Enabling Decision Support Services inside virtual learning environments

Andrea Molinari
Department of Economics and Management
University of Trento
Trento, Italy
andrea.molinari@unitn.it

***Abstract*—Decision-making processes are more and more important today, and are pervading our information systems. In this paper, we present an analysis of how and where this type of processes may be found inside virtual learning environments, and how we have created the respective tools to implement them. The reference point is a virtual community platform that we have created and developed along the years, used in our University and in many public and private organizations. The platform is oriented towards the support of collaborative processes, where of course eLearning is one of the most important, but not the only one. In the integration of these collaboration services with the information system of the hosting organization, many situations appeared where a set of decision support processes would have needed, and these processes would have had a great improvement if implemented inside the services provided by our platform. This paper describes the rationale behind the creation of these software services, some characteristics of their implementations and the results obtained inside the organizations.**

***Index Terms*—Elearning, virtual learning environments, decision support systems**

I. Introduction

The context of eLearning is subject to the dynamics associated with the introduction and the metabolization of new technologies and ICT. While technology and infrastructure for distance learning have long been available, right now there is a growing demand by companies for this type of value services, taking advantage in terms of organization and saving costs and resources. Computers today play a central role in decision-making processes, by the presence of hardware and software tools devoted specifically to these tasks. Decision support systems, under different names or implementation, are well-established software tools in every information system, from trivial spreadsheet-based models prepared by single users, to sophisticated mathematical-oriented software tools like data mining, OLAP or custom-made systems to support management and executives in their decision process.

The application of methods and tools supporting decisions is welcomed also in eLearning settings, because of many different needs mainly deriving from the collection of data regarding students' performances in training path, specifically using SCORM-complaint learning objects. In any case, being Learning Management Systems (LMS) software platforms exposing many services, the need of analytics in eLearning is a well-known research topic. Learning analytics [1] can be used in different contexts, from decision making support to improving learners' performance [2], [3], [4]. In this paper we want to present our approach to the refactoring of a virtual communities software platform, used mainly in eLearning contexts, where a generalized set of decision support tools has been implemented. The idea is that, in general:

- LMSs should be part of the information system of the institution, and not just an isolated system used just by people with training needs
- Services provided by LMSs should be available to the rest of the organization, thus avoiding improper duplications of tools, credentials, installation and maintenance costs
- Using a generalized virtual communities system is a better choice respect to a traditional LMS with its limited and finalized objectives. Virtual communities platforms could be available not only for eLearning needs but in general for the management of any virtual community inside the organization (a workgroup, a department, a recreation group, a course, a meeting,….)
- Considering the plethora on needs of services inside a virtual community, many application of decision support tools are available.

In this paper, a review of these application fields will be presented, together with the rationale about how a virtual communities system could better support these needs respect to a "simple" LMS.

II. LMSs and virtual communities

Elearning systems are increasingly supporting cooperative interactions among participants, thus moving away from being a simple file repository of educational material. Web 2.0 and

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other collaborative paradigms (like social networks, or more in general systems that support collaboration and time management) have become very popular among users, therefore creating similar expectations in the educational fields.

Elearning became so popular thanks to many factors, like network availability, multimedia, increased power of client workstations etc., but the role of software platforms like Moodle™, Docebo™, Dokeus™, Sakay™, Webct™ is clearly a central role. At the same time, these approaches have proven to be very effective in contexts not necessarily connected to education, therefore posing the issue of the evolution of software platforms towards services that are not necessarily related to traditional educational tasks. Last but not the least, the integration of eLearning (or collaborative) platforms with the rest of the information system of the hosting organization represents a clear evidence of the role of software platforms today in education.

From a meta-architectural point of view, eLearning platforms have based their pillars on the idea of "course", or "class", meaning that the basic container for relationships among users is a virtual place that resembles in some way what happens in any educational organization: collecting people in a (virtual) classroom. From our perspective, what clearly emerged from the evolution of last years, together with our preliminary experiments, is the need of a different funding paradigm: the "community", or better, the "virtual community". The interesting perspectives opened up by this paradigm shift are multifaceted.

Private and public institutions need virtual collaboration spaces, places on the web with collaboration and web 2.0 tools available for their employees / partners, but most of the time they are forced to use many different software platforms: an integrated solution would be a great help to these unstructured tasks. Even the arrangement of a meeting could be apparently easier using technologies and web support, but in the end it requires a lot of effort and, most of all, the use of different software tools. Members will need to collect participants' email and something to share files, a tool for organizing the agenda of the invited people, a planning tool, a videoconferencing tool, probably a shared whiteboard, and then a forum or a blog for the post-meeting tasks.

Many great tools are available for these and other tasks related with collaboration but no one is providing the whole solution, forcing participants to use different tools, different credentials, different interfaces, not counting the problems in exchanging data among the different platforms. A unified platform is not always available, or it is very expensive, or could not be used in other contexts, or company's security policies deny the possibility of using some well-known collaboration platform because based in countries with unfair privacy policies, or because they lack specific tools, like the educational settings and respective specialized tools (for example, SCORM players.)

The annoying thing is the relation between these collaboration needs, the cost/complexity of assembling a collaboration solution, and what is already available within LMS. Sharing files, sending emails, aggregating people, managing agendas, posting in forums etc., all these services are common to training and collaboration environments, very often duplicated in different platforms but substantially delivering the same (software) services to stakeholders, but without the possibility of optimizing the usage or sharing data.

IT teams tend to provide different solutions for similar problems: eLearning has been considered as separated from the rest of the information system, rarely integrated in it. On the contrary, eLearning platforms benefit from an integration with the rest of the information system in many aspects, from authentication to HR integration, from social network integration to accounting, from directory services integration to email services etc.

Currently, large platforms devoted to collaboration, such as Liferay ™, SharePoint ™, IBM Lotus Domino ™, or CMS used to create websites (such as Joomla ™) are sometimes preferred to support blended learning processes, as they are more integrated with the rest of the information system, and more devoted to the creation of collaboration between participants. However, these tools poorly support the specific training. On the other hand, traditional LMS, like Moodle™, Sakay™ or Docebo™ are not suitable for collaboration needs, mainly because they are oriented to eLearning, and their pillars are metaphors like "classroom", "class", "course", rather than other ideas more oriented to collaboration, like "community", "group", "team", "secretary", "board", "office", "department". A classroom is of course a community, where collaboration is oriented towards a specific target, i.e., training.

This is just one component of collaboration, very important but does not cover the bunch of needs that companies / public administrations have. The metaphor of "course", the most used by the eLearning systems, is not able to cover all the interactions that may take place within working groups, aggregative and collaborative structures that we can define "virtual communities".

The community is a container ready for didactic tasks, but not only: research teams, recreation groups, friends, secretariats, board of directors, evaluation teams, commissions, colleagues, anything that could be an aggregation of people around a scope using virtual spaces on the web. Social networks like Facebook, Twitter, Youtube, etc. are not suitable for companies to solve these needs of internal collaboration, as their large numbers and main objectives are not fitting well with small, "private" communities where collaboration can take place in a private, reserved, personalized space. The main objective is "the more we are, the more we will interact": this is not exactly what a company or a public institution wants in most settings.

All these considerations are a perspective of evolution, if not radical change, inside the architecture of software platforms for eLearning, leading them to conquer others' prerogatives like collaboration spaces, videoconferencing, decision support systems, time management, process management etc. All these new topics for eLearning blur the distinction between a collaboration process that is mainly unbalanced, i.e., the relationship between the teacher and the learner. It opens, on one side, a richer set of approaches to educational tasks, more devoted to collaboration and support to decision processes. On the other side, it changes the market perspectives of software

platforms and even of information systems, where legacy and data-oriented applications are leaving the floor to software that manage unstructured data and informal knowledge, cooperation, collaboration and decision-making.

III. Brief presentation of "Online Communities" platform

Business models are typical of any product / service that can aspire to success, and software systems have the same needs like any other product. In the case of educational activities and Learning Management systems, the model below pertains to how a certain system hypothesizes that the teaching activities of an educational organization are performed. Therefore the use of a software platform imposes limits on how the task for which the LMS is designed will be conducted.

In the implementation of decision support services inside a collaboration platform, we used our software platform developed along the years and now used by several organizations in our region. "Online Communities" is a web application created starting from 1998, and then progressively empowered with many services, in order to support collaboration and educational processes. "On Line Communities" has been created to support blended learning activities by the University of Trento. Specifically, our activities have been oriented towards three main different settings:

- students of the faculties of the University of Trento: at the moment, we have approximately 16.000 users enrolled in more than 6.000 different virtual communities;
- public employees of our provincial administration (Autonomous Province of Trento - P.A.T.- Italy). The name of the project, "L3-lifelong learning", is clearly identifying target and objectives of the initiative. In this case, we are talking about potentially 20.000 users. The system has been recently opened to all the public institutions of our province, so at the moment we have approximately 5.000 users, and this number will surely increase in the very near future;
- employees of private organizations with various needs of collaboration services, sharing, social interaction, cooperation etc. All these activities are related, but not necessarily *only*, with educational activities.

These use-cases, and especially the last one, have clearly demonstrated, in our opinion, the need of a tight integration between our virtual communities platform and the information systems of the respective organizations. This integration is not simply an exchange of data between different databases, but it is a more complex, personalized set of services that should share and keep aligned different sets of information. In our projects, we realized that the simple re-design of a traditional eLearning system was too limited in respect to the needs, mainly:

- sharing and collaboration services that do not imply external or complex tools: for example, direct access with my credential from everywhere in a single-sign-on perspective;
- users' active participation in a more "social" sense, following not only the hype of web 2.0, but effectively allowing the user to collaborate with more sophisticate tools rather than the usual e-mail message with attachments;
- deep integration with the information systems of the organization, i.e., a full set of services that transparently allow the users to see educational and collaboration activities like any other service available on my desktop: for example, substituting the traditional corporate shared disk resources with repositories organization by project and virtual community the user is participating to. What we observed when introducing such a platform into organizations are the effects produced on users and information system of the hosting organization;
- the need of integration with existing sub-systems: just to mention the simplest ones, single-sign-on for users connecting to the information system's services and the collaboration platform;
- the overlapping of some functionalities of our Virtual communities' platform with pre-existing functionalities in the information system of the organization. Examples: document repository, mailing distribution, virtual room management, forum, etc.;
- Competition with possible new systems entering in the organization, mainly due to the web 2.0 functionalities that nowadays most of the companies intend to implement, and that normally any (serious) LMS is able to supply:
- partially overlapping and competing with some functionalities already present in other software. These are the most insidious aspect, because none of the systems (LMS and other information systems) are able to satisfy the specific needs, but all of them are able in some way to provide part of the functionalities needed. The typical example we founded in our experience is the support to document sharing for groups of people without mounting some network disk, normally not appreciated by system administrators, and most of the time not accessible via web. In this case, virtual communities are better candidates, as the on-the-fly creation of a virtual community with a set of services available for the members is a perfect solution for many of these situations, not necessarily related with educational activities.

According to our interpretation, a Virtual Community is not the result of a process of social networking. In fact, it is a virtual space shared by groups of people who have a common goal. A community's virtual space can be simple or complex; for example it can contain further virtual communities, thus establishing a "father-child" relationship. The (virtual) community can be an open space accessible to anyone, but also a restricted space reserved only to people authorized by the community administrator. The users can have different roles with rights and duties which vary according to the virtual community. The system provides users of a community with a range of on-demand services that can be activated and used in accordance with the permissions granted and the roles assigned.

This structure has allowed us to shape the organizational structure of an educational institution easily. For example, the communities of the teaching courses are components of larger communities called “Degree courses”, which are in turn part of the “Faculty” community.

On the other hand the community “Faculty” also includes the community “Faculty council”, restricted to the only members of the council, as well as other heterogeneous communities, such as the “chess circle” or “first year students” community, promoted by the Faculty Board to help new students settle down rapidly. Every community exists within a scope and with one or more goals, and according to these goals, different services provided by the platform can be activated. *On Line Communities* includes many services: the system is able to offer services such as:

- “traditional” asynchronous/synchronous services;
- Lifelong Learning and training on the job services (tutorship, training on demand, contextual search tools,FAQ, etc.);
- Integration with external information systems, such as students’ service office , register of the lectures;
- offline courses, recorded, digitized and provided to communities of users with the opportunity of synchronizing the videos with slides, podcasts, webcasts, SCORM modules, etc.;
- self-assessment tools, questionnaires, surveys, opinion polls;
- statistical analysis of users’ behavior, collecting in a data warehouse the actions performed by users.

IV. USING DSS TOOLS IN EDUCATIONAL PATH SELECTION

When the size of eLearning needs grows, turning an LMS from a simple repository of material to a tool devoted to integration, collaboration, cooperation between virtual communities is not so trivial. We realize how distance education is nothing but a tool for collaboration between teacher and student, but extending these tools to other contexts greatly expands the application fields.

However, an adaptation of the platforms, their customization or assembly of different tools in "patchworks" is often inefficient and unusable. This means for organizations to intervene heavily with customizations , often distorting and then losing or compromising compatibility with future releases, or devoting considerable efforts to be able to keep. The growing phenomenon of MOOCs , for example, sees a proliferation of platforms created specifically to handle these important levels of complexity

Especially in these enterprise contexts, it is essential to have advanced tools to support activities that often are not limited to simply supplying and managing training. These tools widen the horizon in different contexts in which the availability of a web-based software platform is an essential element to reduce space and time barriers and enable collaboration "anytime - anywhere", so much desired by the "digital" company. These new tools should expand the training activities to the more general collaborative activities. Examples of these activities are planning and time management , the management of the events related to the activities of the community, decision support and process evaluation, managing tenders and so on. Similarly, with the increase of complexity, tools for collaboration, sharing and distributed decision support within the communities are becoming increasingly crucial.

What has been implemented inside “Online communities is a set of advanced components taken from research in the field of decision support systems, such as mathematical tools for the distributed consensus management and multi-criteria evaluations. The introduction of components from the field of soft computing inside a full-fledged eLearning platform is quite unique to our knowledge, and this further expands and evolves the application field of our platform from simple contexts related with teaching to all those contexts where support for decision-making in presence of several experts / evaluators and multiple evaluation criteria is needed.

The initial stimulus came from the request to support the decision making process aiming at selecting the most suitable eLearning path(s) for certain students. We introduced a multi-attribute, multi-expert model where several attributes are used for evaluating different eLearning paths, according to the rankings expressed by a group of experts [5]. Then, a consensus modelling mechanism has been introduced to find an agreement among the individual rankings. The multi-attribute evaluation is based on fuzzy TOPSIS [6] [7] [8] while the consensual ranking is obtained through a constrained optimization model.

Fuzzy logic in eLearning has been used according to different perspectives. Some fuzzy approaches to eLearning have been presented in [9], where fuzzy logic has been applied to the identification of eLearning design requirements and to select the most suitable eLearning service provider. Other approaches [10] use fuzzy inference to analyze students’ way of working and group’s behavior, while in other research areas fuzzy logic has been used to improve search capabilities of Learning Management Systems (LMSs) [11]. In the field of evaluation, under different perspectives we find the application of fuzzy logic to the evaluation of students’ performances according to their profile [12], or to an evaluation teaching systems’ quality [13].

The system implemented is a generalized tool for supporting and providing “Online Communities” services with some primitives (APIs) to be used in different contexts. This allows the system to:

- choose the type of model to be used, according to the needs of the administrator of the community according to the decision processes to be implemented. This is the crucial moment for the entire usage of the tool, as it requires an adequate background and knowledge about the best approach to be used in that specific context, what is the meaning and how to interpret the output and, most of all, the meaning and the right values for the different parameters required by the model. For example, using linguistic (fuzzy) operators is apparently natural for human operators, but the effects related to some parameters (alpha-cut, triangular of trapezoidal fuzzy numbers etc.) must be clearly managed as they influence the final results.

- Set parameters of the module
- Set number of experts
- Set the criteria needed for the implementation of the decision process

This is just to mention the main actions, repeating the fact that the configuration phase is the most delicate one. The platform, according to the parameters, prepares the interface for acquiring input from experts via web, thus facilitating the decision and enabling a quicker decision process. In our early experiments conducted together with the Trentino Local Development Agency, a process for the evaluation of public tenders regarding spin-off financing required almost six months of lead time mainly spent in organizing meetings among evaluators, collecting and aggregating their judgment. Thanks to the usage of "Online Communities" platform, its collaboration and management tools, and the application of the DSS model, all the process of collecting proposals, involving evaluators, collecting their evaluation according to the model proposed, aggregating results and formulating the final ranking required less than three weeks. Most of all, vis-à-vis sections have been limited to an initial session to meet each other and share the evaluation criteria, and the final meeting for the formal approval of the ranking.

The DSS engine uses a two-stage decision making process, where in the first stage each expert evaluates alternative paths using a TOPSIS-based approach, assuming that the scores are linguistically expressed. The computations of individual rankings are carried out representing linguistic labels as positive fuzzy numbers. The second stage is devoted to the description of the consensus modelling process aiming at finding the group ranking according to the minimization of a distance function.

The DSS module includes a set of modules with different but coordinated objectives:

- a module for estimating the experts' individual assessments expressed by linguistic variables represented by triangular or trapezoidal fuzzy numbers;
- an algebra for the treatment of linguistic evaluation and a corresponding mechanism of linguistic approximation based on the distance between fuzzy numbers;
- an algorithm for the representation of individual preferences (binary fuzzy relations) aimed at introducing a sort of preference among alternatives;
- a module for the aggregation of individual judgments to determine a final consensus by the expert group. We are in the process of introducing and testing the use of advanced operators such as OWA and Choquet Integrals, to allow the representation of the interdependencies between the criteria;
- an edit form to allow modification of consensus in the event that the level achieved is not sufficient. For this purpose, we will use neural networks to implement the dynamics of change of individual preferences;
- an alternative system for the determination of consensus based on a model of mathematical optimization in which the objective function represents the distance between the individual judgments and a judgment considered as the benchmark, while the constraints representing a predetermined level of consensus expected.

The most remarkable novelty of our approach consists in proposing a mixed procedure which permits to combine individual ranking regarding the objects under evaluation, as carried in a multi-attribute setting by each member of a group of experts, with a linear constrained optimization process whose purpose is to determine a distance-based group consensual ranking.

This approach could be applied to different contexts, i.e., evaluation of different eLearning path proposals or evaluation of projects proposals, but could also be extended to other settings inside learning environments, where multi-attribute and multi-expert evaluation can be applied. Examples of these application fields are those situations where a reputation attribute must be derived from the evaluation of an experts' panel respect to the contribution of different learners. The voting mechanism in a forum, the selection of a wiki item's proposal respect to different proposals made by learners, or the item added to the FAQs by different contributors and evaluated by a team of experts (teachers or simply other participants to the learning community) are examples of the application of our model to eLearning settings.

As an example applied to educational settings, learning processes are usually implemented through the interaction of the learner with a LMS and, in some cases, through the usage of learning, or eLearning, paths. A learning path, as referred inside a LMS, is represented by a set of LO mixed with other tools and services available in the LMS, like questionnaires, forums, wikis, FAQ etc., This combination of information chunks and services is devoted to obtain the educational objectives defined by an instructional designer.

In eLearning settings, the evaluation of different alternatives regarding learning paths' proposal is nowadays crucial, due to the great attention devoted to the construction of learning objects (LO) available through Learning Management Systems (LMS). This is a typical decision that should be based on some DSS model, but that is not strictly related with learning analytics. It could be affected and improved as a decision by integrating with data coming from previous analysis about how, what, where and why some learning objects have been viewed[14], but basically is a decision process that involve (hopefully) more than one expert, and that involve more than one criteria in order to define the best path for the students.

While testing large scale implementation of virtual communities systems, we noticed that SCORM objects and pre-defined learning paths[15], are more and more important in educational settings today. The market is responding to this request, thanks to adequate technologies for the design, realization and delivery of these pre-constructed educational tools. SCORM packages themselves, if well designed, could be self-consistent learning paths.

According to this scenario, educational institutions and specifically the industry rather than academy, are very often in front of the process of evaluating different possible learning paths, composed by different learning objects, composing different contents and representing different approaches and

responses to the educational needs stated by the educational stakeholders. The criteria for choosing which alternative better fits with these needs are most of the time based on simple considerations (mainly cost of the learning objects), taken by people with no complete view of different aspects of the learning paths[16], not taking into consideration all the aspects that should be needed for such an important step.

Elearning has many advantages, but for sure the best application field of its pros is in presence of large numbers of users, where a wrong choice about the learning path to be offered could have serious consequences.

V. Conclusions

The paper presented how decision-making processes could be integrated inside a learning platform to support educational processes, and how a virtual community approach could better allow users to switch from traditional learning/training tasks to decision support tasks. Even educational institution and the respective actors have today many decisional tasks, and these tasks are most of the time conducted or supported by technologies. The starting point of the DSS tools developed is a virtual community platform that has been created and developed along the years to support collaborative tasks. The paper presented the rationale, the main characteristics and needs behind the creation of these software services, that in our opinion are indispensable for conducting many tasks associated with e-learning.

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