NUCLEO: Adaptive Computer Supported Collaborative Learning in a Role Game Based Scenario

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Abstract

This paper presents the adaptation model used in NUCLEO, a pilot e-learning environment that is currently being developed at the Complutense University of Madrid. The NUCLEO system combines two approaches grounded in the constructive pedagogical stream, the Computer Supported Collaborative Learning and the Problem Based Learning, with the engaging and immersive formats of the videogames. It provides a futurist scenario in which students (represented by avatars and organized in small teams) have to collaborate to solve a learning "mission" following the mechanics of a classical role based play. In order to increase the efficiency of the collaborative work and to reduce the teacher's workload, NUCLEO applies user modeling techniques to the students' learning strategies, considering a simplified framework of Vermunt's model for learning styles. The model determines how the system brings together students whose learning strategies are complementary to build up collaborative and semi-autonomous learning teams. Examples from an ongoing study with NUCLEO to teach programming disciplines illustrate the presentation of these adaptation models.

1. Introduction

The *Net Generation* [16] has already arrived to university and college. They completely differ from the teachers in charge of their education in the role that ubiquitous technologies have played in their everyday lives. Today students have grown up using devices like computers, mobile phones, and video consoles for almost any activity; from studies and work to entertainment or communication. This has probably altered the way in which they perceive and interact with the environment, both physically and socially. Nevertheless, most teaching strategies ignore these social changes and remain anchored in traditional text based instructional formats, provoking problems like a rising lack of students' motivation. However, the educational community is now willing to use new approaches with the appealing features of videogames and Internet tools in educational applications [13].

NUCLEO is an e-learning environment deeply grounded in the socio-constructive pedagogical stream [14], [18]. In NUCLEO, active and collaborative learning procedures take place in the scenario of a virtual world presented in the format of a role-play videogame. NUCLEO takes the learner (represented by an avatar) into a futurist scenario where he/she has to solve a mission working in collaboration with other students inside a team. In this context, students gain knowledge during the following processes:

- *Problem solving procedures*. The missions proposed to the students are complex programming cases. Their presentation format respects the style of the videogame metaphor and it is rendered in a virtual scenario.
- *Collaboration procedures*. The missions are conceived to be solved collaboratively inside a team specifically formed for that purpose.

Therefore, NUCLEO combines the Problem Based Learning (PBL) [15] and the Computer Supported Collaborative Learning (CSCL) [9] approaches in a framework that uses a multiplayer role videogame as the delivery format.

An implicit assumption in collaborative learning is that students learn one from another. Therefore, the way in which students are grouped has a strong impact on the results of the learning process. A positive learning experience might turn into a negative one depending on the group composition.

Even so, for CSCL and PBL to be effective, the students need some guidance through the different stages. In lack of adequate guidance and help, students may easily loose focus and get frustrated [5]. This means a considerable increase of the workload for teachers. They not only have to change their role from knowledge transmitters to some sort of expert co-learners who give hints and guidance but, moreover, they also have to track the progress of a number of small students' groups.

NUCLEO addresses these two problems by means of an adaptation model that relies on Vermunt's conception and classification of learning styles [17]. The Vermunt's "Inventory of Learning Styles" helps us to distinguish the students that need a more intensive guidance through the learning process, from those who are more capable of driving alone their own learning experience. By grouping students according to this criterion, we presume that the most autonomous and capable students will assume part of the teacher's job in leading and guiding the group. At the same time, the effectiveness of the collaboration process within a team will improve by joining students with complementary learning strategies.

NUCLEO is now under test in several programming courses that cover different areas of the Spanish education context: four groups at university level at the UCM (two from Physics and two more in Computer Science) and one at high school level.

The rest of the paper is structured as follows: Section 2 outlines some relevant aspects of the pedagogical foundation underlying NUCLEO. The overall architecture of the system is described in section 3 together with a brief functional description. Section 4 presents the adaptation model of NUCLEO system. Finally, some preliminary results of the current experiments are presented together with the conclusions.

2. Pedagogical approach in NUCLEO

Educational literature has shown the benefits of combining PBL and CSCL to improve students' thinking skills [10]. This combination leads to deeper levels of learning, critical thinking, shared understanding, and long-term retention of the learning material. Furthermore, collaborative learning also provides opportunities for developing social and communication skills, acquiring positive attitudes towards co-members and learning material, and building social relationships and group cohesion [7].

Although a number of variables have been identified as factors that potentially influence the effectiveness of collaborative learning, social interaction appears to be the key to collaboration [4]. Nevertheless, just placing students into groups and giving support to some kind of communication among them does not guarantee the emergence of the social interactions that lead to effective collaboration. To improve the collaborative learning, NUCLEO applies a set of instructional approaches simultaneously, each reinforcing and/or complementing the other. The most remarkable are:

- *A virtual world and a role game to set the learning scenario*. Among the educational benefits that videogames can bring to instructional methods, we are very interested in the social bonds formed between players, especially in multiplayer games. These bonds may foster the creation of *communities of practice* [12].
- *Collaboration scripts to structure interactions among students*. Research studies show that when learners are left to their own devices, they rarely engage in educationally relevant activities [3]. In CSCL, collaboration scripts aim at structuring collaborative learning processes in order to trigger group interactions that rarely take place in free collaboration. NUCLEO collaboration procedures among team co-members are regulated by scripts expressed using IMS Learning Design (IMS LD) [6], which is the "de facto" standard language for pedagogical modeling.
- *An adaptation model to form effective teams*. By grouping students according to their learning styles [17], NUCLEO promotes the learning effectiveness of the teams and fosters collaboration, as the students interact with peers with compatible learning strategies. Section 4 explains in more detail the adaptation model developed for NUCLEO.

3. Functional description and system architecture

For motivational purposes and also to reinforce the social interaction among students, NUCLEO sets the theoretical pedagogical background described above in an environment where the learning experience occurs within a multi player game in a fantastic futurist scenario. The mechanics of the game follow a classical role based playing approach. The metaphor takes the student to an artificial universe populated by a special kind of living beings in the form of Artificial Intelligences (AI). The civilization of these AI, which is known as the NUCLEO, is threatened to extinction by a mysterious virus that is destroying their entire virtual worlds. To confront this terrible menace, small combat units (usually 3 or 4 members) fight the threat through different missions. Students' avatars play the role of these champions and their type of participation, duties, and skills are conditioned by their tribe. There are three tribes in the NUCLEO civilization. The *Evians* are specially qualified AI with powerful minds trained in strategies and logics. They inhabit the metropolis of the NUCLEO. The *Ruks* are an itinerant tribe native of the peripheral regions of NUCLEO. It is mainly composed by pirates and mercenaries. The *Exters* are strange and unpredictable AI that have evolved in extreme conditions. They are mutants with odd forms and strange powers difficult to control.

The social interaction within the game takes place at two levels:

- *Intra group collaboration*. To structure the collaboration activities inside a team, NUCLEO uses scripts modeled with IMS LD. These scripts conduct the students through different learning activities conceived to get educationally relevant interactions.
- *Inter group social interaction*. The interaction among different groups happens in two different forms, competition and collaboration. NUCLEO is a game in which teams and students compete to get the best group and individual scores respectively. To promote collaboration among members of different teams, students get individual rewards when they help another team.

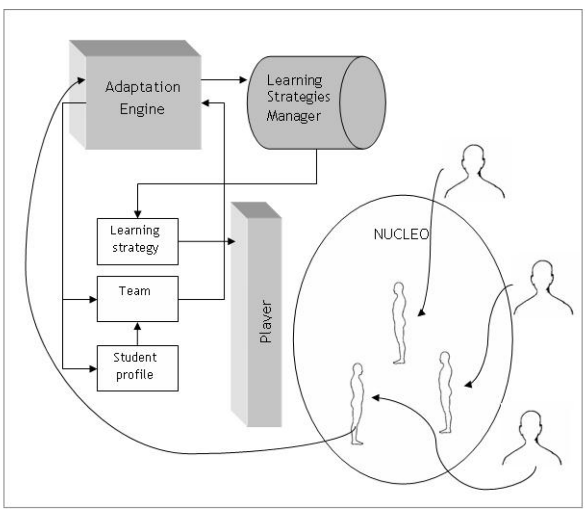

Figure 1. NUCLEO Architecture

Figure 1 shows the system architecture supporting these requirements. It comprehends three main components: the *learning strategies manager*, the *adaptation engine*, and the *player*.

The *learning strategies manager* is in charge of the creation, storage, and management of the personalized learning strategies and all their components (i.e. phases, roles, activities, environments, tools, and learning objects). The learning strategies are described by scripts expressed in IMS LD.

The *player* is in charge of three main duties [8]. First, it interprets and sets up the learning design files provided by the manager. Second, it provides the user interface. Finally, it assigns to the persons the correct roles (i.e. the NUCLEO tribes) and represents the learner's avatars and the futurist scenario where the metaphor is livened up (see Figure 2). In addition to this, it collects data from the user interaction that will be sent to the adaptation engine.

The *adaptation engine* contains the adaptation model and it is in charge of providing adaptive behavior. The following section explains it in more detail.

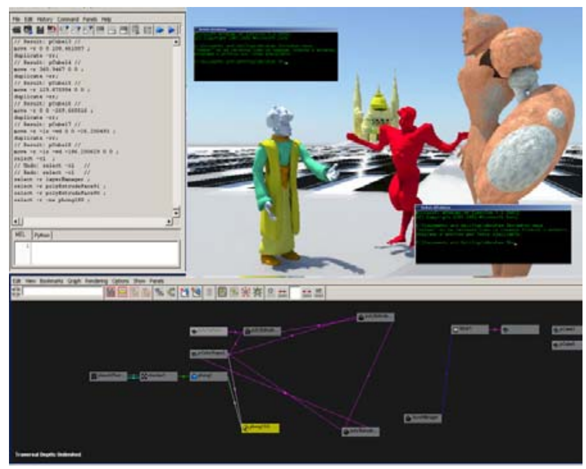

Figure 2. System user interface

4. Adaptation model

User adaptation in e-learning can be characterized as the ability of a system to personalize the learning experience to different individual conditions over time. In general, the adaptation process includes three stages [1]: retrieving information about the user; processing the information to initialize and update a user model; and using the model to provide the adaptive behavior. One of the student's' features that can be part of the user model is their learning style. This subject has generated a lot of debate over the past years mainly because, in spite of long empirical efforts to pin them down, the identification of learning styles remains elusive. Nevertheless, some approaches that describe learning styles as flexible strategies to tackle learning have got positive evaluations in relevant independent studies [2], particularly the Vermunt’s framework. In addition to this, Vermunt's framework was specially conceived for university students and it is really more a classification of students according to the strategies they usually employ to approach to learning than a learning style classification, which fits with our idea of reaching auto-regulated teams. We are also studying other possibilities for the conceptual model behind the team formation like Kirton's Adaptation-Innovation theory [11].

Vermunt classifies students into four types depending on the attitudes they adopt in five different areas of learning. These four learning styles are: meaning-directed (MD), application-directed (AD), reproduction-directed (RD), and undirected (U). We have merged these four profiles into three attending to the learner’s capability to regulate his/her own learning process. We have correlated the resultant profiles with the three NUCLEO tribes. Those students who are able to self-regulate their learning processes would benefit from a loose teacher strategy. This is usually highly correlated with MD and AD patterns that correspond to the “evian” tribe. On the other side, students that do not present this capability would need strong teacher’s control and guidance. This corresponds to the RD (for the “ruks” tribe) and the U patterns (for the “exters”). Therefore, we try to group together a capable student



	Meaning-directed	Application-directed	Reproduction-directed	Undirected
Cognitive processing	Look for relationships between key concepts/theories: build an overview	Relate topics to everyday experience: look for concrete examples and uses	Select main points to retain	Find study difficult: read and re-read
Learning orientation	Self-improvement and enrichment	Vocational or “real world” outcomes	Prove competency by getting good marks	Ambivalent; insecure
Mental model of learning	Dialogue with experts stimulates thinking and engagement with subject through exchange of views	Learn in order to use knowledge	Look for structure in teaching and texts to help take in knowledge and pass examinations. Do not value critical processing or peer discussion.	Want teachers to do more. Seek peer support
Regulation of learning	Self-guided by interest and their own questions; diagnose and correct poor understanding	Think of problems and examples to test understanding, especially of abstract concepts	Use objectives to check understanding; self-test; rehearse	Not adaptive

Figure 3. Correlation between Vermunt's profiles and NUCLEO tribes

(an “evian” usually) with others that demand stronger lead through the learning process, implicitly assuming that the students will learn from and teach one another.

The adaptation cycle in NUCLEO follows the next steps:

1) *The system classifies the student into a certain learning profile*. The information for this classification is gathered by means of the Vermunt’s “Inventory of Learning Styles” questionnaire. Among all the different features analyzed by the questionnaire, the most relevant for our user model is his/her auto-regulation capabilities.
2) *The adaptable elements are modified according to the students’ models*. In this case, the team itself is the adaptation subject. According to the student profile, teams are constituted (each team stands for the crew of a space ship), usually by three members (though there might be special cases with 2 or 4 members per team). Each member has a duty depending on the tribe he belongs to: the evians are the captains of the crew in charge of the work organization, the ruks are in charge of maintaining a logbook (in which the progresses are tracked) and the exters' duty is to assure that everybody in the crew understands the complete software in all its parts.
3) The student profile is updated by a feedback loop. Three are the channels to gather the information:
   - The results that the whole team has obtained in the mission.
   - The individual score obtained in the peer evaluation among team co-members.
   - Some data generated in the system-user interaction process, which give hints of the student’s level of participation (e.g. number of files created, exchanged messages, or answered messages).

Depending on the results obtained in step 3) teams could be reformed or maintained for the next mission.

5. Preliminary results of the experiments and conclusions

The NUCLEO system is now under test in three educational settings (two at university level and one at high school level). Even though none of the experiments has completely finished yet, some preliminary results can be advanced.

First, the impact on the student’s motivation is being very positive (even if the programming topic is not probably the best suited application domain). In two 40 students sub-groups of a Programming Course at the Physics School, the subgroup that has followed the traditional teaching approach presents 63% ratio of students' drop off. Meanwhile, in the NUCLEO subgroup this ratio decreases below 20%.

We have also observed that, even though the courses evaluation has not yet concluded, the marks obtained by the students that belong to the NUCLEO group in partial evaluations are slightly better (around 10%) than the ones obtained by members in the traditional group.

Although the partial results are optimistic, we have observed that the knowledge acquired by the NUCLEO students seems to follow a very irregular and unstructured pattern. It seems as if they had deepen in the aspects they were interested in, acquiring a great amount of knowledge, while at the same time they have totally neglected other aspects. We are waiting for the final results of the system evaluation to come to a conclusion about the accuracy of the user model approach in the terms we have exposed in this article. Specially, these results will allow evaluating the effect of the learning style profile in the improvement on the student grouping strategies and the group performance.

To conclude, we have observed during the course of the experiment that the approach presented here has changed the attitude of the students towards the study, helping them to develop valuable abilities and more responsibility towards their own learning process, without implying an increase of the teacher's workload.

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