EM) on the basis of the details that have been presented in Section 3. We would expect hence that an EM would support customers in a number of ways, in an e-learning context. By ‘customers’, we mean the users of EM’s services; those could be students and teachers (in the simplest case). Furthermore, we address (for the sake of brevity) only EM’s advice provisioning service: *a customer can receive from EM advice which of the Student/Teacher entities (registered in the system) best satisfy a need* (for example, which is the best teacher with respect to a particular student demand). To receive advice from EM, the customer approaches EM’s *ADVISOR* (an entity inside EM, which is responsible for handling the advice provisioning). It should be nevertheless noted that the Advisor may be shielded from the customer by the EM and in such a case the customer would be ‘talking’ to the EM and the EM would in turn route requests to (and results from) the Advisor. Approaching the Advisor, the customer should specify a request: course type (e.g. lecturing course or experimental course), preferences (e.g. closest to a particular subject), and so on. Based on this (and acting ‘through’ the Match-maker, to be introduced further on in this paragraph), EM’s *REQUEST HANDLER* (an entity inside the EM which processes requests) generates a standardized request specification, appropriately synthesizing some of the information provided by the customer. This is delivered then to EM’s *MATCH-MAKER* (an entity inside EM, which is responsible for finding a match using the standardized request and considering what is currently available); the Match-maker realizes matches driven by particular criteria, chosen by the customer (and represented in the standardized request), for instance: a preference for a teacher from a particular country or institution or the earliest available teacher. In order to realize a criterion-driven match, the Match-maker applies relevant rules and procedures, nevertheless needing input from EM’s *DATA SEARCHER* (an entity inside EM that is responsible for searching). The Data searcher searches through the information concerning the available (Student/Teacher) entities and also applies procedures to it. This hence supports the identification of candidate matches relevant to the particular customer’s request. The Match-maker applies its rules and procedures to realize a final match, passing this information to the EM’s Advisor.

Considering the above-presented briefing, a business entity model is built (Figure 7), with the same notations as we have already used in building the model that is presented in Figure 1.

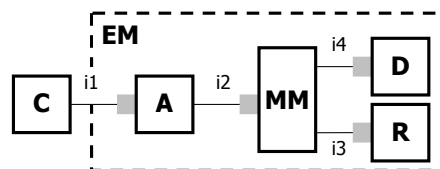


Fig. 7. Business entity model for the EM case.

The identified entities are presented in named boxes as in the previous model – these are Customer (C), Advisor (A), Match-maker (MM), Request handler (R), and Data searcher (D). Interactions i1 – i4 are identified as follows: between C and A (i1), between A and MM (i2), between MM and R (i3) and between MM and D (i4). As for the delimitation, C is positioned in the environment of the education mediation system EM, and A, MM, R and D together form the EM system.

We model then interactions using the notations of UML Activity Diagram [16]: i3 and i4 are to be progressing in parallel and only after they have been exhausted (the standardized requests and candidate matches have been delivered) the match-making can be done (i2) followed by the advice (i1) – this is illustrated in Figure 8 (upper part). This is the *business process level*, as labeled in the figure, and it is assumed that human-driven roles (and responsibilities) stay behind each of the interactions and as it is about human activities, much is driven by complex organizational (and societal) norms, much is actually done using best practices, and much is done in an intuitive way. IT services nevertheless require defining everything explicitly. That's why the IT services that correspond to the business-process-level interactions, are considered together with other related issues, as it is shown in Figure 8 (lower part), depicting the *IT service level*, as labeled in the figure.

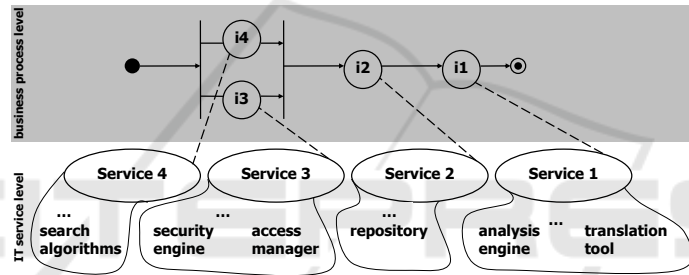


Fig. 8. Service derivation for the EM case.

As it is seen from the figure, searching requires search algorithms, request processing requires an adequate supportive security engine and access control facilities, match-making needs repositories with candidate matches and match criteria, the delivery of an advice requires an analysis engine and sometimes, a translate facility, just to name a few.

We need to extend further this model, particularly with respect to ‘IT Services level’, by considering our adopted service pattern that is depicted in Figure 3, which pattern is driven, as it has been discussed already, by a coordination service, responsible for orchestration. The EM service model is presented in Figure 9:

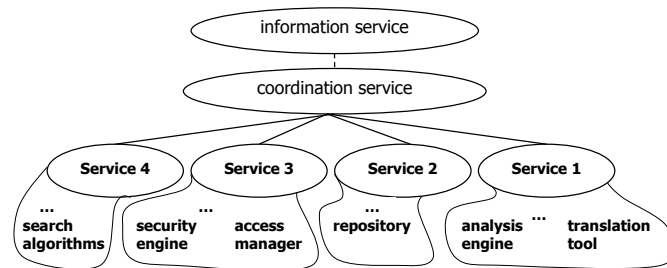


Fig. 9. Service model for the EM case.

As it is suggested by the figure, a coordination service (supported by an information service) orchestrates the work of the other services, namely Service 1, Service 2, Service 3, and Service 4, in a way that has been discussed in Section 4. Taking into account the case information and the considered domain, we label these 4 services in the following way:

- Service 1: **Educational Mediation Service;**
- Service 2: **Educational Broker Service;**
- Service 3: **Educational User Agent Service;**
- Service 4: **Educational Resource Discovery Service.**

We claim hence that the service pattern presented in Figure 9 as well as this short list of services (which can be extended) are useful for further related research in the area of technology-enhanced learning.

With respect to crosscutting concerns, the already identified ones are valid for this case, taking into account the discussion that has been already presented in Section 4:

- Crosscutting concern 1: **Synchronization;**
- Crosscutting concern 2: **Distribution;**
- Crosscutting concern 3: **Security;**
- Crosscutting concern 4: **Privacy;**
- Crosscutting concern 5: **Logging.**

This is as well a useful short list of crosscutting concerns (which can be extended), useful for further research in the area of technology-enhanced learning.

We will not consider in this example policy enforcement, for the sake of brevity.

6 Related Work and Conclusions

In this paper, we have presented solution directions that concern technology-enhanced learning and in particular the adoption of a service-oriented architecture for accomplishing better coordination and ease of application and use.

The current developments that concern technology-enhanced-learning-related systems point in several directions, namely: (i) Virtualization of learning; (ii) Adoption of Service-Oriented Architecture for enterprise systems in Education; (iii) Tooling.

With regard to virtualization, the project LiLa [10] addresses the challenge of making lab experiments more widely accessible, through automation and control from distance via Internet, driven by advanced access control mechanisms. With regard to service-orientation and related solutions, IMS Global Learning Consortium [8] has proposed an architecture for education-related enterprise systems, inspired by some of the latest SOA-related achievements. With regard to tooling, tools such as Moodle [12] are currently undergoing development that nevertheless strongly depends on the envisioned upcoming advances in the direction of service-orientation.

Distinctive features of the proposed solution directions are: (i) Methodological derivation of IT services, based on business analysis and modeling; (ii) Consideration of (service-oriented) coordination as a way for orchestrating and facilitating the work of an e-learning system; (iii) Envisioning underlying infrastructures for the next generation of e-learning systems.

To further this research, we plan to achieve a holistic perspective on technology-enhanced learning, in which we will consider the aspects mentioned above.

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