Adaptative communities of practice through games in the "NUCLEO" e-learning framework

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ABSTRACT

Today students grow up in an environment that strongly differs about tools and experiences from those of previous generations. This environment is characterized by ubiquitous technologies and very tight loops of interaction and reward. However, educational techniques are anchored in the features of previous generations, causing an increasing lack of learning effectiveness in students. The NUCLEO e-learning system tries to confront this lack of adaptation by providing engaging and motivating educational experience to these new students. The system is built over two basic pedagogical pillars; the socio-constructive theories of learning and specifically the communities of practice, and the student centered instruction models. NUCLEO provides a futurist scenario in which students, who are represented by avatars, have to collaborate to solve a proposed learning "mission" following a classical role based play mechanics. The educational strategy proposed to individual students is adapted to his learning style pattern according to their knowledge acquisition profiles.

Keywords

Game based learning, adaptive learning, collaborative learning, e-learning standards.

1. INTRODUCTION

Reports about the decreasing success rates of students have become common in last years in most of developed countries. Educators find great difficulties in motivating students that usually perceive their lessons as mere repetitive exercises that do not motivate them neither for their content nor for their presentation. Some authors [24], [11] have pointed out to the technology as the key factor in this apparent lack of interest. New generations have grown up using technology in their everyday lives for almost any activity. Entertainment, studies, work, or communication happen through devices like computers, mobile phones and video consoles that have changed their ways of perceiving and interacting with the environment, both physical and social. For instance, it is very difficult for these students to concentrate on a text for a long time when they are used to quickly look for information in the web while asking for help to friends with some instant messaging program. Besides, although educational contents have evolved with a greater use of multi-media interactive contents, they are far away of the impressive and immersive contents obtained by the entertainment industry for their video games, music, or Internet. Modern students might be simply bored by most of today's education content formats [25].

Given these observations, the idea that the educational process might benefit by approaching the learning experience to the exciting and engaging formats students are used to is gaining a wider acceptance [23]. As a part of this trend, the use of video-gaming and communities of practice are two interesting possibilities that educators are beginning to explore.

Modern videogames are industrial works that build very realistic scenarios where the player is not just a reactive subject, but the driver of the story. In this sense, the player's decisions must consider how they influence on the future development of his gaming path and the effect of his actions over the environment. In order to acquire this information, games propose a very tight feedback loop. The player is encouraged to better understand and know the mechanics of the game through an almost immediate and measurable progress to the success in the game (e.g. to finish the game or to obtain greater scores than other players). A very important issue to consider about games is how communities of practice are naturally formed around them. It is common that players share their knowledge and stories to improve their experiences. Although this effect also appears in stand-alone games, some argue that there is an even stronger foundation underlying multiplayer games [30]. Multiplayer games may motivate through independent roles and the social bonds that are formed between players. For this reason, they rise as a natural medium for sustaining the sort of self regulated communities of practice where learning takes place by actively participating in the social activities and events of that community [17]. Nevertheless, learning environments based on communities of practice through gaming cannot be considered a one catch for all option. Even when there are common features to current students, there are still a wide variety of learning styles. That is, people acquire knowledge and skills using very different techniques and with changing rates of success that depend on the topics and their situation. Thus, the application of any educational framework to a variety of types of students demands to be able to target individual needs.

The use of student-centered models [13] may give the tools the ability to tackle with the diversity of students' backgrounds, attitudes, and learning habits. These models offer insights about how the learning process happens from the point of view of the student, and techniques to take advantage of some specific features that appears in these processes. In this sense, these profiles switch the educational focus from the traditional tutor perspective to a learner centered instruction. The implementation of these models in online educational tools needs that they include adaptation mechanisms to customize instruction concerning aspects like: previous domain knowledge [22], learning styles

[12], or preferences [2]. For the scope of the work described in this paper, the adaptation model only considers the student's learning style using a simplification of Vermunt's proposal [33]. Among all the proposals of learning style models, Vermunt's framework has two relevant features for the purposes of the NUCLEO system. First, it was specifically designed for university students and the first target students of the NUCLEO system belong to several faculties of Spanish universities. The second one is that Vermunt's model has proved a very high reliability in this context [32]. In this sense, it is one of the models with a greater number of case studies supporting it.

For Vermunt, the terms "approach to learning" and "learning style" are synonymous. A "learning style" is defined as "a coherent whole of learning activities that students usually employ, their learning orientation and their mental model of learning". Students belong to one of four different learning types (i.e. MD, AD, RD, and U) depending on the attitudes they adopt in four different areas of learning. This classification produces the 4x4 matrix shown in Table 1. The NUCLEO framework currently considers a simplification of this model that merges AD and MD learning styles into one style.

Table 1. Vermunt's learning styles types (source [6]).

	Meaning-directed (MD)	**Application-directed (AD)**	**Reproduction-directed (RD)**	**Undirected (U)**
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

NUCLEO reconciles this theoretical background with the features of modern students through an environment where the learning experience occurs within a game set in a fantastic futurist scenario. The mechanics of the game follows a classical role based playing approach. The metaphor of NUCLEO takes the students to an artificial universe populated by a special kind of living beings in the form of Artificial Intelligences (AIs). The civilization of these AIs, which they called the NUCLEO, is threatened to extinction by a mysterious virus capable to destroy the entire virtual worlds where they inhabit. The AIs superior council, formed by the most wise and oldest AIs, decides to call beings from the most important tribes of the NUCLEO to combat this terrible menace. In this context, students' avatars build up these fighting units. These units cannot achieve success without collaboration among their members, who are provided with different skills. Their success will lead to the defeat of the virus and the endurance of the AIs civilization. The educational modeling of the learning process in the system uses IMS LD specification [14], which is the *de-facto* standard for educational modeling.

The remaining paper is structured as follows. Section 2 describes the pedagogical foundation of the NUCLEO framework and its prototype. The architecture of the systems is outlined in section 3. The following subsections pay attention to the main features of the system components. Finally, some conclusions and future work are discussed.

2. PEDAGOGICAL FRAMEWORK.

As already stated in the introduction, the system presented in this paper is built over two pedagogical pillars: socio-constructivism theories of learning and learning styles.

Socio-constructivist theories ([35], [17], [9]) considers that learning happens through the participation in social activities where the student establish a complex interaction with his environment. In these interactions, the student and tutor roles are blurred and exchanged according to the specific and changing circumstances of the interaction. Among the variety of proposals included in this stream, multiplayer videogames constitute a powerful example of learning through communities of practice with a stimulating and engaging format. In NUCLEO e-learning environment knowledge is gained through collaboration procedures among students teams designed to solve a complex problem in the format of a mission. Students, represented by avatars, interact with each inside a role-based game scenario. Students play a predefined role in the team (i.e. the community of practice) in order to solve the proposed mission which corresponds to a certain learning objective.

Roles in AIs teams are related with the adaptation of the learning strategy to student's learning styles according to Vermunt's model. Not all students may benefit from learning through gaming and collaboration, or at least not all the time. There may be certain learning profiles which need deeper guidance and assistance through the learning process. In NUCLEO, AIs are organized in three tribes that stand for the three learning styles types in the simplified Vermunt's model of NUCLEO. Thus, the role the student plays in the learning scenario is determined by his learning style, what conditions his duties in the proposed mission as well as the tools he is allowed to use. Along with the common mission, individual learning activities may also be proposed to the student depending on his role. The purpose of these customized activities is to address specific learning needs of his learning style type.

The output of the adaptation process supported by the learning styles is a personalized learning proposal which has a twofold objective: First, to get optimum results in terms of acquiring domain knowledge by customizing the instruction strategy to the specific learning habits of the student; and second, to gradually turn RD and U strategies into the MD one. Vermunt considers that MD strategies give superior knowledge quality, which is availed by multiple experiences ([18], [4]).

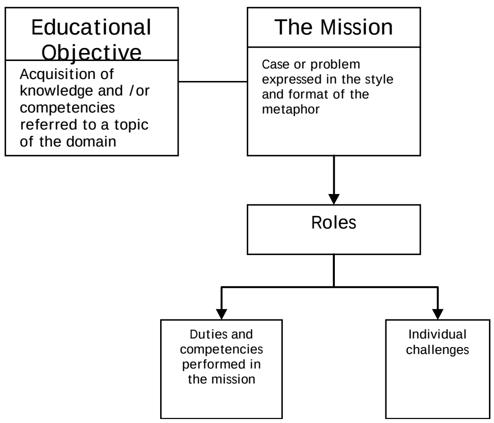

Fig 1. Structure of a learning strategy in "NUCLEO"

The previous elements of the NUCLEO framework are integrated personalized learning strategies proposed to the student. These strategies are modelled according to the structure outlined in Figure 1. Its elements are:

- The educational learning objectives describe the knowledge and skills that constitute the target of a given scenario.
- Missions are problem or cases described in a way that respects the style and format of the metaphor. The missions are conceived to achieve their intended learning objectives. With the purpose of encouraging effective communities of practice, missions should be solved in collaboration.
- The duties and the role performed by the student during the mission solving process are determined by his learning style. There are three possible roles that match the three learning style types. These roles are represented by the tribes of IAs: The “evians”, these are the members of a tribe that inhabits the metropolis of the NUCLEO. This is the role associated to the MD and AD learning styles; the “ruks”, an iterant tribe in the peripheral regions of NUCLEO. They are pirates and mercenaries. This is the role for the RD learning style type; the “exters”, strange and unpredictable IAs that have evolved in extreme conditions. They are mutants, rare being forms with strange powers difficult to control. This is the role assigned to the U students.
- Along with the common mission, individual challenges may also be proposed to a particular student. These individual challenges are conceived to address certain necessities concerning his particular learning style.

3. SYSTEM COMPONENTS.

The system architecture that uses the learning strategies described in the previous section is divided into three main components that are outlined in Figure 2: the learning strategies management system, the adaptation engine, and the player.

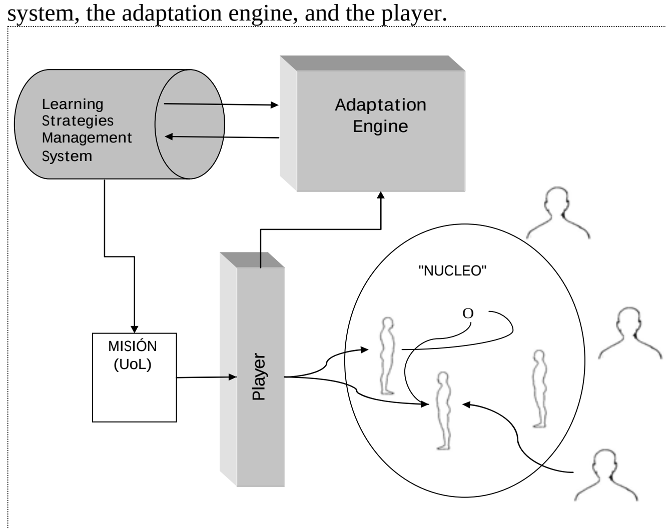

Fig 2. System Architecture.

3.1 The Learning Strategies Management System.

This part is in charge of the creation, storage and management of the personalized learning strategies and all their components (i.e. activities, environments, tools, and learning objects).

The learning strategies are modeled using IMS-LD [14]. According to [15] a *learning design* specifies the teaching-learning process, that is to say, under which conditions, what activities have to be performed by learners and teachers to attain the desired learning objectives. The packaging unit for a learning design and its associated resources is called a Unit of Learning (UoL). A UoL refers to a complete, self-contained unit of education or training that can be instantiated and reused in an online environment. It can be identified for instance with a course, a workshop, or a lesson. In addition IMS LD has two features that are extremely valuable for our system, its support to adaptation and to complex learning strategies.

IMS-LD is equipped with powerful features in order to support adaptation [5]. In the definition of the learning design, designers have to specify all the activities to be performed by the different roles involved in the learning process and they have also to define the sequence of the activity execution (i.e. the method). As stated in the specification, the design of personalization in IMS LD is supported by a mechanism of conditions and properties. Personal characteristics and information about the state of the learning experience are stored in “properties”. Conditions can be defined to adapt the learning design to learner characteristics during the execution of the learning experience (see Figure 3). This approach has been used in a number of UoLs developed at the Open University of the Netherlands such as those described in [31].

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<imsld:if>
  <imsld:greater-than>
    <imsld:sum>
      <!-- Sum of all fall-related test properties (range [0..1]) -->
    </imsld:sum>
    <imsld:property-value>5</imsld:property-value>
  </imsld:greater-than>
</imsld:if>
<imsld:then>
  <imsld:change-property-value>
    <imsld:property-ref ref="PrevKnowledgeInFallProtection"/>
    <imsld:property-value>true</imsld:property-value>
  </imsld:change-property-value>
</imsld:then>

<imsld:if>
  <imsld:greater-than>
    <imsld:sum>
      <!-- Sum of all electricity-related test properties (range [0..1])-->
    </imsld:sum>
    <imsld:property-value>5</imsld:property-value>
  </imsld:greater-than>
</imsld:if>
<imsld:then>
  <imsld:change-property-value>
    <imsld:property-ref ref="PrevKnowledgeInElectricityProtection"/>
    <imsld:property-value>true</imsld:property-value>
  </imsld:change-property-value>
</imsld:then>

<imsld:if>
  <imsld:greater-than>
    <imsld:sum>
      <!-- Sum of all properties related to
           meaning-directed factors in the ILS test -->
    </imsld:sum>
    <imsld:property-value>12</imsld:property-value>
  </imsld:greater-than>
</imsld:if>
<imsld:then>
  <imsld:change-property-value>
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    <imsld:property-value>meaning-directed</imsld:property-value>
  </imsld:change-property-value>
</imsld:then>
<imsld:else>
  <imsld:change-property-value>
    <imsld:property-ref ref="LearningStyle"/>
    <imsld:property-value>application-directed</imsld:property-value>
  </imsld:change-property-value>
</imsld:else>
```

Fig. 3. An excerpt of the IMS LD description of the Unit of Learning

Besides the mechanisms described above, NUCLEO uses two more possibilities for implementing adaptive instruction using Learning Design specifications:

- Associate roles provided in the specification to the different student profiles. According to the specification, there are two basic roles that take part in a learning process: student and staff (tutors and course designers). Nevertheless, Koper [15] recognizes the need of extending the specification "to include the multi-role interactions and the various pedagogical models that are needed to provide real support for learners and teachers in more advanced and newly developing educational practices". By this mechanism, certain activities in a defined UoL will be only performed by certain roles (i.e. profiles).
- Associate different learning paths to different student profiles. A learning design could be described in terms of patterns, as described in [7] or [28], or as different fixed sets of activities or activity structures.

The second relevant advantage of IMS-LD for NUCLEO is that it supports collaborative approaches to learning [16]. Other e-learning standards only support the model of single learners working in isolation, such as the model behind SCORM [1]. In this manner, IMS-LD has the potential to be able to support the implementation of mechanisms related with communities of practice.

In NUCLEO, a "Mission" is codified in a UoL and it contains the selected activities, their sequence of performance and to whom these activities are assigned. It also specifies the tools and environments that can be used for every activity.

3.2 The Adaptation Engine.

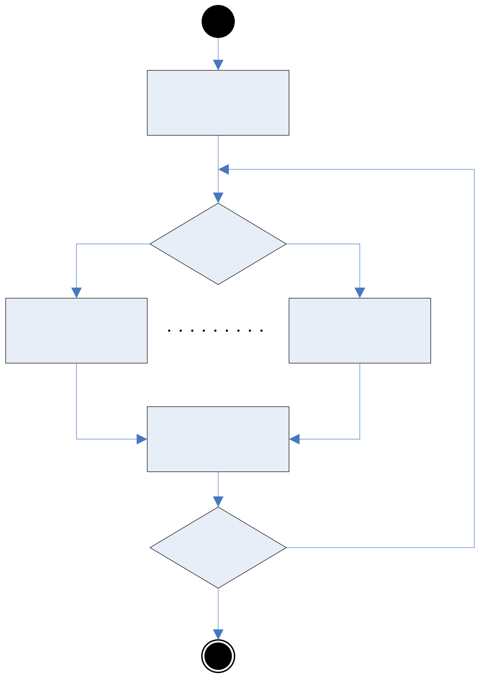
Achieving adaptive behavior, which is a key issue in e-learning, can be characterized as the ability of an e-learning system to adapt itself to different conditions over time in order to optimize pre-defined success metrics (e.g. learning time, economical costs, or user satisfaction). Adaptability involves many different aspects such as user models, learning context, or accessing devices and taking into account many aspects of the student. In particular we have found learning styles quite relevant in order to decide how to apply game-based strategies in an adaptive learning scenarios.

Nevertheless, adaptive learning in terms of students' learning styles remains an elusive milestone for mainstream online learning applications [3]. One of the reasons can be found on the controversy around learning styles models, with researchers considering learning style models as the educational panacea [19], others hinting that there is a lack of experimental results that sustain the pedagogical efficiency of most of the models [6], and others between both extremes demanding a consensus [26], [27].

Although the details are still open to discussion, NUCLEO assumes as a hypothesis to check as part of its work the usefulness of these models. That is, both learner motivation and performance benefit from adapting education to learning styles in all educational paradigms, including constructivism and, particularly, game based learning. As stated in the introduction, NUCLEO have selected Vermunt's framework. This choice is based on the results obtained in [6] in addition to its acceptable experimental results, and considering the target learning sector it Vermunt's framework was originally conceived for (it was specifically designed to apply to university students).

Figure 2. A Structure of adaptive cycle in NUCLEO.

The adaptation engine of NUCLEO is in charge of creating and maintaining the student's model based on which the personal learning proposal is created. In our case, and for the scope of this work, the user model refers only to the student's learning style. Among the variety of proposals for user modelling [3], NUCLEO uses dynamic stereotyping. Its implementation applies the adaptive cycle shown in Figure 2, which reflects common practices in adaptive learning. At the first step (labeled as *pre-test)* the system classifies the student into a certain learning profile. This profile is gathered using previous tests to classify the student. This stage uses a simplified version of Vermunt's Inventory of Learning Styles (ILS) questionnaire [34] as a pre-test to determine the student's learning style. Those students with MD and AD patterns are classified as "evians", those with RD as "ruks", and U students are assigned to the "exter" role. Once the student has been profiled, the adaptation engine has to update and maintain the student profile. For that purpose NUCLEO uses two different strategies (labeled as post-test in Figure 2):



- Assess the results achieved by the learner in the individual challenges proposed. This procedure works as a measure of the suitability of the learner profile and the success of the learning strategy.
- Some of the individual challenges proposed are aimed at redirecting student's strategies to the MD habits. The successful completion of this special kind of challenges gives the student the possibility of getting certain "qualifications" to be promoted to a different role.

Therefore, the information gathered in these two procedures is used to enhance the profiling of the student. It allows establishing the feedback loop indicated in the figure.

3.3 The Player.

A Learning Design Player is a tool capable to open a UoL and provide the participants with an appropriate interface to perform the required activities during the learning process. A UoL encapsulates all the information required to perform the teaching and learning process; the activities to be done, who is supposed to do them, and in what sequence they have to be completed. These activities can refer to different learning objects (e.g. books, articles, software programs, pictures, and games) and services (e.g. forums, chats, and wikis) that are used to collaborate and to communicate in the teaching-learning process [16]. Thus, the player is in charge of the following duties: Interpret and set up learning design files; Provide a user interface; Integrate all the services that are referred to in the Learning Design; Create a run of the Unit of Learning; Assign the persons to the correct roles; Connect to external systems. In addition to all these features, which are common to every learning design player, the NUCLEO player has to be enhanced to provide support for learner's virtual representations (i.e. avatars) and a graphical interface that recreates the futurist scenario where the metaphor is livened up (see Figure 3). Our intention is to use the SLeD player [29] as a basis and then provide the special functionalities needed for the NUCLEO player. SLeD uses CopperCore Engine [8] and offers an improved player system for learning design by separating out the player functionality from the underlying engine [20].

Figure 3. First approach to NUCLEO interface.

4. CONCLUSIONS AND FUTURE WORK

Our research team is concerned about finding e-learning solutions to improve our student's performance at the Complutense University of Madrid ([10]; [21]; [28]). The approach presented in this paper, belongs to the socio-constructivist pedagogical stream and it implements a student centred model restricted to his learning style type. For that purpose, we have created a futurist metaphor implemented as a role play game in which students have to collaborate to solve a proposed mission which stands for a certain learning objective. The duties and the activities proposed to a certain student are conditioned by his role. We believe this type of pedagogical approach can succeed in making contents more engaging and motivating for students and that it may improve their learning performance globally; first by optimizing the knowledge acquisition, and second by helping the student to acquire better learning habits. On the other hand, we think our approach can contribute in the formation of communities of practice among the students as it is based on collaboration in a role game based scenario. In order to prove our hypothesis, a pilot system will be used for teaching a programming course in C++ next semester at the Physics Faculty of the Universidad Complutense de Madrid in Spain.

At our next project stage a modified Learning Design Player has to be developed based on the already existing SLeD player by enhancing its features to support our system requirements. Eventually the adaptation model of "NUCLEO" will be extended to cope with additional student characteristics such as previous knowledge or knowledge objectives.

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