A Novel Teaching-Learning Strategy for Teamwork based on Agreement Technologies

Sergio Pajares
Universitat Politècnica de València
Camino de Vera, s/n
46022 - Valencia, Spain

Víctor Sánchez-Anguix
Universitat Politècnica de València
Camino de Vera, s/n
46022 - Valencia, Spain

Alejandro Torreño
Universitat Politècnica de València
Camino de Vera, s/n
46022 - Valencia, Spain

Sergio Esparcia
Universitat Politècnica de València
Camino de Vera, s/n
46022 - Valencia, Spain

ABSTRACT
The new framework introduced by the European Space for Higher Education entails the reformulation of teaching strategies, which must not only be based on the teaching process, but also on the learning process. Given the importance of teamwork in nowadays' engineering labour market, we propose a teaching-learning strategy, which applies a competency-based education approach and aims to reinforce the generic teamwork competence. Its foundations are drawn from the research on agreement technologies and multi-agent systems, which are key research topics in the field of Artificial Intelligence.

General Terms
Agents, Internet and Distributed Computer Systems.

Keywords
Teaching-learning strategy, teamwork competence, multi-agent systems, cooperative learning, continuous assessment, learning management systems.

1. INTRODUCTION
In the convergence process to the European Space for Higher Education, competency-based education has become particularly relevant [1,2]. This new approach allows the student to acquire specific competences related to a certain subject, and generic competences common to several subjects of the curriculum. From the latter group stands out the **teamwork** competence [50], which pursues the development of cooperation between students in order to achieve common learning results.

More specifically, the teamwork competence promotes **cooperative learning** [3,4] over individualistic learning. On the one hand, several studies show that the learning results are better when the students are placed in a cooperative environment [3,4]. On the other hand, the labour market is being increasingly oriented towards projects developed by multidisciplinary teams that require teamwork skills. In practice, project-based subjects allow the teacher to establish teaching-learning strategies based on cooperative learning, which reinforce the teamwork competence.

Multi-agent systems (MAS) [5,6] constitute one of the current research disciplines in Artificial Intelligence (AI) field [7]. These systems provide computational models based on theories from sociology, psychology, economics and so forth. Therefore, we argue that experiences obtained from this research field can be successfully applied in the education context and learning management systems.

The main objective of the present article is to explore a novel learning-teaching strategy which is inspired by the research in multi-agent systems. This strategy pursues the promotion of the teamwork competence in project-based subjects. Since the aforementioned competence is directly related to the use of **information and communication technologies** (ITC) [8] in Computer-Supported Collaborative Learning (CSCL) [9] environments, our final research goal consists of the design and deployment of the proposed strategy in a learning management platform. More precisely, we propose the Sakai-based **PoliformaT**[1] platform [10,11,12], which has been adopted by the Universitat Politècnica de València (UPV)[2].

The remainder of this article is structured as follows: Section 2 provides background on the main topics related to this article. Section 3 describes the different phases of our teaching-learning strategy, contextualizing the use of PoliformaT in each of them. Section 4 shows a case study in which the described strategy is applied to an actual subject. Finally, section 5 concludes and suggests possible directions to extend the present strategy.

[2]https://poliformat.upv.es/portal
[2]http://www.upv.es/

2. BACKGROUND

Teaching-learning strategies pursue both specific and generic learning results, such as teamwork. The learning level acquired by the student is measured by the evaluation system defined by the strategy. It is important to remark that not only the teacher must evaluate the student, but also the student should provide feedback about the teaching-learning strategy.

The work proposed in this article is supported by concepts extracted from MAS theories, i.e. distributed systems composed by autonomous entities called agents [5,6]. An intelligent agent is an entity which bases its behaviour in theories from psychology, economics, sociology, etc.; it is characterized for being autonomous, reactive to changes on its environment, proactive in the sense that it performs actions by itself to achieve its goals, and social, since it cooperates with other agents to reach its objectives. In the field of MAS, agreement technologies[3] (AT) [13] provide computational models for autonomous agents that act on behalf of human users, in applications like electronic markets [14] or emergency management systems [15]. Among the aforementioned technologies, the following can be highlighted:

- Negotiation and Argumentation: Negotiation focuses on concession and proposal strategies that aim to maximize the preferences of the agents which take part in the negotiation process [16,17], while argumentation [18,19] allows agents to reason about their preferences and discuss them according to facts, beliefs, threats, and so on.
- Planning: This technique allows the agents to establish a course of action in order to reach a set of objectives from an initial situation [20,21].
- Organizations: Sets of agents that interact together to coordinate their behavior and often cooperate to achieve some collective goal [22,23]. The organization assigns roles to agents in order to distribute tasks, and imposes norms [24,25] to regulate the behavior of the agents through sanctions and rewards.
- Reputation: Since agents can show opportunistic behaviors, it is necessary to establish reputation systems to determine the agents that are more suitable to interact with. Reputation is defined by the society of agents to acknowledge collaborative and correct behavior [26].

Some agreement technologies are conceptually represented in different works regarding cooperative learning and teamwork [3,4]. Despite the fact that MAS have been employed in education in order to implement intelligent tutoring systems [27], develop specific parts of e-learning systems [28], and simulate educational environments [29], as far as we know, the experiences extracted from MAS research have not been applied to design teaching-learning strategies to encourage teamwork.

Since our teaching-learning strategy is strongly related with the ITC, we have sketched it to be supported by a learning management system. For this purpose, we have chosen PoliformaT [10,11], the UPV learning management system. PoliformaT is based on the 2.6 version of the Sakai Collaboration and Learning Environment [12]. This learning management system was adopted by the UPV in 2006, and since then, it has become a core element in the university, being used by more than 38000 students, 2600 teachers and 1700 researchers in more than 40 degrees [10]. It integrates a set of tools and services to reinforce learning through the Internet.

Although Sakai offers tools to facilitate research and project collaboration, PoliformaT is strongly focused on learning management. Hence, the environment is organised by subjects. This way, teachers and students can access all the information regarding their on-going subjects in PoliformaT. Students are allowed to consult subjects' contents, laboratory practices, marks, and so forth, whereas teachers also have the possibility of editing such contents and assessing the students. It also offers tools to enhance communications between teachers and students, like forums, chat rooms, and so on.

3. TEACHING-LEARNING STRATEGY

The proposed strategy is composed of the following phases: (i) team formation, (ii) activity proposal, (iii) analysis and temporal planning of the proposal, and (iv) team dynamics and continuous assessment [34]. The learning results that we want to achieve by applying this strategy involve the acquisition of both specific competences related to a subject and generic competences common to different subjects. The main generic competence that is promoted by this strategy is teamwork. Moreover, it promotes a set of generic competences known as human relations, such as oral expression and leadership.

The following subsections describe in detail the different phases of our strategy, contextualizing how PoliformaT (see Figure 1) tools can be used and extended to support each of them.

3.1 Team formation

This first phase, which focuses on establishing work teams [52], is organized in three steps: team building, roles assignment and norms definition. Note that the team members get to know each other and discover their own strengths and limits in this phase. It should be also pointed out that the collective team identification process [30] also starts during this phase. Social science studies suggest that collective team identification helps multidisciplinary teams' performance. Thus, the teacher should foster practices that enhance collective team identification. Next, we describe each step involved in detail.

[3]http://www.agreement-technologies.org/

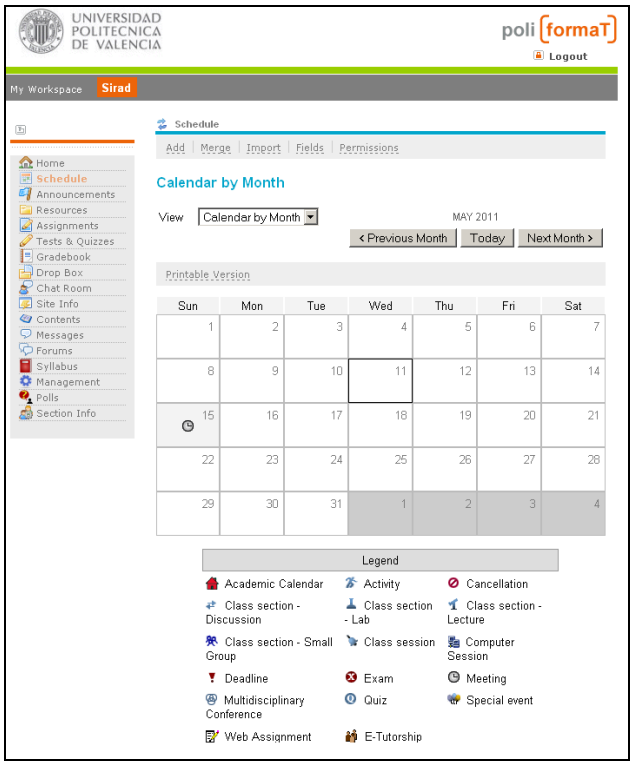

Fig 1: The PoliformaT learning management system.

3.1.1 Team building

The teacher can allow students to build their own teams, or he/she can form them by himself/herself. This last choice is more adequate due to the fact that it makes it possible for the teacher to establish work conditions similar to those found in the engineering labour market, since students will probably join an unknown team imposed a priori by their managers. Teamwork allows students to reinforce their knowledge by means of interaction, since their individual marks depend on the learning results achieved by the team. The following criteria, which are obtained from previously collected information (e.g. by means of surveys and questionnaires) from other subjects, may help the teacher to build heterogeneous teams (i.e. teams are comprised of members from different backgrounds):

- Level of development of specific competences by the students: This criterion is useful if the specific competences of the subject are directly related to specific competences from other subjects of the curriculum.
- Level of development of generic competences by the students: Includes competences like teamwork, leadership, oral expression, etc. The objective is to promote that the team's heterogeneity facilitates the learning of students with a lower level of development of a certain competence, with the help of the most advanced students, which constitutes one of the goals of teamwork and cooperative learning.
- Previous experiences: They are taken into account to avoid conflict situations caused by an incorrect team formation.
- Complementary knowledge: Team diversity motivated by the different areas of interest of the students, offers complementary points of view that help to enrich team's knowledge.

To register the established teams in PoliformaT, the teacher will use the Section Info tool, which allows defining different types of sections (groups) and assigning students to them. More precisely, the teacher should create a new section type *work teams*, and then create a section for each team. Finally, he/she will edit the students' memberships to assign each of them to the section corresponding to their teams.

3.1.2 Role assignment

Work teams can be seen as agent organizations where every student plays a specific role. These roles, which are initially assigned when the team is built and imply the execution of a set of tasks, will rotate between students during the development of the activity, so that competences associated to the role are evaluated for every student.

One of the students will take the *leader* role, assuming team coordination that assures the proper development of the activity. A second role, the *spokesperson*, will act as a link between the team and the teacher. Its tasks include fixing meetings, conveying decisions to the teacher, representing the team, and so forth. The rest of the students will take the *participant* role, which does not imply any additional obligation. The teacher, who takes the homonymous role, supervises and controls the work that is being carried out by the students.

Currently, PoliformaT supports roles which are focused on controlling the access to the different tools of the system. These roles are not visible by the students and they are only changeable by the administrator. Hence, they are not suitable to model team's roles, (i.e. *leader*, *spokesperson*, etc.). As of today, the only way for the team to inform the teacher about the roles assignment is to send an informative message to the teacher via the Messages tool. Nevertheless, we propose as a future extension the introduction of a new tool that allows the explicit definition of team's roles.

3.1.3 Norms definition

Team formation is completed with the definition of norms that govern team's behavior. The teacher should urge the team to discuss its own behavioral norms such as punctuality, respect for the speaking turns and the rest of the members of the team, obligations associated with roles, etc. It should be noted that these norms only regulate internal team dynamics and they do not affect teacher's evaluation criteria. In MAS research, norms have associated a reward system, where actions that are beneficial for the team should be rewarded, whilst detrimental actions should be sanctioned. These norms, and their associated

reward system, will be lately included in a learning contract [31] signed between the team and the teacher (see section 3.3).

PoliformaT does not support the definition of team's norms and its associated reward system in a native way. Therefore, if students were to define these elements for their team, they would have to inform the teacher by means of a document in the Drop Box tool or a message via the Message tool. Albeit the fact that this solution may partially provide support for norms, we argue that a PoliformaT's extension would be more suitable for this task. For instance, this extension could suggest pre-defined types of norms and pre-defined types of sanctions, and allow students to change/accept/deny these norms when decided by the team. The teacher would be informed by the tool about changes in norms since they will be used to evaluate the students.

3.2 Activity proposal

In this phase, the team members and the teacher will perform a negotiation process to define the activity. The teacher can come up with three different alternatives: (i) allow the students to propose an activity according to the subject's specific competences (*fully negotiable activity*), (ii) propose a predefined list of activities with negotiable aspects (*partially negotiable activity*), or (iii) propose fully defined activities (without negotiation, which would omit the present phase). Regarding the first cases, totally and partially negotiable, it must be taken into consideration that the teams may be heterogeneous, which may cause an unavoidable conflict of interests.

The divergence of interests among the team can be associated to the content and the extent of the activity, temporal constraints, or the different aspirations of the team members regarding the evaluation of the activity. The team should organize meetings prior to the negotiation with the teacher in order to identify compatible and incompatible interests and define proposals that satisfy the preferences of all the team members. This way, the team can plan the negotiation by previously establishing a ranking of preferences about the acceptable activity proposals. To do so, the students can rely on team dynamics processes like brainstorming [32], negotiation [16], voting [33], etc.

Afterwards, in the meeting with the teacher, the student playing the '*spokesperson*' role will bring up the negotiation according to the agreements established in the team meetings. Note that a meeting can be considered as an academic tutoring session [35].

As it can be observed above, this step mainly involves negotiation among team members and the teacher. The decision-making process may be carried out face-to-face (i.e., on-site education [36]) or remotely (i.e., distance education [37]). In the first case, team members negotiate in person and hence, they may not need the support of a learning management system. However, in the second case it may be useful to use some of the tools provided by PoliformaT like the Chat Room and Forum tools. This type of negotiation may be further enhanced by the inclusion of tools like the ones found in group decision support systems [38] (e.g., voting systems, videoconference, shared blackboards, etc.). In any case, the final agreement should be reflected in the learning contract, which can be stored in PoliformaT by means of a shared document.

3.3 Analysis and planning of the activity

In this phase, the team must face up the planning of the activity by identifying the tasks to be performed and establishing their temporal scheduling. The planning process will be supervised and validated by the teacher, who will be in charge of validating the resulting plan.

3.3.1 *Task identification*

To ensure an adequate development of the activity, the team should split it in a set of tasks. A task is a process that involves all the members of the team and is interrelated with the rest of the activity through its inputs and outputs. To define these tasks, the team should identify the following aspects:

- Objectives: Definition of the task's goals and the work to be developed in order to reach them.
- Effort: This estimation assesses the duration of each task and the workload to complete them. These values approximate the weight of each task in the context of the activity.
- Products: They determine the results of the task, and have a double utility on the educational field. On the one hand, they constitute the outputs of the task, which will be reused as an input by subsequent tasks. On the other hand, they are support elements for the assessment process, since they provide objective evidences of the work developed within the team.
- Precedencies: The team must establish the precedence relations among the tasks. To do so, the inputs of each task must be detected, i.e. the products required to start the development of the task.

Finally, compulsory coordination tasks will be scheduled in order to share the latest developments, and to argue about the state of the activity. Consequently, teamwork dynamics are guaranteed.

3.3.2 *Scheduling of the tasks*

This stage can be carried out in a semiautomatic way, by using planning tools for teaching-learning activities [39]. These tools establish a temporal planning of the tasks according to the duration, resources and precedence constraints set up, which allows detecting the sequence of tasks whose delay would provoke a delay in the completion of the activity. From the temporal planning obtained, the team members may negotiate its details in order to adequate the plan to their preferences.

3.3.3 Plan monitoring and validation

The teacher will supervise the planning process and negotiate some of its specificities to guarantee a successful development

of the activity. For this purpose, the following aspects will be verified by the teacher:

- Activity splitting: The division in tasks and the agreed precedence relationships will be revised by the teacher in order to check if they are appropriate for the activity.
- Effort estimation: The teacher can adjust the duration of the tasks if the team has not performed a realistic estimation.

Once the plan is validated, the teacher will negotiate with the team to schedule a set of checkpoints in order to assess the development of the activity (see subsection 3.4) and the performance of the team.

Finally, the teacher and the team will sign a learning contract [31]. This document reflects the agreements reached until this point. By this contract, the team commits to accept the established norms (see subsection 3.1.3) and the agreed plan, while the teacher assumes the responsibility of guiding the activity development in order to ensure that the team members achieve the expected learning outcomes.

This phase may be semi-automated by the inclusion of planning and scheduling tools. Even though PoliformaT does not include this kind of tools, there are several research projects that have studied the application of these kinds of techniques to educational domains. More specifically, we have been involved in AdaptaPlan [39,40], an educational system which is able to plan the academic year of a subject according to the available learning objects, teaching resources, temporal constraints, and students' preferences. We argue that some of the techniques designed for this project can be used to enhance the functionalities offered by PoliformaT.

3.4 Team dynamics and continuous assessment

In this phase, the team faces up the actual development of the activity. The teacher will encourage the use of argumentation mechanisms between students, to ensure that each proposal is justified through argumentative dialogues [18,51]. Throughout this phase, the teacher will carry out the continuous assessment process, while the students will provide feedback to evaluate the teaching-learning strategy at the end of the activity.

The purpose of the evaluation is to assess the learning of the students [41]. Recent works [42] expose the need for a continuous assessment by the teacher. The present work proposes three different evaluation mechanisms in each marked checkpoint (see subsection 3.3.3), dealing this way with the continuous assessment of the activity:

- A team member, randomly chosen (it is not mandatory that this student is currently playing the role of *spokesman*) by the teacher, will present the current state of the team's activity to the teacher and the other teams, who may ask for clarification at some point of the presentation. The presentation will be used to evaluate the whole team, ensuring this way that the team members are fully committed with the activity and team dynamics are followed instead of group dynamics, as discussed in [43].
- The teacher will be reported about the execution of the assigned roles in the team by means of anonymous surveys that will be distributed among team members.
- The teacher will evaluate the objective evidences obtained so far, i.e. the products of the completed tasks until the present checkpoint (see subsection 3.3), which represent the productivity and efficiency. Additionally, these products help the teacher to determine whether deadlines are met.

Once the checkpoint is passed, the roles defined will rotate among students. Moreover, the following evaluation mechanisms will be applied throughout the activity development:

- Definition of reputation systems [44,45] to assess the teamwork competence. The students will evaluate the development of the teamwork competence by means of anonymous surveys. This will allow building global reputation rankings concerning the cooperation level of the students. Using this kind of systems, collaborative work is promoted as an important aspect among students' education and evaluation.

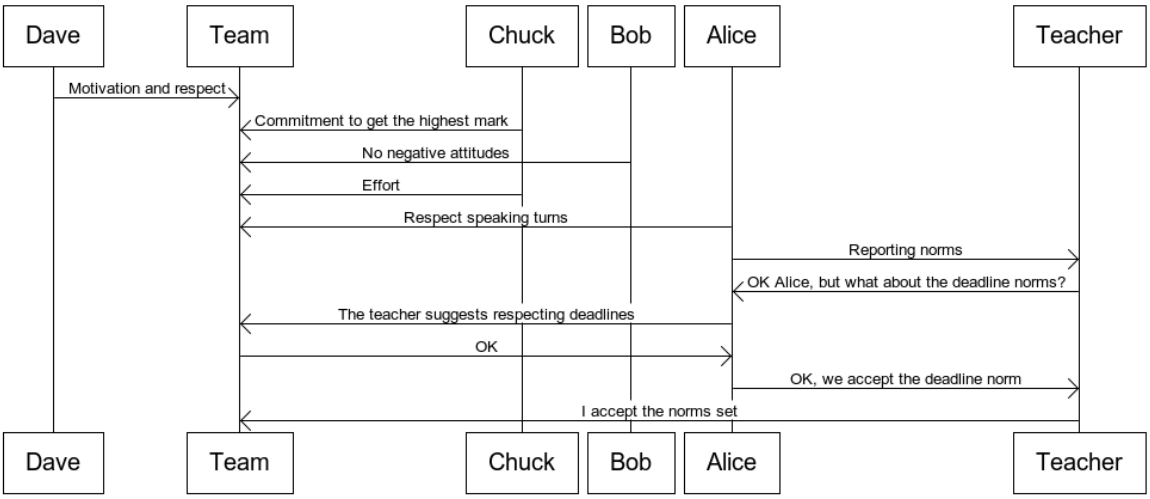

Fig 2: Dialogue between team members and the teacher to determine team's norms.

- Introduction of an incident management system that will be responsible of quickly informing the teacher in case of the infrigement of a norm by any team member. For instance, each time a norm violation is reported, the teacher could be informed by means of an email.

The last step consists on evaluating the strategy followed by the teacher, thus obtaining feedback that will be used to refine this teaching-learning strategy in its following iterations. For this purpose, each student will fill in a set of individual surveys. This process, combined with the students' academic performance in the activity, will be taken into account to refine this teaching-learning strategy in future activities.

Finally, once the activity development has concluded, the teacher will give a final mark to each student on the team, according to his/her specific evaluation criteria. To do so, the teacher will take into account the continuous assessment performed and other factors such as each student's context, attitudes and behaviour, class presentations, punctuality when delivering tasks, etc.

Opposing to the previous phases, this phase is almost fully supported by PoliformaT. Currently, PoliformaT offers Gradebook, Announcements and Polls as three of its core tools. First, the Gradebook tool can be used to perform a continuous assessment, setting a mark after each checkpoint is reached. Second, Announcements can be useful to remind the date of checkpoints or for alerting in case that an unexpected situation occurs. Third, the teacher is able to present the team with surveys (by means of the Polls tool) for different purposes, such as evaluating other teams, teammates or even the teaching-learning strategy that has been applied by the teacher. Finally, it should be highlighted that reputation and incident management systems are not currently supported by PoliformaT. Thus, it could be necessary to extend this learning management system in that direction.

4. CASE STUDY

In this section, we expose the application of our strategy to an actual subject. More precisely, we have considered the Intelligent Recommendation and Decision Support Systems (**SIRAD**) subject, which is part of the MSc in Artificial Intelligence, Pattern Recognition and Digital Image[4] at Universitat Politècnica de València. Note that our strategy is currently at an exploratory stage, so this case study should only be considered as an illustrative example and not as an exact trace.

This subject, which offers a vision of the different reasoning models that are used in Artificial Intelligence systems, focuses on the development of a project by teams of three or four students. However, the current learning results of the subject are related only to the subject's specific competences. According to the European Space for Higher Education, generic competences such as teamwork should also be assessed within university subjects. Thus, we have selected this subject to develop the illustrative example depicted in this section.

[4]http://www.popinformatica.upv.es/iarfid.html

We propose the adoption of the strategy sketched in this article,

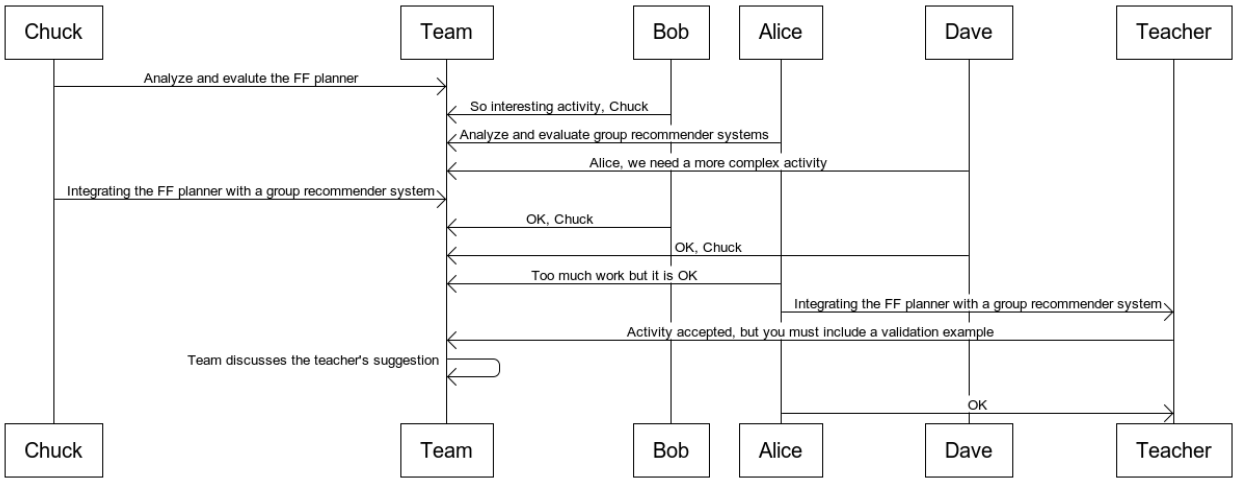

Fig 3: Dialogue between team members and the teacher to determine the activity proposal.

not only to allow the teacher to assess the subject's specific competences, but also to facilitate the evaluation of the generic teamwork competence. From this point, we will assume that all the dialogs carried out in each phase of the strategy (both among students and between team and teacher) follow a turn-based protocol, where all the students are equally treated. However, it would be possible to assume any other dialog protocol. Following, we detail the development of the different phases of our teaching-learning strategy applied to the SIRAD subject.

Table 1. Academic profiles: Values range from 0 (lowest) to 10 (higher)

		Bob	Alice	Chuck	Dave
Academic info	Expertise field	Networks	AI	AI	Databases
	Average number of examination sessions	1	5	2	1
	Artificial intelligence subject mark	9	7	7	8
	Final degree project mark	10	7	10	9
Abilities	Oral skills	1	1	5	8
	Leadership	1	9	0	9
	Previous teamwork experience	5	0	9	3
Beliefs	Cooperative student	8	5	8	9
	Motivation	9	3	9	8
Preferences	Works on weekends?	YES	NO	YES	YES
	English speaking skills	9	9	4	6
Goals	Expected mark	8	5	10	10

The teaching-learning strategy starts with the team formation phase. The teacher builds a team composed by the students Alice, Bob, Chuck and Dave. The teacher will have built personal profiles of the team members by means of surveys and questionnaires. These profiles describe their current development of certain generic and specific competences in terms of academic grades, abilities, beliefs, preferences and goals. As it can be observed in Table 1, the students have different objectives and expertise fields, configuring in this way a heterogeneous team.

Initially, the team assigns the *leader* role to Bob, while Alice assumes the *spokesperson* role, and Chuck and Dave act as *participants*. Afterwards, they propose the set of norms (see Figure 2) that will govern the team's behaviour from now on. Once the students have reached an agreement about the team's norms, Bob will prepare a learning contract that will have to be validated by the teacher.

In the activity proposal phase, the teacher decides to allow the team to propose an activity related to the specific competences of the SIRAD subject. The team will follow a brainstorming process (see Figure 3) to define an activity that satisfies the team members' preferences. Initially, Chuck proposes an activity which is subsequently refined by Alice. After being informed about the agreed activity ("Integrating the Fast-Forward planner [46] with a group recommender system"), the teacher ensures that it adjusts properly to the specific competences of the subject before approving it.

Concerning the analysis and planning phase, the students initially split the activity into six different tasks (see Figure 4),

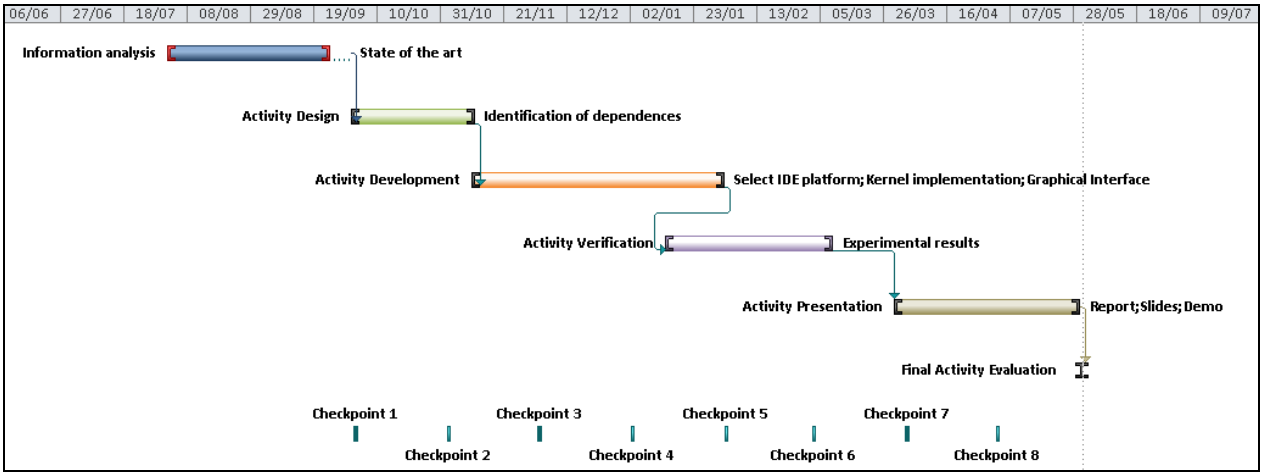

Fig 4: Temporal scheduling of the activity and the checkpoints.

which involve analysis, design, development, verification, presentation and evaluation of this activity. Once the tasks have been identified, the team carries out the temporal scheduling, as depicted in Figure 4. Following, the team negotiates the scheduling details in order to accommodate their preferences. For instance, Alice does not want to work at weekends, so the team accepts this adjustment with the condition that all the team members work on the activity during the week.

Once the teacher agrees with the planning, she establishes several checkpoints in the calendar which will serve as evaluation points and role-changing events within the team. Lastly, the teacher and the team update the learning contract with the planning of the activity.

The team starts to work cooperatively on the activity during the fourth phase of our strategy. Once the first checkpoint is reached, Chuck is randomly chosen as the oral presenter of the activity status. The teacher asks him about the current state of the activity, and gathers evidences, by means of PoliformaT's Polls tool, which shows that the work is not being developed as expected.

Then, the teacher uses this testimony and the information gathered through the reputation system and the incident management system to determine which members of the team are not performing as expected. Additionally, the different surveys will also reflect how the students have performed the different roles and their associated competences. Then, the teacher arranges a meeting with the team to point them out the shortcomings of their work and encourage them to improve their team dynamics and generic competences.

After the checkpoint, the roles inside the team are shifted by the teacher. Chuck and Dave will play, respectively, the *leader* and *spokesperson* roles, while Alice and Bob will assume the *participant* role.

From this point, the team takes into account the teacher's recommendations and starts improving team dynamics. The activity development continues until the final checkpoint, in which the teacher gives the final marks to the team members, according to the evidences gathered by means of PoliformaT throughout the whole activity development. Hence, the information available in PoliformaT may be seen as a teaching portfolio [47] of the activity.

5. CONCLUSIONS AND FUTURE WORK

This article has explored a teaching-learning strategy aimed at reinforcing the teamwork competence in project-based subjects. This teaching-learning strategy is based on experiences drawn from agreement technologies, one of the current research topics in Artificial Intelligence and multi-agent systems. It allows the design of activities for teams of students and their continuous assessment by the teacher throughout the learning process.

The teaching-learning strategy is strongly related to the information and communication technologies. Hence, we have analysed the application and possible extensions of the Sakai-based PoliformaT learning management system to each phase of our strategy.

As for future work, several directions appear to be promising: applying the present strategy in an actual educational environment such as the SIRAD subject (as proposed in the case study); suggesting extensions to the PoliformaT learning management system to meet the requirements detected in the present article; or developing our own set of Computer-Supported Collaborative Learning tools in order to support it, allowing the teacher to supervise the activity and evaluate the

progress of both the teamwork competence and the rest of specific competences.

Moreover, we believe that our teaching-learning strategy can be extended to satisfy **special educational needs** [48]. These needs include giftedness, learning and communication challenges, and behavioural and developmental disorders. This way, we pursue the adaptation of our teaching-learning strategy, allowing students with special educational needs to integrate within a work team and successfully acquire the subject's generic and specific competences.

Finally, we also propose the adaptation of our teaching-learning strategy to deal with off-campus education, also known as **distance education** [49] or external study, which brings students and teachers that are separated by geographical distance the possibility to collaborate in the same team. Currently, the proposed strategy includes some on-site phases, so our goal is to adapt these phases to allow the teacher and the team to choose between carrying them out on-site or off-campus.

6. ACKNOWLEDGMENTS

The work is supported by the TIN2008-04446, TIN2008-06701-C03-01, TIN2009-13839-C03-01, PROMETEO/2008/051 projects of the Spanish Government, CONSOLIDER-INGENIO 2010 under grant CSD2007-00022, and the FPU grants from the Spanish Ministry of Education awarded to Sergio Pajares Ferrando with reference AP2009-1896, and to Víctor Sanchez-Anguix with reference AP2008-00600.

7. REFERENCES

[1] Perrenaud, P., Noreste, E., and Sáez, J.C. 1999. Construir competencias desde la escuela. Santiago de Chile, Dolmen Ediciones.

[2] Chappell, C., Gonczi, A., and Hager, P. 2000. Competency-based education. National Centre for Vocational Education Research (NCVER).

[3] Johnson, D.W., Johnson, R.T., and Smith, K. 2007. The state of cooperative learning in postsecondary and professional settings. Educ. Psychol. Rev. 19(1), 15-29.

[4] Slavin, R.E. 1980. Cooperative Learning. Review of Educational Research. 50(2), 315-342.

[5] Wooldridge, M.J. 2009. An introduction to multiagent systems. Wiley.

[6] Ferber, J. 1999. Multi-agent Systems: An Introduction to Distributed Artificial Intelligence. Addison Wesley Longman.

[7] Russell, S., and Norvig, P. 2003. Artificial Intelligence: A Modern Approach. Pearson Education.

[8] Guitert, M., Romeu, T., and Pérez-Mateo, M. 2007. Competencias TIC y trabajo en equipo en entornos virtuales. Revista de Universidad y Sociedad del Conocimiento, 4(1).

[9] Stahl, G., Koschmann, T., and Suthers, D. 2006. Computer-supported collaborative learning: An historical perspective. Cambridge University Press.

[10] Busquets Mataix, J., Roldán Martínez, D., Martínez Naharro, S., del Blanco Orobitg, D. 2006. PoliformaT: una estrategia para la formación on-line en la Educación Superior. In Proceedings of the Virtual Educa 2006.

[11] Mengod, R. 2006. PoliformaT, the Sakai-based on-line campus for UPV – history of a success. In Proceedings of the 5th Sakai Conference.

[12] White, A. 2005. Introducing the Sakai Community. In Proceedings of the 4th Sakai Conference.

[13] Sierra, C., Botti, V., and Ossowski, S. 2011. Agreement computing. Künstliche Intelligenz, 25(1), 57-61.

[14] Botti, V., Garrido, A., Gimeno, J.A., Giret, A., Igual, F., and Noriega, P. 2010. An Electronic Institution for Simulating Water-Right Markets. In Proceedings of the 3rd Workshop on Agreement Technologies, 3-18.

[15] Centeno, R., Fagundes, M., Billhardt, H., Ossowski, S., Corchado, J.M., Julián, V., and Fernandez, A. 2009. An Organization-based Multiagent System for Medical Emergency Assistance. In Lecture Notes in Computer Science, volume 5517/2009, 561-568.

[16] Sánchez-Anguix, V., Julian, V., Botti, V., and García-Fornes, A. 2011. Analyzing Intra-Team Strategies for Agent-Based Negotiation Teams. In Proceedings of the 10th International Conference on Autonomous Agents and Multiagent Systems, 929-936.

[17] Jennings, N.R., Faratin, P., Lomuscio, A.R., Parsons, S., Wooldridge, M.J., and Sierra, C. 2001. Automated negotiation: Prospects, methods and challenges. Group Decision and Negotiation, 10(2), 199-215.

[18] Pardo, P., Pajares, S., Onaindía, E., Godo, L., and Dellunde, P. 2011. Multiagent Argumentation for Cooperative Planning in DeLP-POP. In Proceedings of the 10th International Conference on Autonomous Agents and Multiagent Systems, 971-978.

[19] Rahwan, I., Ramchurn, S.D., Jennings, N.R., McBurney, P., Parsons, S., and Sonenberg, L. 2003. Argumentation-based negotiation. The Knowledge Engineering Review, 18:4, 343-375.

[20] Onaindía, E., Sapena, O., and Torreño, A. 2010. Cooperative Distributed Planning through Argumentation. International Journal of Artificial Intelligence, 4(S10), 118-136.

[21] Rintanen, J., and Hoffmann, J. 2001. An Overview of Recent Algorithms for AI Planning. Künstliche Intelligenz, Volume 2/01, 5-11.

[22] Esparcia, S., and Argente, E. 2011. Formalizing Virtual Organizations. In Proceedings of the 3rd International Conference on Agents and Artificial Intelligence, volume 2, 84-93, SciTePress.

[23] Ferber, J., Gutknecht, O., and Michel, F. 2003. From agents to organizations: an organizational view of multi-agent

systems. Agent-Oriented Software Engineering IV, 443-459, Springer.

[24] Criado, N., Julian, V., Botti, V., and Argente, E. 2010. A Norm-based Organization Management System. In Coordination, Organizations, Institutions, and Norms in Agent Systems V, volume 6069, 19-35, Springer.

[25] Boella, G., van der Torre, L., and Verhagen, H. 2006. Introduction to normative multiagent systems. Computational and Mathematical Organization Theory, volume 12(2-3), 71-79.

[26] Sabater, J., and Sierra, C. 2005. Review on computational trust and reputation models. Artificial Intelligence Review, 24(1), 33-60.

[27] Chou, C., Chan, T., and Lin, C. 2003. Redefining the learning companion: the past, present, and future of educational agents. Comput. Educ., 40(3), 255-269.

[28] Norman, T.J., and Jennings, N.R. 2002. Constructing a virtual training laboratory using intelligent agents. International Journal of Continuing Engineering Education and Life Long Learning, 12(1), 201-213.

[29] Sklar, E., Davies, M., and Co, M.S.T. 2004. SimEd: Simulating Education as a Multi Agent System. In Proceedings of the 3rd International Conference on Autonomous Agents and Multiagent Systems, volume 4, 998-1005.

[30] van der Vegt, G.S., and Bunderson, J.S. 2005. Learning and performance in multidisciplinary teams: The importance of collective team identification, The Academy of Management Journal, 48(3), 532-547.

[31] Zuo, J., Pullen, S., and Birchmore, R. 2008. The use of a learning contract in higher education-a case study. AUBEA and Unitec.

[32] Isaksen, S.G., and Gaulin, J.P. 2005. A reexamination of brainstorming research: Implications for research and practice. Gifted Child Quarterly, 49(4), 315-329, Sage Publications.

[33] Nurmi, H. 2010. Voting Systems for Social Choice. Handbook of Group Decision and Negotiation, 4(2), 167-182, Springer.

[34] Neary, M. 2000. Supporting students' learning and professional development through the process of continuous assessment and mentorship. Nurse Education Today, 20(6), 463-474.

[35] Thomas, L., Nutt, C., and Wall, T. 2009. Personal tutoring and academic advising: improving student success. Widening Participation and Lifelong Learning, 11(3), 2-5.

[36] Mamary, E.M., and Charles, P. 2000. On-site to on-line: Barriers to the use of computers for continuing education. Journal of Continuing Education in the Health Professions, 20(3), 171-175.

[37] Menchaca, M.P., and Bekele, T.A. 2008. Learner and instructor identified success factors in distance education. Distance Education, 29(3), 231-252.

[38] Turban, E., and Aronson, J.E. 2000. Decision support systems and intelligent systems. Decision support systems and intelligent systems, Prentice Hall PTR.

[39] Garrido, A., Onaindia, E., and Sapena, O. 2009. Automated planning for personalized course composition. In Proceedings of the 9th IEEE International Conference on Advanced Learning Technologies, 178-182.

[40] Garrido, A., Fernandez, S., Morales, L., Onaindia, E., Borrajo, D., and Castillo, L. 2010. On the automatic compilation of e-learning models to planning. The Knowledge Engineering Review, 00(0), 1-24.

[41] Bernad, J.A. 2001. Modelo cognitivo de evaluación educativa. Narcea.

[42] Delgado, A.M., and Cuello, R.O. 2006. La evaluación continua en un nuevo escenario docente. Revista de Universidad y Sociedad del Conocimiento, 3(1), 1-13.

[43] Katzenbach, J.R., Smith, D.K., and Bookspan, M. 1993. The wisdom of teams. Harvard Business School Press.

[44] Temperini, M., and Sterbini, A. 2008. Learning from peers: motivating students through reputation systems. In Proceedings of the International Symposium on Applications and the Internet, 305-308.

[45] Voss, M. 2004. Privacy preserving online reputation systems. Information Security Management. Education and Privacy, 249-264.

[46] Hoffmann, J. 2001. FF: The Fast-Forward Planning System. AI Magazine, 22(3), 57-62.

[47] Barootchi, N., Keshavarz, M.H. 2001. Assessment of achievement through portfolios and teacher-made tests. Educational Research, 44(3), 279-288.

[48] Friend, M., and Bursuck, W. 1996. Including Students with Special Needs: A Practical Guide for Classroom Teachers. Prentice Hall.

[49] Beldarrain, Y. 2006. Distance education trends: Integrating new technologies to foster student interaction and collaboration. Distance Education, 27(2), 139-153.

[50] Fellers, J.W. 1996. Teaching teamwork: exploring the use of cooperative learning teams in information systems education. ACM SIGMIS, 27(2), 44-60.

[51] Veerman, A., Andriessen, J., and Kanselaar, G. 2002. Collaborative argumentation in academic education. Instructional Science, 30(3), 155-186.

[52] Deibel, K. 2005. Team formation methods for increasing interaction during in-class group work. ACM SIGCSE, 37(3), 291-295.