STSIM: Semantic-web Based Tool to Student Instruction Monitoring

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Abstract: In this article, a tool so-called STSIM is presented. It is able to monitor the student's progress along learning experiences. This tool, based on semantic web, allows students and teachers to monitor the knowledge student state including, among others, the learning objective state -achieved and not achieved- in different types of activities with psychomotors, cognitives or affective competences, and the efficiency accomplished in activity execution to facilitate the tutor or student the supervision of learning in a more adaptive way according to the individual characteristics and student knowledge state in each moment. To achieve this goal, STSIM uses a flexible student model supported by an ontology network, the *Student Ontology*. The tool has been developed to be multiplatform, multilingual, based on current and open-source web technology and characterized by its usability. STSIM is built on the UML-based web engineering (UWE) methodology and the Model-View-Controller (MVC) pattern.

1 INTRODUCTION

The technological advances have encouraged a bright evolution in many areas including the educational arena. In this way, one of the mostly researched aspects is the monitoring which, in general, consists of observing a situation, process, event, etc. through a receptor in order to check the quality and discover anomalies. In education, monitoring is a method that constantly analyses the student's evolution in correspondence with the proposed objectives. It allows teachers to ensure the process's direction; the software/human tutor can have a more accurate vision of the student's knowledge and, therefore, can take more informed and personalized tutoring decisions.

In this sense, it is important to highlight the difference between monitoring and supervision because both terms are often used interchangeably. Monitoring tries to find out if the student's evolution corresponds to the proposed objectives and, otherwise, the tool allows the responsible to take an adequate decision to correct the variations. Supervision is responsible for monitoring and making proper decisions.

A monitoring system is usually made up of the following components:

- **Indicators.** Measures summarizing the data.
- **Record.** Tools and methods to collect information.
- **Interpretation.** It analyses the stored data and
- **Visualization.** It shows the information in a specific instant.

The indicators, record and interpretation are necessary in all monitoring system. Nevertheless, the visualization is an optional component in all monitoring systems (Sampieri, 2008).

The tool explained in this article tries to progress in improving the quality of the educational system through the student's learning monitoring taking into account so many information sources such as the interaction possibilities derived from the use of Virtual Environments (VEs) to provide valuable information on the student's kwnowlede state, the student's behavior along different learning sessions, etc., so that the tutor can make sensible tutoring decisions or provide the most suitable feedback to the student in each moment. Thanks to it, STSIM may be easily used for differents learning environments and contexts in the short term. Furthermore, it is based on the semantic web process, specifically in the use of ontologies. There are multiple definitions about ontologies, but one of the most popular is the following: "An ontology is a formal and explicit

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specification of shared conceptualization" (Gruber et al., 1993).

This tool is supported by the Student Ontology (Clemente, 2011) consisting of an ontology network or, in other words, a collection of ontologies connected by some relationships such us mapping, modularization, version and dependency (Suárez-Figueroa et al., 2008). Student Ontology contains a wide range of types for modelling student in an Intelligent Tutoring system (ITS) and other complex learning environments such as the so-called Intelligent Virtual Environments for Training and/or Instruction (IVETs). The data registered in terms of the Student Ontology allows to carry out a pedagogical-cognitive diagnosis with non-monotonic reasoning capacities, that is able to infer the state of the learning objectives encompassed by the ITS and correspondingly infer the student's knowledge state (Clemente et al., 2013).

The article begins with a brief description of some important related work on the student's learning monitoring. The paper continues with a description of the adopted solution including a general overview of its architecture, design based on MVC pattern and technologies involved. Besides, some details on both the goals of present work and Student Ontology structure are given. Next, an application example is described. The paper ends with the main future work lines and conclusions.

2 APPROACHES TO MONITORING STUDENTS' LEARNING

The student's learning monitoring has been a highly researched topic since the last 20^{th} century when 12 modules for validating new technologies were identified including the monitoring (Zelkowitz et al., 1998).

Currently, there are some works closely related to student's learning monitoring which are worth emphasizing such as: a) the theorical study and the tool about the progress of student's learning (Sampieri, 2008). The tool consists of two modules supported by a database that can be used by teachers and student providing feedback to them through different graphs about the mark and efficiency during the course. b) the approach of OeLE platform (Sánchez-Vera et al., 2012). OeLE tries to evaluate the answers to open questions and to give feedback to teachers and students. Some of the most important characteristics of OeLE are the ability of monitoring the learning objective state and the use of ontologies.

Another important research line in this study is the feedback since it is essential that teachers and students receive suggestions to improve the teaching/learning process. From this perspective, we should highlight the work about data mining (Dyckhoff et al., 2011) involving the tool eLat. This tool offers support to teachers in the process of improving the efficiency in the group. It examines the

Table 1: Analysis of student's learning monitoring tools.

Tools	Author	Year	Technology	Objectives	Monitoring & feedback		Supervision		Indicators			Future potential
					Student	Teacher	Human	Software	Mark	Efficiency	Objectives	
eLat	Dyckhoff, A.L. et al.	2012	Data mining	Improve the course effectiveness	NO	YES	YES	NO	Participation in forums and number of request to content.			Medium
OeLE	Sánchez, M.d.M. et al.	2012	Ontologies	Evaluate the answers to open questions	YES	YES	YES	YES	NO	NO	YES	High
Check my activity	Fritz, J.	2011	Blackboard	Provide comparative reports to students	YES	NO	YES	NO	YES	NO	NO	Medium
LiMS	Sorenson, P. et al.	2010	Web	Extract the achieved objectives by the student	NO	YES	YES	NO	NO	NO	YES	Medium
ETR	Sampieri, M.	2008	Database	Monitor the student's learning	YES	YES	YES	NO	YES	YES	NO	Medium

number of mails sent by a student or the number of times that a student access to content of the subject and gives feedback to the teacher concerning the student's results. In this line, *Check my activity* was created (Fritz, 2011). This tool offers the students some comparative reports about the answers given by their classmates in an anonymous way. The aim of this tool is that the students receive feedback and ask for help when they need it.

Other interesting proposal that has been researched is LiMS (Sorenson and Macfadyen, 2010). This tool consists on the extraction of the objectives achieved by the students through contents published on the web.

In the table 1 a comparative analysis of some main features (year, used technology, objectives, monitoring and feedback, supervision, different indicators, future potential) of the mentioned tools related to student's learning monitoring as well as several main projects developed in the last five years (2008-2013) are shown.

As seen in Table 1, the related tools use different technology in order to profit from the advantages of each one. eLat use data mining in order to extract information to improve the course effectiveness. OeLE is the only tool based on ontologies in order to evaluate the answers to open questions. *Check my activity* uses the platform Blackboard to provide information to students. LiMS searches on the web to get the objectives achieved by students and ETR uses common databases to monitor the student's learning.

Moreover, the analysed tools have different monitoring and feedback targets. OeLE and ETR provide monitoring and feedback to teachers and students. Nevertheless, eLat and LiMS only provide the information to teachers and *Check my activity* gives information only to students.

Regarding supervision, it is important to emphasize that all tools allow the human supervision. However, only OeLE allows also the software supervision. This idea is essential because it offers a great potential in the future because mistakes can be detected and corrected more easily.

Another important aspect is the indicators which help teachers to understand the students. The mark is only measured in ETR and *Check my activity*. However, the efficiency is more exceptional because it is only measured in ETR. The objectives are considered in the OeLE platform and LiMS, respectively. Finally, eLat includes other indicators like participation in forums or number of requests to content.

3 PROPOSED SOLUTION

Our proposed solution to a monitoring tool is a Semantic-web based Tool to Student Instruction Monitoring (STSIM). It is a Java web application using a Model-View-Controller pattern. MVC facilitates the application's development (Leff and Rayfield, 2001), dividing the tool into three components:

- **Model**. It communicates the application with the Student Ontology through the Jena framework[1] and SparQL query language (Prud'Hommeaux et al., 2008).
- **Controller**. It contains the application logic communicating the Model with the View. It

[1] http://jena.apache.org/.

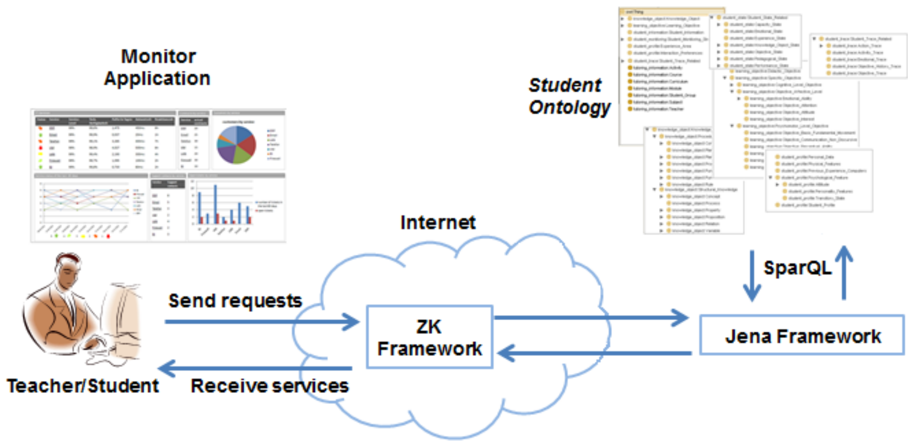


Figure 1: STSIM general architecture.

is implemented in ZK[2], a event-driven and component based pattern framework.

- **View**. It lets the user (teacher or student) request information from the Model and later, it generates an output representation to the user in several visual formats (graphics, tables, or plain text).

In the Figure 1, the different application components of STSIM and their connections are presented. The user interacts with the application Views through a web navigator. The Controller catches different actions from the users and requests to Model the required information. The Model consults the Student Ontology about the information which is sent to a new view in order to be visualised by the user.

STSIM is a web application built using UWE methodology. UWE (Koch and Kraus, 2002) is a web extension of the UML modelling standard.

The developed application tries to monitor the student's learning process in a subject matter based on an instructional design. It implies defining a group of activities and the objectives that the student should achieve in each activity. The relationship between learning objectives and the knowledge objects involved in a course is stored in Student Ontology. This representation is fundamental because it will allow a monitoring with different granularity levels; a monitoring of the reached or not reached learning objective states (coarse-grained monitoring) or a monitoring of student's specific knowledge state (fine-grained monitoring). In this way, monitoring the student's learning evolution provides greater assistance in the generation of a personalized plan for each student.

In STSIM, a instructional design of a course is used, which implies defining a group of activities for the subject matter to be taught and the objectives that the student should achieve in each activity.

As well as the objectives, other aspects can be monitored such as the mark in an activity or the efficiency in a course or activity. All these options are offered in the tool in order to provide teachers and students a more complete and better feedback about the student's learning.

3.1 The Student Ontology

The Student Ontology is, in fact, an ontology network composed originally by seven ontologies (Clemente et al., 2011). It was developed using the Protégé editor[3] and the ontology language OWL to be used, among others, in IVETs. It has been extended as support of the monitoring tool presented here with a new ontology so-called *Tutoring_Information* which contains information about teachers, activities, subjects and their relationships. Therefore, this ontology network is composed by the following main ontologies:

- **Tutoring_Information**. It includes, among others, the information about the student groups created in a course for a certain subject, teachers, modules or activities belonging to a subject, etc. In the Figure 2, the conceptual model of *Tutoring_Information* can be observed. It is composed by seven classes: (a) *Activity* contains the activity weight, required and achieved objectives and the module where it is located. (b) *Course* provides information about the associated curriculums and subjects. (c) *Curriculum* stores the syllabus it belongs to, its courses, etc. (d) *Module* offers information about its activities, objectives required and achieved by the module,

[2]http://www.zkoss.org/.

[3]http://protege.stanford.edu/.

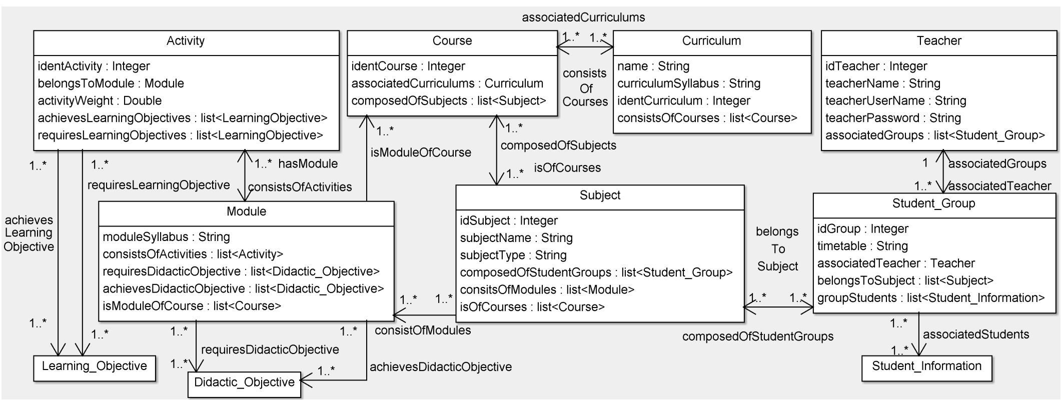


Figure 2: Conceptual model of *Tutoring_Information*.

etc. (e) *Student_Group* contains the data about timetable, teacher, students, etc. (f) *Subject* includes type, modules, etc. (g) *Teacher* provides some personal data, student groups who he/she teaches, etc.

- **Learning_Objective**. It represents the learning objectives defined in an educational process at cognitive, psychomotor or affective level. It is divided into Didactic_Objective and Specific_Objective.
- **Knowledge_Object**. It depicts a knowledge element which can be learned in a particular educational process. This ontology does not depend on any other.
- **Student_State**. It describes the student's knowledge, the acquired learning objectives, the degree of completion of the instructional design of the course, and an assessment of the student's performance throughout different learning sessions.
- **Student_Information**. It is created as an aggregate of all the information specific for each student. It includes the *Student_Profile*, *Student_Monitoring*, *Student_State* and *Student_Trace* ontologies. This ontology is also related to the new ontology *Tutoring_information*.
- **Student_Monitoring**. This single ontology allows us to define varied monitory strategies for the different variables that the tutor may be interested in monitoring (position of a student in the Virtual Environment, student's gaze direction, etc.).
- **Student_Profile**. It contains some personal information about the students (demographic data, preferences, physical and psychological features, etc.).
- **Student_Trace**. It describes the temporal registry of the student's activity during his learning experience in a subject.

A more detailed description of the above ontologies can be found in (Clemente et al., 2011). Additionally, a new simple ontology and the relationships with previous ontologies have been added to the ontology network: *Tutoring_Information*.

Furthermore, it is important to highlight that the Student Ontology was built using a modular network with the methodology NeOn (Gómez-Pérez and Suárez-Figueroa, 2009) because currently it is the only one that allows the development of ontology modular networks.

In the Figure 3, the ontology relationships between the different components of Student Ontology can be observed. The new ontology and its relationships with the previous already existing one, created in this work, (Tutoring_Information, Learning_Objective and Student_Information) appears in red color. The original ontology network is shown in blue color.

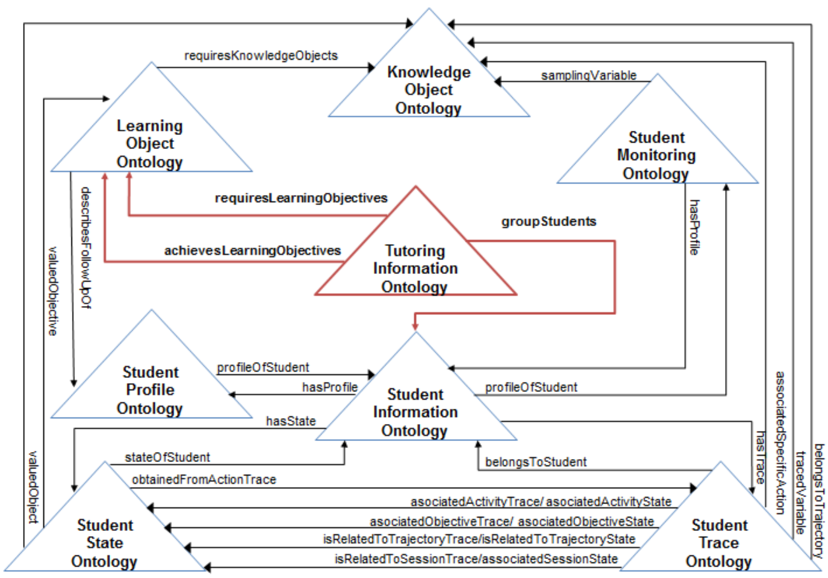


Figure 3: Ontology modular network in STSIM.

3.2 Objectives

The use of this tool is intended to provide teachers and students with some information[4] which lets them prepare a specific learning plan for each student according to their current knowledge state and their particular characteristics.

Furthermore, other important objectives pursued with the development are:

- **Extensibility**. The application is characterized by the extensibility in the used student modelling (Student Ontology) and in the application development.
- **Multiplatform**. It represents the possibility of using the tool in different Operating Systems and web browsers.
- **Multilingual**. The tool should be provided in different international languages and it offers the possibility to add new languages easily.
- **User-friendly**. The users of this platform will only log into the web application. Moreover, the application will offer different alternatives of help such as pop-ups and an user's manual in order to show the user all the possibilities to take advantage of the monitoring application.
- **Based on Semantic Web**. It is intended to use the semantic web technology, in particular, ontology technology since it offers reusability, extensibility and the possibility to infer knowledge that, in the future, could help in the supervision task.

[4]In the current initial state of STSIM tool, the large amount and diversity of stored information in the used ontology network is not being exploited more than at very low level for monitoring student's learning evolution.

4 TOOL EXAMPLE

In this sense, the learning objectives associated with the activity `Development of a minishell` have been previously defined within a pedagogical design. The initial state for the objectives in each learning activity depends on several factors such as tutoring strategy, student's background, whether the objectives have already been reached in previous activities, etc. We suppose that the student has not already acquired the required theoretical knowledge to do the practice so, we assume the initial state *acquired=false* for the objectives. Besides, the Student Ontology provides instances about the knowledge objects involved in the course *Operative System*; the dependencies between the activities objectives and the knowledge objects; students' profile; subject information (modules, activities, teacher(s), student's groups, etc.). The students answer questions and, consequently, some rules are fired and the ontology content is updated with the new objective states (achieved or not achieved) (Clemente et al., 2013). Thereafter, we can see in Figure 4 and Figure 5, STSIM allows users (student/subject teachers) to see student's learning monitoring data though graphics, tables and plain text. Also, STSIM presents a great potential in the near future taking advantage of ontology inference capability, specifically, inferring from the information stored in the Student Ontology.

The Figure 4 shows four groups of bars. The first is the mark percentage, the second is the correct answers percentage, the third is the incorrect answers percentage and the forth is weight percentage which has been obtained by the student *Antonio Martín Pérez* in activity *Development of a minishell* of *Operating Systems* subject on a degree course in *Computer Science*. The red bars represent the student attributes, the blue bars show the average values of the

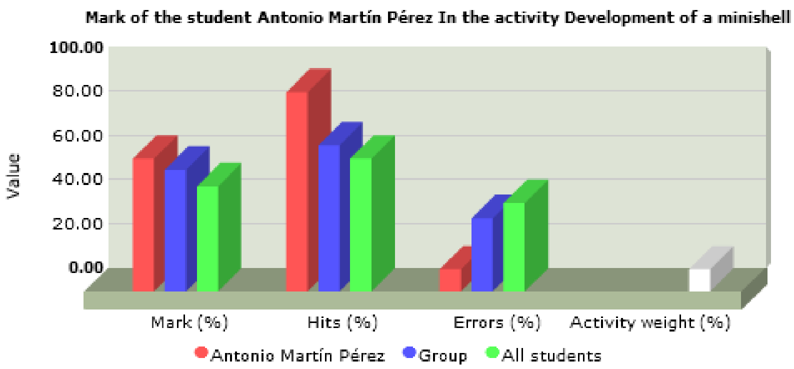
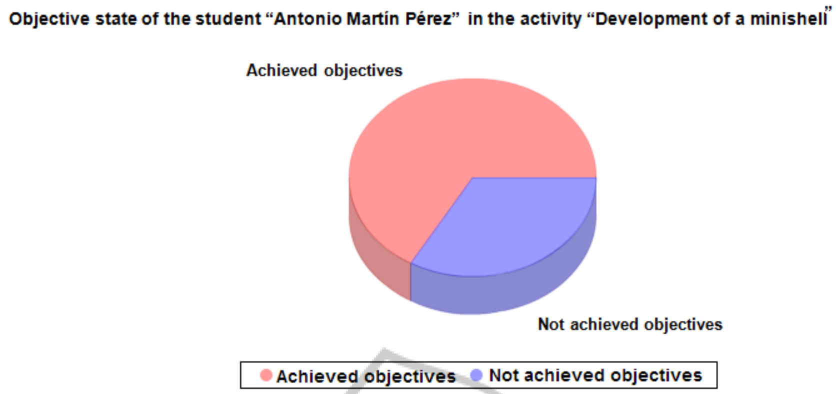


Figure 4: Mark obtained by a student.



Objective	Achieved
Being able to understand the basic functions in a shell	✓
Being able to understand the difference between background and foreground execution.	✓
Being able to understand the difference between internal order and external order in Unix / Linux.	

Figure 5: Learning objective states of a particular student.

student group, the green bars depict the average of all the students that have carried out the activity and the white bar stands for the activity weight on the subject.

The Figure 5 represents the objectives achieved and not achieved by the student *Antonio Martín Pérez* in the activity *Development of a minishell* of *Operating Systems* subject on a degree course in *Computer Science*. At the top of the figure, a pie chart with the achieved and not achieved objectives is shown and at the bottom of the figure, a table indicates the specific objectives achieved and not achieved by the student in the above-mentioned activity.

Despite teachers and students can monitor objective state, the teacher has more options for monitoring because it can monitor a student, a student group or all groups of a subject taught by him. However, the student can only monitor himself and obtain the averages of his student's class.

5 FUTURE WORK

With the tool presented in this article, we intend to open several lines of future work. The first and most important line of research consists on using automated tools such as planners (Plaza et al., 2008) may provide support for the planning and supervision of the student's learning evolution taking to support monitoring output of STSIM tool.

Another working lines are related to enhancing the tool development:

- From a functional point of view: a) the monitoring tasks can be extended with other key indicators to monitor the student's learning process. It includes, information such as the relationship between the objective states (achieved or not achieved) and its associated learning objects. Likewise, from this focus, using the tool in Intelligent Virtual Environments (IVE) provides teachers much information about student's knowledge states based on information related to these environment types already registered in terms of Student Ontology. b) Using semantic technology to infer additional knowledge from the information stored in the ontology allows the teacher to adopt tutoring decisions more adaptable to the particular characteristics and knowledge states of each student at every moment of their learning. c) Carring out a survey of accessibility and usability of the tool developed using standard techniques and tools. From the previous analysis, adequately improve in the tool (Slatin and Rush, 2003). d) Extending the multilingual capability of STSIM (currently it is offered in English, French, German and Spanish). e) Adapting the web application to be used in different environments and types of activities like forums, physical tests, etc.
- From a structural point of view: extending the ontology of the student in some weak points. For example, in learning objective ontology, student profile ontology (personal characteristics that influence student's learning), or other aspects not yet covered as tutoring strategies. In this line, perhaps other ontological or not ontological resources currently existing in repositories, etc, could be reused.

The great potential offering this project is the future line implementation because the technological advances in semantic web are able to provide improvements in the educational field. In a future, this tool will be able to be implemented into different environments and work in a collaborative way with other ontologies and monitoring tools.

6 CONCLUSIONS

This article has described a solution to monitor the student's learning process. The general goal of this work has been the development of a monitor tool so-named STSIM, based on web and ontology technology with the following main characteristics: available for teachers and students, multilingual, multiplatform, easily extensible, user-friendly and developed using the framework ZK, a Web application framework based on patterns and events, and Jena framework.

Besides, it is worth mentioning the importance of monitoring as information source to the human supervision (tutor or the student throughout his learning) or software supervision because it has a great potential to detect weaknesses in the student's learning process using ontological inference and monitoring information.

We should emphasize the importance of the use of ontologies and its advantages, including the the ability of inference from their knowledge. It can benefit and enrich greatly the monitoring and supervision of student's learning and, ultimately, encourage advance towards the improvement of educational processes, essential goal of our work. A wide representation of information relating to complex environments such as the Virtual Environments for Training/Instruction, whose benefits have been proven in the field of education (Mantovani, 2001) and, specifically, the IVETs, already exists in the ontology network used in STSIM tool that can be exploited and extended in the future to achieve the final goal.

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