STUDENT-CENTERED MULTI-AGENT MODEL FOR ADAPTIVE VIRTUAL COURSES DEVELOPMENT AND LEARNING OBJECT SELECTION

Demetrio Arturo Ovalle, Francisco Javier Arias and Julian Moreno
GIDIA - Artificial Intelligence Research & Development Group, Systems & Computer Science Department, School of Mines, National University of Colombia, Campus Medellin

ABSTRACT

In recent decades, the use of artificial intelligence (AI) techniques has been efficiently employed not only for problem solving but also for modeling, simulation, and development of complex systems. The construction of virtual university courses is complex since such computational systems must adapt their behavior to the student’s characteristics in a customized way. Thus, the aim of this paper is to propose student-centered virtual courses design and construction with adaptive features, through the integration of AI techniques involving multi-agent systems and AI planning. It should be noted that the virtual courses adaptation has been performed with an emphasis on both instructional planning and student-centered intelligent selection of learning objects. The validation of the AI-based student-centered learning model was made through the construction of an experimental computational platform called CIA (Spanish acronym for Adaptive Intelligent Virtual Courses), which carries out learning planning and individual LO selection in an intelligent way, taking into account the students’ knowledge level, as well as their learning styles, and their most used brain hemisphere.

KEYWORDS

Student-centered learning, adaptive virtual university courses, learning styles, learning objects selection, pedagogical multi-agent systems, artificial intelligence-based learning planning.

1. INTRODUCTION

In the last decade, the main contribution that has occurred to virtual university courses development is the adaptation capacity. Diverse kinds of adaptation have been mainly used on the following issues (Brusilovsky et al., 2004): instructional plans, knowledge level assessments, and educational contents. This article, is focused on design and construction of virtual university courses using adaptive characteristics, through the integration of artificial intelligence (AI) techniques such as multi-agent systems (Weiss, 2007; Wooldridge, 2010) and intelligent planning (Duque, 2006, 2009). It is important to highlight that the virtual courses adaptation will be emphasized in both the instructional planning and the student-centered intelligent selection of learning objects.

The rest of the paper is organized as follows: In Section 2, the theoretical framework is presented and related works are described and analyzed in Section 3. In Section 4, the proposed architecture for adaptive virtual university courses construction is shown. In Section 5, a multi-agent model related to the proposed architecture is offered and in Section 6, some results obtained from the validation of the proposed model are discussed. Finally, Section 7 displays the main conclusions and the future work.

2. THEORETICAL FRAMEWORK

Adaptive virtual courses (AVC) are computational systems designed to intelligently support teaching-learning processes focused on the student-system interaction and considering the execution of several customized educational tasks (Brusilovsky et al., 2003). Most of the AVC make use of the following three components: domain model, student model, and pedagogical model. Additionally, learning objects (LOs)

(Wiley, 2000) that support the AVC can be defined as any educational resource with a pedagogical intention, composed of one or several educational contents, describing themselves through metadata. Thus, LOs can be used within a teaching-learning virtual platform and have the very relevant characteristic of being reusable.

Instructional planning (Duque, 2006, 2009; Arias, 2010) comprises one of the most important tasks within the educational systems allowing students to attain adaptation purposes of their instruction. Instructional planning is the AVC's main component whose role is to continuously determine the sequence (learning plan) of consistent and coherent pedagogical activities. In addition, the goal of the instructional planning is to optimize the learning process for each of the students allowing them to reach their instructional goals (IG) generated dynamically during a virtual learning session.

One of the most frequent problems remaining when pedagogical developers are working with LOs (Wiley, 2000), is the difficulty of establishing which LOs are the most appropriate for a specific instruction definition. In the AVC, this difficulty also appears, thus, it is important to consider two issues of high relevance: the personal characteristics of each student and the specific features of the selected LO.

The multi-agent systems-MAS (Weiss, 2007; Wooldridge, 2010) that have emerged from the distributed AI (DAI) field are focused on the intelligent coordination among a collection of smart autonomous or nearly-autonomous entities called "agents". Software agents can execute within any context or environment but also can communicate to each other and coordinate their knowledge, goals, plans, etc. for decision making purposes or for jointly solving complex problems.

3. RELATED WORKS

Jimenez (2006) proposes an instructional planning model based on case-based reasoning and pedagogical MAS. The model allows the system to adapt the instruction to the specific needs of each student, providing flexibility and autonomy to the teaching-learning educational environment according to the software agents' characteristics. However, this approach does not consider student-centered adaptive LOs selection.

Duque (2006), on the other hand, exhibits a model for the generation of virtual courses that adapts itself to the own characteristics of each student. The model is oriented by educational goals (EG) that are expected to be fulfilled by the student when he/she interacts with the virtual course. For doing so, this system applies artificial intelligence planning techniques. Peña et al. (2005) propose an adaptive intelligent tutoring system (ITS) based on learning styles without considering AI planning techniques and LOs selection.

Morales (2007) presents a way to evaluate LOs from a technical and pedagogical perspective using an assessment range that will be included within their metadata. The purpose is that such assessment values can be accessed in an automatic way through intelligent agents using the LO's quality criterion for their selection. Lopez (2005) makes a research intended to define a conceptual model that structures LOs Repositories in such a way that the interoperability among different repositories along with the e-learning environment's components can be attained.

4. ARCHITECTURE PROPOSED

Our approach proposes a hybrid architecture for the design and development of AVC, based on the following AI research axes: the instructional planning, intelligent student-centered LOs selection, and the MAS approach that offers an AVC's generic architecture. The main components of an AVC's generic architecture are the domain model, the student model, and the pedagogical model.

In the domain model the structure of the virtual course and its related knowledge base are stored. It is important to note that in this model, the use of a specific structure of courses is not mandatory, but it is recommended to develop a pedagogical structure that be composed of the following main elements (Arias, 2010): general course, learning basic units (LBUs), topics, instructional goals (IG), IG's pre-requirements, pedagogical activities, and LOs.

The student model contains the body of knowledge that will characterize the student and is represented through different perspectives such as: the most relevant student's psycho-sociological features that affect his/her learning processes; the knowledge level that he/she has on the virtual topic's domain, and the skills and minimum abilities that he/she must have to perform a task. In addition, this model must be able to gather the evolutionary behavior of the student during different learning sessions and to be able of modeling the student's mental state. That means: "What does he/she know about a topic? and What does not?" and starting from this allowing the system to adapt its behavior on the basis of his/her answers. According to Jimenez (2006) this model comprises the following elements: Student's attained IG (Instructional Goals), cognitive profile, contextual characteristics, learning styles, and psycho-sociological profile.

The pedagogical model acts as a tutor or teacher and this is the reason why this model is in charge of carrying out instructional planning strategies as well as selection of Los, in a customized way, based on the student's characteristics (learning styles, most used cerebral hemisphere, etc).

The instructional planning strategy is based on the AVC's generic architecture and also on the AI planning basic concepts and thus should be described as follows:

• Problem: formulation that expresses the knowledge associated to topics of a specific course that the students try to acquire.

• Initial state: the student has basic concepts in the field, which will help him/her to acquire new concepts.

• Final state: the student has acquired new knowledge and thus has attained one or several IG.

• Activities: they are specified by the teachers while they build the corresponding virtual course and they must be associated to the IG.

• Elements: they are related to the LO that will be used when a pedagogical activity is performed. Each one of them must contain specific metadata allowing to carry out the LO selection in adaptive way.

• Restrictions: they can be established at two levels; the first level is related to the structure of the virtual course and are known as "pre-requirements" that indicate what IG must be attained in order to reach another IG. Given the subdivision of the course structure in the four related components—general course, LBUs, topics, and learning activities—, when a pre-requirement is defined for an IG, such a pre-requirement should also be applied to a topic, to a LBU, and to the entire course.

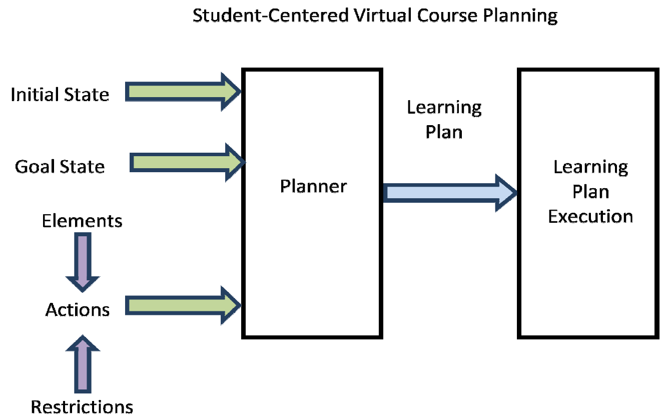

Figure 1. Basic Concepts of the Learning Planning Technique.

The second level concerns the instruction of the students and can be named as goals by student. The student information elements with adaptive purposes that the system will store are: data and personal characteristics, academic profile, personal profile, contextual characteristics, learning performance, and knowledge of the tasks.

In order to develop the planning strategy the following stages should be carried out:

• Teachers must structure their virtual courses according to the elements specified within the domain model by using requirements and pre-requirements that are associated to each IG. It is important to remark that there must exist at least one IG without pre-requirements in order that the system can plan the virtual course's initial activities.

• When a student enters to the teacher's virtual course, the system using the pre-requirements must verify which IG the student can study in such a way that a listing of topics will be generated to be selected by the student.

• The system thus generates an adapted instructional plan tailored to the student's knowledge level and to her/his preferences. This learning plan is composed of one or several IGs that the student should attain when performing one or several learning activities.

• The system guides the student through the instructional plan's activities. In addition, it is important to note that each activity can be made by the student using one or several LO. The selection of LO is needed to be done taking into account the student's learning styles previously matched with the metadata that describe them.

• When the student has performed all the activities associated to the instructional plan, it is considered necessary to verify if the student actually learned the concepts related to the selected topics, hence a knowledge assessment is launched by the system for learning validation purposes.

• The system is in charge of updating the student's knowledge level according to the achieved results (IGs attained by the student) based on the previously instructional plan assessment. It is important to underline that once the student's knowledge level is updated consequently new virtual course's topics are activated to be pursued.

Concerning the LO selection strategy the student's learning styles are considered which were acquired through Felder & Sylverman Test (Felder & Spurlin, 2005) and the student's dominant cerebral hemisphere using the TQDT-Triadic Quotient Detector Test (De Gregori, 1999).

In order to perform the LO selection according to the students' profiles within the AVC, the model must perform the following steps:

• The system firstly captures the students' learning styles using the Felder & Sylverman Test that is composed of 44 questions in order to classify students learning abilities respect to the following four dichotomies: [Active, Reflective], [Sensing, Intuitive],[Visual, Verbal], [Sequential, Global], having 11 questions for each dichotomy. After applying this learning test, a given student could have, for instance, following results: ([7,4],[3,8],[9,2],[5,6]) meaning that the student is 63% more active than reflective (37%); 73% more intuitive than sensing (27%); 82% more visual than verbal (18%); and 55% more global than sequential (45%).

Table 1. Comparative table exhibiting different "LO resource types" and "LO resource formats" best fitting for different kind of student's learning styles.

	LEARNING STYLES							
	Sensing	**Intuitive**	**Active**	**Reflective**	**Visual**	**Verbal**	**Sequential**	**Global**
LO Resource Type	experiment, diagram	lecture, questionnaire	simulation, experiment, problem statement	self assessment, reflective & analytical text	figure, graph, diagram	narrative text, essay	index, guide, graph, diagram	slide, narrative text
LO Resource Format	swf, avi, mpg, exe	doc, txt, ppt, xlsx	swf, avi, mpg, exe	doc, txt, pdf	jpg, png, gif, tif, bmp	doc, txt,pdf	ppt, gif, jpg,png	doc, txt, ppt

• The students' dominant cerebral hemispheres through application of TQDT-Triadic Quotient Detector Test are then acquired by the system. According to Waldemar De Gregori (1999) the brain and its three main processes: logic-scientific-rational side (left hemisphere); intuitive-spiritual-mystic-proactive and visionary side (right hemisphere); and central-organizational-administrative-productive side (central hemisphere), must be used and developed in such a way that an individual be able of taking advantage and seize on all his brain capacity. This test is composed of 27 questions in which 9 are associated to each one of the hemispheres (left, right, and central). Each question is graded within the range [1,5] meaning that each hemisphere can obtain a minimum total value of 9 and a maximum of 45. After applying this learning test, a given student could have, for instance, following results: [39,12,23] meaning that the student is an individual 87% logic-scientific-rational; 27% intuitive-spiritual-mystic-proactive; and 51% central-organizational-administrative-productive.

• The system go on with the selection of the best kind of resources (e.g. simulation, graphic, experiment, document, etc.) as well as the best kind of suitable educational resource formats (e.g. avi, ppt, swf, jpg, wav, etc.) that better match in accordance with obtained values for student's Learning Styles & Triadic Cerebral Quotient.

• A list with the "top of LO resources types" and the "top of LO formats" is generated for a given student using student's test results and LO metadata specified under IEEE LOM standard (IEEE P1484.12.3, 2005) inside following categories: General Description (name, content description, keywords, etc), Educational (Interactivity style: active, sensitive, reflective, visual, verbal, etc) & Technical (format & size: swf, avi, doc, txt, jpg, ppt, etc). Thus, while active students prefer using LO resources like simulations, experiments, problem statements, among others (see table 1); reflective ones prefer using self assessment, reflective & analytical texts, among others (see table 1).

• The systems pursues with the generation of a list that represents all the possible combinations between individual student's tables "top of LO resources types" and "top of LO resource formats".

• When the student is performing the instructional plan, previous to perform an activity, the system should check that learning objects selected for his/her fulfill with the most relevant characteristics according to the table that represents all the possible combinations between individual student's tables "top resources" and "top of resource formats".

5. MULTI- AGENT MODEL FOR THE PROPOSED ARCHITECTURE

The multi-agent model proposed is following described based on the MAS-CommonKADS methodology (Iglesias, 1999). This methodology is mainly composed of the following three phases: conceptualization, design and analysis.

In the conceptualization phase the problem to be solved is defined and the scope of the model is established. Also, the entities that compose the AVC are identified and in general, the global operation of the system is established. From the basic architecture of the proposed AVC, the following actors were identified:

• Teachers: Their main role will be creating and structuring virtual courses, and continuously monitoring the students' performance.

• Students: Their main purpose in the system is acquiring knowledge about a course, through the use and application of instructional planning generated by the system and adapted to their academic level and learning styles.

• Planner: His role is to adapt instructional plans to students in such a way that the student be guided by the system through a teaching-learning process in the same way as it could be performed by a real teacher.

In the analysis phase the MAS-CommonKADS methodology proposes the following models for the construction of multi-agent based systems: agent, organization, task, experience (or knowledge), communication and coordination.

In the **agent model** every agent characteristics are specified: reasoning skills, abilities, services to offer, sensors, effectors, agent groups to whom it belongs and agent's kind. An agent can be a human, software, or any entity capable of using an agent communication language (ACL). The description of those features is carried out by using an agent template.

The **organization model** allows analyzing the human organization in which the multi-agent system will be developed and also describes the software agent's organization and its connections with the environment.

The **task model** describes the tasks that pedagogical agents are capable of performing. A task can be define as the set of activities that have to be developed to achieve a specific goal in a given domain. For each task, the following items must be specified: name, goal, inputs, outputs, subtasks, and models. Figure 2 describes each of the tasks that were identified for the learning system. It should be noted that a main task is composed in turn of four subtasks known as: Main task: it provides individualized learning for a specific AVC; ST1 (Subtask 1) is in charge of updating the domain model; TS2 (Subtask 2): whose role consist in generating instructional plans; ST3 (Subtask 3) is in charge of updating the student's model; ST4 (Subtask 4) presents student's learning process results.

The **expertise model** (or knowledge model) firstly has as main role to identify the most appropriate ontologies that are needed to be used within the problem's domain, in this way handled concepts in the system are clearly recognized. Another relevant feature of this model concerns to the identification of reasoning mechanisms that should be developed within the system provided through intelligent skills of software agents.

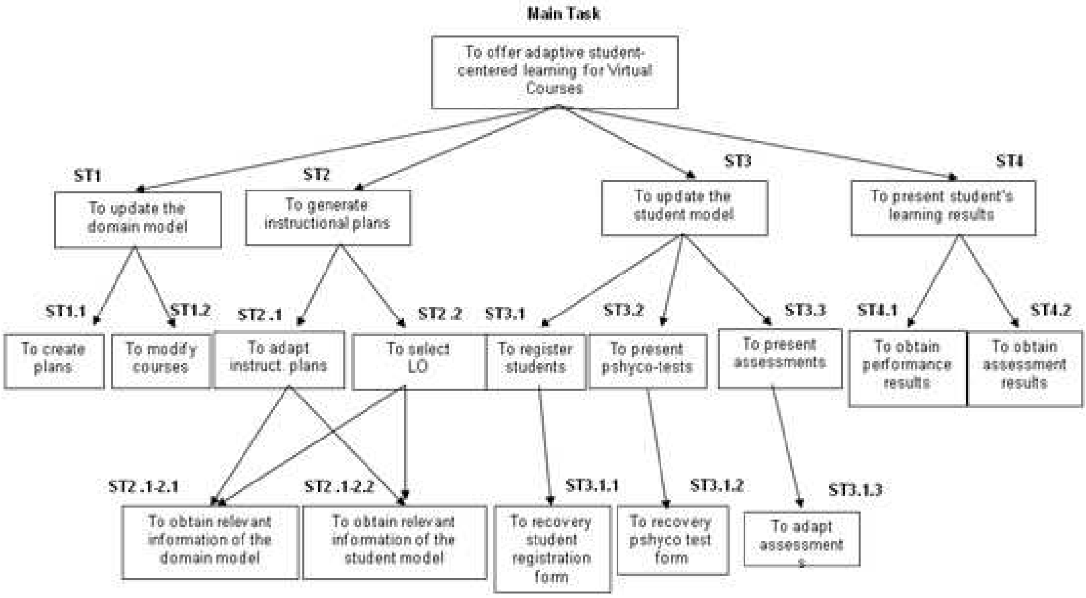

Figure 2. Task model represented by a hierarchical tree.

It is important to highlight that two kind of ontologies focused on the virtual course's information management were handled in this problem. Figure 3 shows, for instance, the flowchart corresponding to the reasoning mechanism employed by ST2.1.

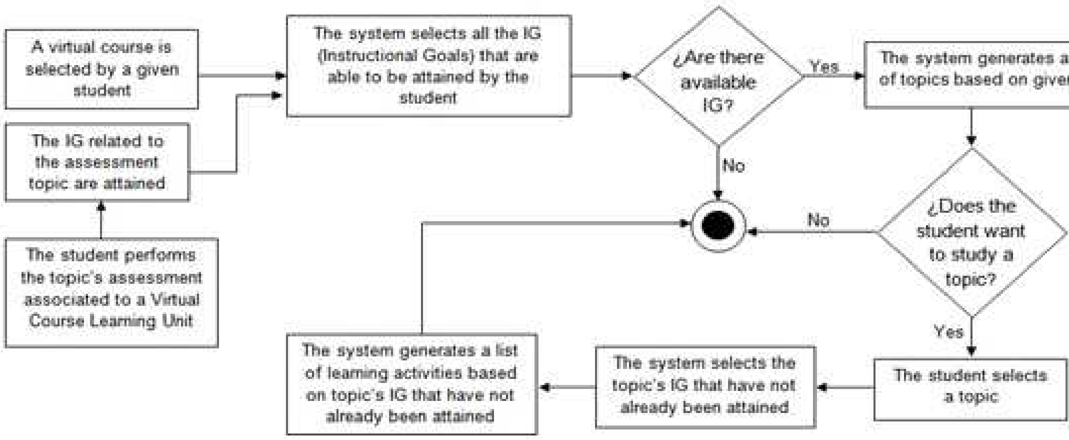

Figure 3. Reasoning mechanism flowchart of subtask "ST2.1: To generate and adapt instructional plans".

The **coordination and communication model** is designed with the aim of modeling the agent-to-agent and human-to-agent interaction. Due to this model presents a very technical approach supported by the agent framework development tool it will not be described here. More details of this model can be found in (Arias, 2010).

Finally, the design phase is in charge of the deployment of components that the system will handle and additionally the definition of computational tools that will be used to carry out the system implementation.

6. ANALYSIS OF RESULTS

The platform CIA (Spanish acronym for Adaptive Intelligent Virtual Courses) is the computational prototype that validate the proposed model and was implemented using the platform JADE (Java Agent Development Framework; Bellifemine, 2005), which is distributed on a LAN network. A Tomcat Web server was housed in a computer located on one of the LAN (Local Area Network)'s nodes. In this site there are located the JADE's main container in which not only provided FIPA (Foundation for Intelligent Physical Agents) compliant JADE agents, such as: AMS (Agent Management System), DF (Directory Facilitator), and RMA (Remote Management Agent) are provided but also some agents of the system, such as: Planner and Evaluator. On the other hand, there are additional containers distributed on different computers located in other nodes of the same LAN network where the other agents of the system such as Students and Teachers, were situated. When a student is registered in the system, the interface agent displays to him/her a form to be filled with personal information and two tests (Felder Sylverman Test and TQDT-Triadic Quotient Detector Test) to be performed by the student in order to capture his/her personal data and learning styles those which are relevant to the learning planning and the LO selection tasks. It is important to underline that the Interface agent acts as an intermediary between human and software agents. Figure 4 shows through a sequence diagram generated by the JADE's sniffer agent (Bellifemine, 2005), the communication protocol established among the interface agent (represented in Figure 4 as Other), the planner agent, and the evaluator agent.

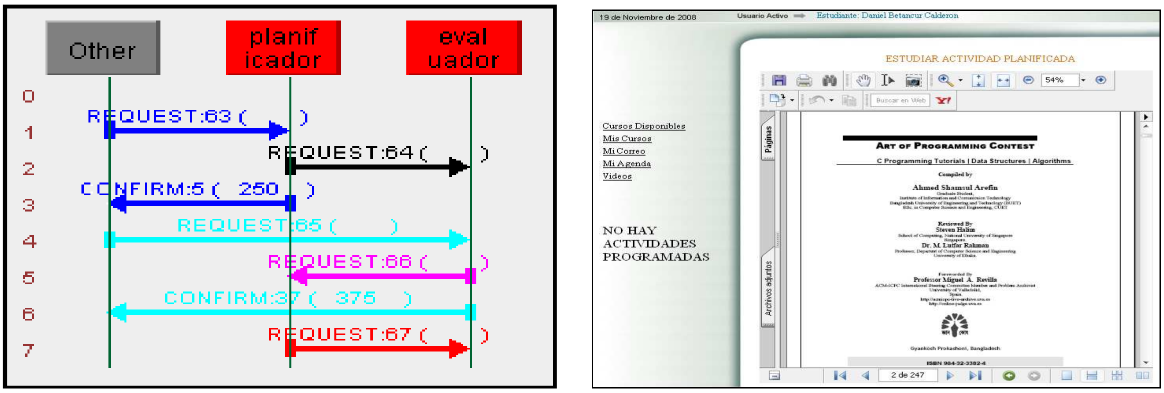

Figure 4. Agent's interaction sequence diagram and display of the student-centered CIA system

The specific learning study case that was considered for this research work is described as follows:

- Step 1. A student, through the Interface agent, sends a planning request (REQUEST:63) after selecting a virtual course topic.
- Step 2. The planner agent receives the request sent by the interface agent and thus generates an adaptive instructional plan according to the planning strategy presented above; asks the Evaluator agent (REQUEST 64) on the assessment planning and a response is sent to the Interface agent about its planning request (CONFIRM 5).
- Step 3. While the student runs his/her individual instructional plan, the most appropriate LO are selected according to the personal student's information provided by the system and the outcome from the LO selection process carried out by the CIA learning strategy (see Table 1).
- Step 4. When the student has finished studying all the activities associated to the instructional plan a knowledge assessment test is then generated and deployed by the evaluator agent in order to update the learning level record of the student.

7. CONCLUSIONS AND FUTURE WORK

This article showed the use of various AI techniques such as AI planning and MAS for the development of student-centered adaptive virtual courses development which carry out learning planning and individual LOs selection in an intelligent way, taking into account the students' knowledge level, as well as their learning styles, and their most used brain hemisphere. The process of LOs selection which involves the adaptive selection of students' most appropriate resource type (e.g. simulation, graph, experiment, document, etc.) and resource format (e.g. avi, ppt, swf, jpg, wav, etc.) uses specific learning style through the application of the Felder & Silverman test and TQDT-Triadic Quotient Detector test. The MAS were successfully used to integrate the strategies of learning planning and LOs selection and to support the AVC construction in a modular, distributed, deliberative, proactive, and cooperative way.

As a future work it will be envisaged to enlarge this student-centered learning model in such a way that it could provide LOs recovery and recommendation from local and remote LOs repositories (e.g. MERLOT, CeLeBraTe, CAREO, etc) or through LOs repository federations (e.g. FEB, aDORE, ARIADNE, etc), in such a way that the system can automatically get learning resources and easily add those to a specific virtual course under the teacher supervision.

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