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Abstract: We present our experiences for recording and analyzing usage of the Learning System Virtuoso at the University of Sofia. The description follows the structure that emerged from the joint work on the Kaleidoscope DPULS Project meetings held on February and April 2005. We also show one possible generalisation and one example pattern for tracking the learning problems described.

1. Introduction

Technology enhanced learning is seen as a strategic tool for enhancing the quality of education. One of most promising technologies in this field are Learning Content Management Systems (LCMS). There are lot of efforts to develop and use such systems, but the results so far are not very optimistic. So, we need to perform very careful and systematic analysis of this phenomena, in order to identify the weaknesses of current LCMS and their usage. One possible research approach is to track the usage of the LCMS, to analyse the traces, to find the more important gaps and problems, and to propose solutions which can improve the results of the usage of the LCMS.
The DPULS Project [1], part of the Network of Excellence Kaleidoscope, is trying to use such an approach. More specifically, the objectives of the DPULS are:

- to collect experiences in order to identify recurrent tracking problems and solutions
- to capitalise knowledge and experiences in order to provide instructional designers with the means to deal with tracking students' activity and analysing recurrent problems
- to create a structured set of Design Patterns for recording and analysing the usage of e-learning systems

In this article we will present our work on recording and analyzing the usage of the Learning System Virtuoso at the University of Sofia. This work was inspired from our participation in the first two workshops of the project DPULS. The description of this case will follow the common structure that emerged from the joint work on these two workshops held on February and April 2005. At the end a generalisation of the experience is proposed, and one example pattern for tracking the learning problems is given.

2. The Context of Use of the System

Virtuoso [3] delivers e-learning to more than 450,000 students enrolled in over 10,000 schools in 150 countries worldwide. Virtuoso is an innovative e-learning platform encompassing three modular components for authoring, delivering, and managing dynamic, Web-accessible learning content. Virtuoso is a complete Web-based e-learning platform

with focus on assessment, collaboration, interactivity and personalized feedback. Virtuoso puts reusability into practice with repositories for course content, assessments, documents, and media. Once created, repository content can be dynamically searched, reassembled and reused, saving time and efforts. We are using Virtuoso as a regular system for the delivery of 15 different courses at four faculties from the University of Sofia, starting with introductory courses (year 1 and 2 students) and ending with MSc courses.

2.1. Users Profiles

When working with the Virtuoso system, we can distinguish the following main users' profiles:

- Learners:
  They can access all courses in which they are enrolled, can work with all learning materials and resources, can take all planned assessments and exams, can participate in collaborative activities, etc.
- Designers:
  They develop and constantly update courses and course materials, assessments, exercises. They are following the quality issues regarding the courses delivery, and are trying to respond to the issues raised by teachers/tutors and learners.
- Teachers/tutors:
  They manage individual courses by starting different learning events, assessments and exams. They monitor the learners' progress, provide tutoring support and consultations to students, and form the final grade for any students in the class. They also analyse all the tracked information from their classes as well from the Virtuoso system, and on the base of the obtained results make decisions for the improvement of the teaching process.
- Administrators:
  They provide all the administrative information into the system: create students and teachers accounts, create classes, enrol teachers and students to the classes, and provide any additional administrative support to the teaching process.

All Virtuoso users can participate in various communities of practice worldwide, created and supported through Virtuoso system. These communities of practice are based on the user profile, on the course subject domain, as well as on the features defined by the users themselves. All members of a given community of practice can communicate through individual emails, discussion boards, help centres and best practice case studies.
All students can use the system from a distance, as well as from the on-line labs at the University of Sofia. Face-to-face sessions are exceptional. As a general rule the students work individually on the learning materials or collaborative sessions from a distance, and participate in practical exercises and assessments in the on-line labs with the presence of the teachers. But the students can work with the learning materials in the labs together with the teachers, as well as they can make practical exercises from a distance.

2.2. Design Model

From the pedagogical point of view, the system is following the standard behavioural instructional design model of learning, based on the performance objectives formulation and the appropriate assessment procedures development. From the technological point of view, the system is built around the concept of Learning Object, and is fully compatible with the IMS learning standards and specifications [2]. The Virtuoso follows the Cisco model for Reusable Learning Object (RLO) and Reusable Information Object (RIO). The RIO contains content, practice, and assessment components. Figure 1. presents Concept

RIO Template . Each RIO is defined as a concept, fact, process, principle or procedure, and tagged appropriately.

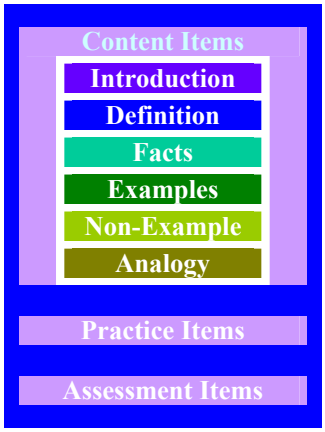

Figure 1. Concept RIO Template

Several RIOs (between five and nine) are combined together to create a RLO. Each RLO, which also includes introduction, summary, and assessment items, is designed to meet a learning objective derived from a specific job task. RLO is the sum of RIOs needed to fulfil that objective.
A RIO can function as an independent performance support aid that can be called up by a learner who needs a specific piece of information or a more in-depth learning experience. RLOs can be sequenced to create a full course on a particular subject. RIOs can be combined together to build custom RLOs that meet the needs of individual learners.
The Cisco strategy aims for creation of personalized learning paths showing each learner which RIOs they've experienced and which are recommended to get them to the desired skills level.
All courses delivered through the Virtuoso system are in the domain of Computer Science – introduction Information technologies courses, basic courses in programming and operating systems, and most courses in computer networks.

3. What Data is Collected for the Analysis and Why

Course designers need the collected and analysed data to improve and make more clear the presentation of the concepts, to improve the assessment, and to improve the practical exercises.
The teachers and tutors need the data to have information about regulation and learning assessment. Knowing where most students face problems from the analysis of the assessments and performance data from previous courses, the teacher/tutor can stress more during the current course delivery on the most difficult for the learners' topics and practices. From the analysis of each particular student's history the tutors can provide the right explanations and give individual advice to each particular student how to proceed further in the course.
Learners can access their history and assessments, and can reflect on the mistakes they have made and on the practice exercises the have failed.
Below we give examples of how data is stored, analysed and used.

3.1. Assessment History

As assessment history we consider: all questions to tests, errors, time and date when assessment was performed, etc. Several examples of these data are:

- Progress of each student (tests passed):
  Data about the progress of each student (tests passed) during the concrete course are collected into the class grade book.
- Errors on every question:
  Errors on every question for each test the teacher can view the detailed picture. Errors on every question are marked with earned by student points (showing that they are not maximum points) in the row of each student. Columns of errors (numbers) formed under some questions show that either topic was not well explained in the course materials, or the question was not clear for the students. Instructors and students can view for each error the correct answer and the wrong answer given by the learner.
- Time and date of assessments:
  The list of all past test activations is available with time and date when assessment was active. For every test's activation the learning system recorded the assessment history data for time and date when assessment was performed.

3.2. Practical Exercises History

As practical exercises history we consider: sequence of steps to achieve a solution, errors made, time consumed, score achieved, help consumed, etc. Several examples of the data from this type are:

- Time reserved and time consumed:
  Time reserved and time consumed for any practical exercise time reserved and time consumed is available through the system. For all students system store information how many times she/he logged to the system, and the time of last login.
- Activities performed
  Activities performed for each student system can show what activities were performed (from the sessions log file) and the final result (configuration files) after activity was completed. When reservation for practical activity was performed the instructor, depending on system configuration, could receive automated e-mail with report on the student activity. This report shows sequence of steps to achieve a solution as well as errors made and is attached as a zip archive with several log files to the automated email.

3.3. Records of Participation in all Community of Practices Events

As community of practices events we consider: discussions, questions, answers, opinions, etc. Example for data from this type is:

- Teachers and learners have access to all the discussion forums for which they are eligible, and also to the full Help desk archive containing all important help advices given to the learners and tutors.

3.4. Additional Data

As additional data we consider: scenarios for course presentations, exercises and course delivery time schedules on the FTP server, personal data for each learner and teacher (name, age, preferences, etc.), metadata (mostly available for teachers, regarding courses and Learning Objects), contextual data (number of students, number of courses, etc.).
Virtuoso system collects lot of information for further analysis and use, but there are still important information not stored from the system– how long the student read the course materials, and what time was needed for getting with each Learning object.

In general, all actors in the learning process have the access to the appropriate data stored from the system. The system not only store a lot of data tracking the users performance, but also provides very rich set of statistical analysis of almost all kind of data stored. So each actor can have different view on the data stored, depending of the needs and the wishes of the user:

- Teachers analyse the huge amount of available statistics on students performance (answers to test questions, solutions to practical exercises, etc.) to produce the individual performance report for each student and to use it for student's grades, identifying strong and weak points of the students performance, and to plan the future learning sessions. They need to know which test questions are most difficult for the most of the students, and to stress during the preparation for the tests on the appropriate examples and explanations. They can use the data from the student's participation in the communities of practice, in order to better understand their wishes, needs and problems, and to plan the individual session in the most appropriate way.
- Learners analyse the results from their performance in order to identify their own weak points and to know what additional learning they need in order to surmount the difficulties they met. On that base they plan their further learning activities.
- Designers, after careful analysis of the statistics available, can identify which test questions seem to be not adequate (either the text is misleading, the question seems to be very difficult, or question seems to be too easy), which learning objects are not well presented, and which practical exercise is either too difficult or too easy for the students. They use the results of this analysis to readjust pedagogical scenarios – to change the objectives, to change the course design, to change learning objects, to change assessment, etc. They can revise the identified not adequate learning objects, test questions or practical exercises.

Each actor, depending of his goals, can use the data stored at different time and on different regularity:

- Usually designers analyse the data at regular time intervals in order to identify if they have to change the course design and delivery.
- Teachers and tutors generally analyse the results before the sessions in order to prepare better for each individual session.
- Learner usually analyse the results after the sessions in order to adjust their learning according to their own performance.

4. Generalization of our Experience

In order to be able to generalize, we have to describe our context in more abstract way. We can identify the following important features:

- learning content management system in which all learning activities are represented as Learning Objects (LOs)
- assessment system, in which it is possible to assign several different assignments to every single LO
- statistical system which can calculate the mean scores for every single student, group of students or for all students regarding given course, every single LO, every single assessment, etc. This system should make it possible to calculate automatically some basic statistical variables used to make conclusion in statistical analysis.

This context is typical for any full featured based on the standards Learning Content Management System. Tests have to be based on the IMS QTI specification. Practical exercises and user data tracking are also typical components for a standard learning

environment based on the constructivist approach. The other contextual data (learner details, metadata, etc.) can also be easy found in a standard LCMS.

4.1. Tracking Problems

At a general level we faced and solved the following most significant tracking problems:

- Monitoring participation and the level of discussion in CoP events
- Analyzing learners' performance to identify:
  - Very difficult topic
  If for a given Learning Object (LO) all students score significantly lower than for other LOs, this indicated that the LO is very difficult for them (could be explained badly, or not appropriate, or not well supported by other needed input LO).
  - Very easy topic
  If for a given LO all students score significantly higher than for other LOs, this indicated that the LO is very easy for them (could be not appropriate, or not well linked with other LOs).
  - Wrong question / assessment
  If for a given LO one of the assessments (test question, exercise, etc.) scores for almost all students differently than other assessments for the same LO.
  - Student weak point
  If for a given LO student scores significantly lower than for other Los.
  - Student strong point
  If for a given LO student scores significantly higher than for other Los.

4.2. General Solutions

On the base of our experience we can suggest the following general solution/recommendation to people who could face the same problems:

- Use powerful and user-friendly statistical package for the analysis of tests and exams results in order to identify easy/difficult course topics, details regarding the learner's model, and what tests/content/exercises seem to be not adequate.
- Use tracking of learner's solutions to practical tasks to identify common performance gaps and to individualize the future learner's path.

4.3. Positive and Negative Effects

In general, we can point the following positive and negative effects:

- When learners have their own view on the tracking data together with recommendations for improving their knowledge and performance, they feel more confident and achieve better results.
- When tutors and teachers can analyse the statistical data from huge number of learners, they are sure what decision to take. From the other side, the use of statistical data coming from different contexts may lead the teachers to wrong predictions and conclusions regarding their own students.

5. Example Tracking Design Pattern

On the base of the analysis and generalization presented above, as well as on the analysis of the state-of-the-art in the field of design and usage learning patterns ([4], [5], [6], [7], [8]),

we are proposing one example structure and description of one learning usage tracking pattern:

Problem domain: Course usage

Problem name: Very difficult course topic

Problem symptoms: Learners have problems to achieve the needed knowledge or skills regarding some particular topic of learning. These symptoms can be seen from discussions, practical exercises, questions raised to the help desks, assessment scores.

Contextual information: We have a learning system in which all learning activities are represented as Learning Objects (LOs). We also have assessment system, in which we can assign several different assignments to every single LO. We also have some statistical system which can calculate the mean score for every single student, group of students or for all students regarding given course, every single LO, every single assessment. The system is able to calculate automatically some basic statistical variables used to make conclusion in statistical analysis.

Problem statement: There is a LO which is causing problems to the learners.

Problem identification: If for a given LO (for all assessments) all students score significantly lower when compared to other LOs, this indicated that the LO is very difficult for them.

Used indicators:

In order to identify the problem, we need to measure, calculate and compare the students' results and performance. The Virtuoso system can give to use two sets of indicators to use – quantitative (direct scores from assessments) and qualitative (in the form of metadata descriptors of the learning objects and the learning process in general). The quantitative indicators are direct scores and calculated scores:

- direct score: an integer in the range 0-100 (higher the number, better the score) assigned to each individual assessment of a single student regarding one particular LO
- calculated scores: integer values calculated on the base of the basic scores using standard statistical techniques. Example for such a score is the mean score for all students for all available assessments regarding particular LO. The system Virtuoso is offering very rich set of calculated scores, and even the ability for the user to define its own calculated score.
- meta-data for the LO (difficulty, prerequisites, technical prerequisites, etc.). They are used for the human analysis of the calculated scores.
- meta-data for the course or set of learning activities (list and sequence of LOs, their possible correct order, etc.) They are also used for the human analysis of the calculated scores.

Possible reasons:

- Reason (1) - this LO could have very low quality (bad explanation caused by wrong design, wrong examples caused again by the wrong course design, very low technical quality caused by the wrong design or the error in the learning system, etc.)
- Reason (2) - this LO could be not appropriate for the current course or learning (designed for MSc level but delivered at BSc level for example) – if the needed LO was not available and was substituted with what is available, or if there is an error in the learning system causint the delivery of not correct LO.
- Reason (3) - this LO could have a list of prerequisite LOs and some of them is not available in the current course (wrong design or error in the learning system)

Solution:

The solution depends on the reason. First we have to identify the reason. (2) and (3) can be checked by examining the appropriate meta-data. If (2) and (3) are not the case, than we have (1).

- Solution for (1):
  The course designer has to re-design this particular LO. In the mean time the teacher/tutor have to plan some support activities in order to help the students in understanding the concepts/skills covered by this LO (additional explanations, special group session, additional practical sessions, etc.)
- Solution for (2):
  Change the LO with the right one, or if not available, apply the solution from (1).
- Solution for (3):
  Find the missing LO and re-arrange the learning. If the missing LO is not available, we have to plan again supporting activities.

Sketch or Diagram: Not available
Links with other to consider:

- It could be possible that the LO is OK, but all assessments for this LO are wrong.
- It could be checked if the learning system has some error which is causing the bad quality of the delivery of this particular LO.
- It could be checked if the learning system has some error causing one of the prerequisite LO not to be delivered to learners.

6. Conclusion

This case is one among several different cases developed and studied during the DPULS workshops. They mark the beginning of the joint research targeting the design and development of the set of Usage Patterns for collecting the experiences of using Learning systems and identifying common generic tracking problems and solutions.
The next steps are linked with experiments for transferring the methods described for other LCMS and collecting the results. This will help us to show how general is our approach and how it could be applied in different learning settings.
Another important step forward is linked with more systematic analysis of the situations described, in order to identify as rich set of possible design patterns as possible. On the base of this analysis, we can combine our research outcomes with the findings of our DPULS project partners from other learning situations, thus going further to the creation of a structured set of Design Patterns for recording and analysing the usage of e-learning systems.

7. References

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