

An Architecture of a Computer Learning Environment for Mapping the Student's Knowledge Level

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Abstract

It is unquestionably essential for students to gather their previous knowledge of specific subjects when they are about to learn new and more complex ones. The gaps left by the absence of well-defined learning prerequisites not only contribute to the increase in the learning difficulties, but also lead many students to fail in school. This situation gets even more serious when students are not aware of these gaps and do not know how to identify them. In this scene, the learning assessment process as a knowledge measuring device occupies a fundamental role.

This paper represents an attempt to set out architecture of a computer learning environment for mapping the student's knowledge level, which allows for a more specific identification of the learning gaps in order to supply the educational system with qualitative information.

Keywords: Interactive Learning Environment, Assessment, Knowledge Acquisition Level.

Introduction

Globalization and the advancements and dissemination of Information Technologies have led to a rapid expansion in the amount of information. If it was difficult to determine a person's knowledge level in the past, nowadays it is almost impossible. In the scope of Educational System, in which the issue at stake is learning, this becomes a problem to be considered, since several researches point to the effect of the previous knowledge on learning (Bransford, 2003).

In this context, the learning assessment as knowledge measuring takes on a crucial role, that is, it is necessary to understand what the student knows and what he does not know in order to teach him accordingly.

Although in theory there is a relation between the educational methods adopted and the assessment methods, in practice a kind of independence of each other can be clearly noticed.

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The effect of evaluation on education can lead to very positive aspects. By way of illustration, a teacher can highlight some contents students fail to grasp based on the results. On the other hand, there are also negative aspects. For instance, a teacher might train students exclusively to pass their exams or students might be concerned only about the subjects that will appear on the test and not about the learning process itself..

The assessment process plays an essential role in producing information that can help students, parents, teachers, and educational administrators to get to know and deal more effectively with the learning gaps. Teachers and the Intelligent Tutoring Systems (ITS) can use this information to adapt the instruction to the student's learning needs and difficulties.

Another important aspect in the learning process relates to the student's metacognitive abilities, *i.e.*, the process of reflecting about their own knowledge, what Flavell (1979) called metacognition. Knowledge of knowledge itself makes it possible for a meaningful learning process because students will be more aware of their own knowledge acquisition level.

A continuous assessment process is supposed to try to collect as much information as possible regarding the learner's cognitive and metacognitive level, thus diagnosing learning gaps, in order to provide everyone involved in the educational system with feedback. However, this data-gathering process would produce a large mass of data, demanding automatic or semi-automatic procedures for treating and analyzing.

Advances in computer technology have made it possible to store and process a larger amount of data and new technologies have been developed to help extract information from these databases, with emphasis on the Knowledge Discovery in Database (KDD) and the Data Mining (DM). KDD is a comprehensive process of finding useful information and patterns in data. Data Mining is the use of algorithms to extract information and patterns (Fayyad, 2002).

Since this paper presents a computer learning environment for mapping the student's knowledge level, it is relevant to point out the difference between the terms "knowledge mapping" and "learning assessment". Whereas the first refers exclusively to the action of determining the student's current knowledge level (regardless of how, when or where it was acquired), the latter refers to what the student has learned throughout an instructional process, taking into consideration what time and through which materials he achieved that goal (a class or a course). For centuries it has been sufficient to certify the level of knowledge at the end of a course. Nonetheless, at the beginning of a new course or a new level, can this certification still represent the student's current knowledge acquisition level (KAL)? Are the learning prerequisites that the student fulfill enough? Would it be helpful if both teachers and students could see a map of the student's KAL? What about if the teacher could see the KAL of the entire class in a specific subject? What are the subjects that most students lack the needed prerequisites?

If the main objective of the educational system is to educate people and, in some respects, certify their knowledge, capacities and abilities, we believe that knowledge-mapping in a continuous process may be satisfactory and effective.

The paper is organized as follows: first, the next Section addresses the role of assessment in the teaching-learning process. Then, some computer environments are listed pointing out how assessment is treated by them. Following, the architecture of the computer environment is introduced and their modules are described. The next Section introduces the products generated and consumed by the environment. Finally, some considerations about this work and future work are made.

Assessment for Learning

Assessment and feedback are essential for helping people learn. A consistent assessment process with the learning principles should be continuous as part of the instruction, and should also supply teachers, parents and students themselves with information about their learning level. Assessment should reflect the quality of the students' reasoning, as well as the specific contents that they have learned (Bransford, 2003; Perrenoud, 2000).

In a continuous learning assessment and accompaniment process, first of all, it is necessary to identify the purposes of the assessment, that is, “why assess?” as summarized in Figure 1, by Falchikov (2005). Answers to this question can be grouped into two main categories: summative and formative. In the first group the main purposes of assessment are restricted to selection, certification, accountability and effectiveness monitoring. Purposes in the latter group are more student-centered, and encompass diagnosis, monitoring, motivation, feedback and learning improvement (Dietel, 1991).

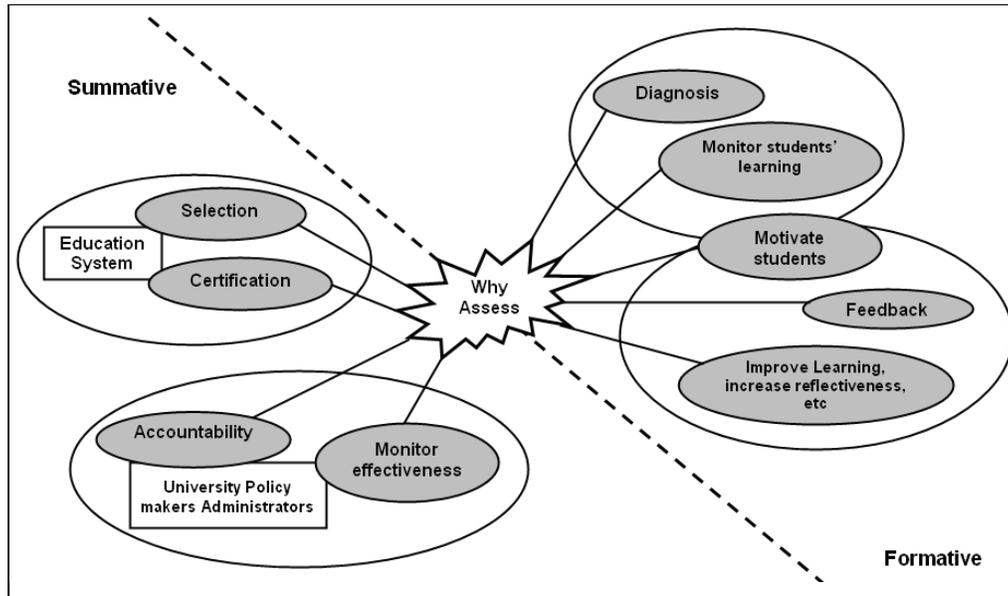


Figure 1: Purposes of Assessment.

However, the assessment systematic is often considered a final process activity. Many teachers still use assessment as an instrument of power and as a threat and students end up seeing nothing beyond the “assessment grade”, in other words, it becomes nothing more than a necessary rite to determine if the student has succeeded or failed (Depresbiteris, 2004).

Several authors have carried out studies on assessment and stated different definitions. Table 1 presents four definitions according to four different authors that are connected to the idea of assessment developed in this paper.

AUTHOR	WHAT IS ASSESSMENT?
Bloom (1983)	Data gathering process that is used to check the student's progress.
Bransford (2003)	Method to better understand the current state of the student's knowledge.
Hadji (2001)	To verify, to judge, to estimate, to point out, to represent establishing a relation between the students' performance and the established criteria.
Mitchell(2003)	System of quality control to determine if all the learning stages are being absorbed by the student

Likewise, authors have identified different purposes of assessment and four of them are presented in Table 2. Summarizing, in this paper, assessment must be seen as a process of catching the student’s current knowledge level in order to identify his learning needs.

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The starting point of any teaching and learning system is to state the Educational Objectives, that is, what teachers want their students to learn as a result of their teaching. For each objective it is necessary to establish assessment points in order to check if it is being reached or not.

The establishment of measures for future assessments implies that it is necessary to define the performance indicators and grading criteria. When a teacher shares with his students the adopted criteria for grading and the indicators determining the measurement of their performance, he is also contributing to the development of the students' metacognitive abilities since he can start to define strategies in order to improve performance. In spite of being quantitative, the criteria is supposed to be based on the existence of the desired quality (Depresbiteris, 2004).

AUTHOR	PURPOSES OF ASSESSMENT
Bloom (1983)	To identify the starting point for instruction adapted to the student's knowledge level.
Bransford (2003)	Decisions about classes, advancements, placement, instructional needs and curriculum
Dietel (19991)	To establish individual diagnosis and individual prescriptions, to monitor the student's progress, to evaluate and review the curriculum, to give certifications and promotions, to motivate students and to determine grades.
Perrenoud (1999)	For teachers to catch the student's learning needs

The analysis of results provides information that enables to judge the destinations of the educative programs or their components: one of them is the students' learning. The analysis task firstly implies organizing all the results, including: grouping them into categories; relating them to each other; identifying patterns and trends and finding relations and inferences in a higher abstract level.

The analysis task is present in some assessment stages but becomes more formal and systematic after the collection of data is concluded. The quantitative results can be analyzed from simple statistics: analysis of the frequency, average, Standard deviation etc. The qualitative results require other forms of analysis before being transformed into quantitative information.

Computer Learning Environments and Assessment

The wide use of computers by people in general has made it possible to apply computer science to education more and more often thus spreading the Computer Learning Environments (CLE).

Computer Learning Environments have incorporated some mechanisms of classroom assessment, classified as first generation of computer-based assessment (Ardigo, 2004).

Objective tests were the assessment tools that prospered the most with the use of computer for assessment. The main technical advantages are:

- The process of creating new assessments is facilitated by accessing the supporting online material and the questions database;
- The simplification of application procedures due to the use of the computer dispensing with paper manipulation;
- Automatic grading.

A second generation of computer-mediated assessment involves the use of multimedia resources and the automatic selection of questions. These questions are randomly selected from a database,

adequately covering the entire knowledge domain to be assessed and at different levels of difficulty.

The third generation is strongly associated with the teaching-learning process, being made highly interactive by presenting students with simulation of real-life situations.

In the following, a brief study on four CLEs is presented, focusing on the assessments resources in these tools (Hack, 2000).

CyberQ

It is an automated assessment system developed by Apollo and InterEd that provides a software implementation of a multi-trait and multi-method assessment strategy, besides a virtual and simultaneous assessment of multiple students at different levels, aggregating very large amounts of data for future analyses (Tucker, 1995).

The software includes the following functional components: transactions profiling, syntax profiling, predicate analysis, adaptive assessment and decision and dissemination information support.

Carnegie Mellon University

In the model developed by Carnegie Mellon University each course displays a number of specific characteristics to represent and to process the assessment (Brusilovsky, 1997). For example, the system generates personalized exams based on different criteria and parameters, including tasks already performed by students, as well as their results.

The grading process is carried out either automatically or later by the teacher, if necessary, and the detailed and personalized results are sent to the student.

As to the student's progress, whenever he accesses a certain study unit, the system registers the access time, as well as the access duration.

AulaNet

AulaNet is a web-based cooperative learning environment developed by Pontifical Catholic University of Rio de Janeiro (PUC-RJ), in the Software Engineering Laboratory (LES) of the Computer Science Department, for the creation and assistance of distance courses (Fuks, 2001).

Aulanet provides assessment tools such as: tests, projects, self-assessment, exams, papers and exercises. By doing exercises and homework, students can debate, create projects and share experiences, that is to say, they actively participate in the learning process. With tests, teacher can provide the formative assessment of the learning process, emphasizing the importance of the cognitive learning aspects.

The tests are managed by a tool developed to create and correct online exams named *Quest* whose objectives are to assist the teacher in creating tests, giving feedback to students and generating reports to the teacher.

TelEduc

TelEduc is an environment for the creation, participation and administration of web-based courses developed by researchers at the Center for Computer Science Applied to Education (NIED), at the University of Campinas (Unicamp). It has been created to support learning based on problem resolution and includes a wide set of communication tools such as: email, Discussion Groups, Panel, Portfolio, Target Log Book and Chat (Rocha, 2002).

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In TelEduc all communication tools provide a log of the individual activities and group interactions and, therefore assessment can be formative and continuous by analyzing the students' participation records. TelEduc includes the tool "Accessos", for extracting reports of each course participant, which describes the number of accesses, date and time of last access, course access attendance, and TelEduc tools accessed (Otsuka, 2003).

The Intermap tool makes it possible the visualization of quantitative interactions data in the environment through some graphical representation forms, such as graphs, bar charts and color codes (Romani, 2000).

Table 3 presents a comparative chart among the CLEs described above. As noted in this table, only CYBERQ and CARNEGIE have adoptive and personalized tests features. Yet, none of them include features related to metacognition or tools that make it possible to the accompaniment of the student's knowledge level, identifying precisely what its learning gaps are.

Table 3: Comparison of Assessment Features in Computer Learning Environments

ASSESSMENT TOOLS	CYBERQ	CARNEGIE	AULANET	TELEDUC
Online Tests	X	X	X	
Tracking System	X	X		X
Text Analysis System	X			X
Web Adaptive Tests	X			
Web homework system		X	X	
Personalized Tests		X		
Chat Log Data				X
Forum Log Data			X	X

Computer Environment Architecture

This section presents the architecture of a computer environment for mapping the Student's Knowledge Level in agreement with Figure 2 that shows the relationships among the modules and submodules.

The use of a computer learning environment will allow the application of the formative assessment purposes and all its characteristics.

From a general setting capable of representing the knowledge to be reached or certified, the computer learning environment in its several modules will allow the diagnosis, learning monitoring, motivation, feedback, learning improvement, involvement and student awareness.

Moreover, intelligent tools will help to identify the cognitive and metacognitive student profile in order to assist the professor and the student himself in the analysis of the results and in setting the next learning stages.

The traditional Intelligent Tutoring System (ITS) architecture has only four modules (Marietto, 2000): Student Module, Tutoring Module, Domain Module and Interface Module. There is a similarity between the proposed architecture and the traditional ITS architecture. The Interface Module in the original architecture could be related to the Communication Module while the Domain Module could be associated with the Knowledge Module. The Tutoring Module is not present in the new architecture because the instructional process is not included in this work. However, this module can be normally connected to this architecture.

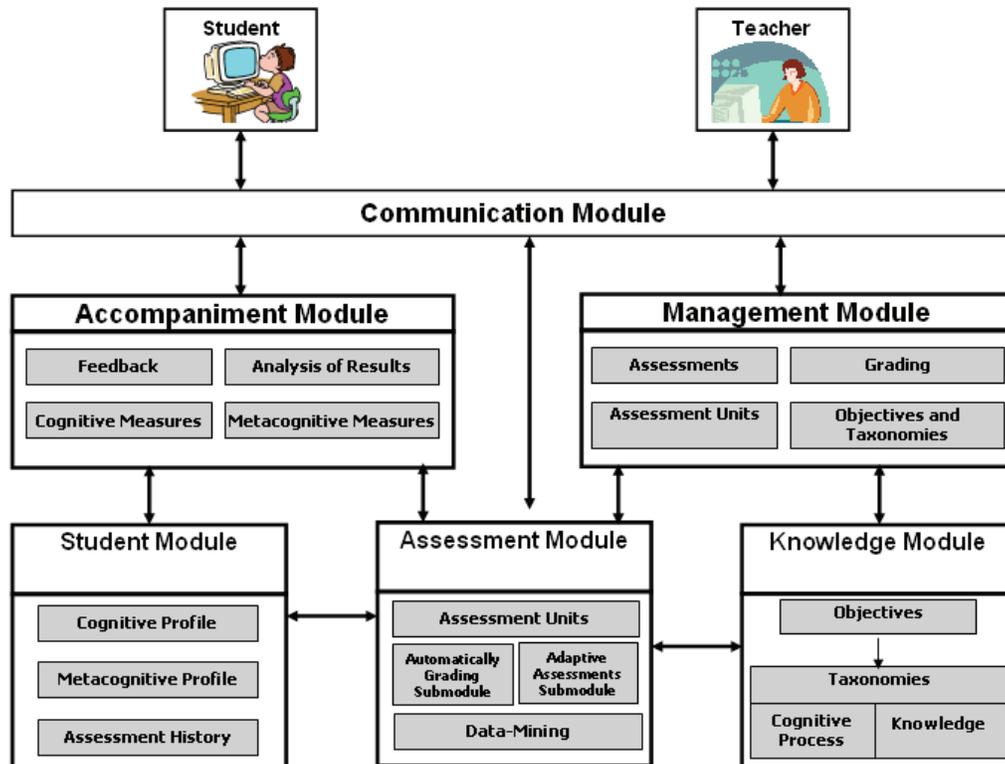


Figure 2: General Computer Environment Architecture.

One of the new differences is the *Assessment Module*, which, by using information from the Student Module and the Domain Module will prompt the generation adaptive assessment according to the cognitive and metacognitive learner profile. Moreover, the diagnosis of the learning gaps will supply information for personalized learning plans, in such a way that, once these gaps are filled, students may resume their learning according to their expectations. In a traditional ITS, the assessment is generally concealed in the Tutoring Module.

The adding of the Assessment Module requires the Management Module that includes the tool for assessment planning. On the other hand, the Accompaniment Module deals with the assessments outcomes.

The next subsection presents the description of the proposed environment modules as well as the relationships among them.

Communication Module

Through this module, teacher and student will be able to interact with the environment in order to perform their respective tasks. The teacher will be able to directly interact with the management module and the accompaniment module and indirectly with the other three modules: student, assessment and knowledge.

The communication module (interface) will adapt to user-end (teacher or student) and to front-end device (personal computer, mobile device, palm-top, cell phone, etc).

Management Module

The management module will be accessed by the teacher or anyone else responsible for the learning assessment and accompaniment process and will enable:

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- To include data gathered from the pedagogical project of the course into knowledge module in order to reflect the learning objectives;
- To record *assessment units* associated with the learning objectives of each content, with the learning process involved equally specified;
- To create diagnostic, summative and formative assessment;
- To grade assessments performed by students when it was required.

Some of these tasks could be done automatically. For example, the selection of unit assessments related to the student's current knowledge level. But this will be controlled by the Assessment Module. About automatic grading, this is something possible but it requires deeper studies.

Knowledge Module

To allow the learning accompaniment, this module will structure the knowledge in learning hierarchies by using ontologies that specify a vocabulary relative to a set domain. This vocabulary defines the terms (classes, predicates, entities, properties and functions) and their relationships, representing a powerful tool to support the specification and the implementation even of complex computer systems (Guizzardi, 2000).

In order to establish the student cognitive state in each knowledge item, this module will record the knowledge representation and the relationship among concepts. It could be said that this module will also contain the Learning Model based on the objectives to be achieved. The objectives will be classified according to Blooms' revised taxonomy, including the knowledge and the cognitive processes associated with each objective.

Student Module

This module will store the cognitive and metacognitive student profile as well as the record of assessments.

Based on these data, it will be possible for the environment to report on the student knowledge level immediately, select tasks or activities in that level or determine the learning needs to be filled to reach the objectives set.

Assessment Module

This is the main module of this computer architecture and will store the assessment units that form the basis for the assessment settings. Each assessment unit will be associated with the objectives and consequently with the taxonomy.

In this paper, an assessment unit can assess even a simple concept, associated with either an indivisible content or some interrelated contents. For this reason, this paper does not use the term *question* found in traditional assessment methods. Hence, the attributing of a measure (right/wrong) to an assessment unit entails doing it in a detailed way, identifying the key failures.

Planning represents an important moment of assessment, since it must not only reflect the proposed objectives, but also record reliably the student's knowledge level. The elaboration of *complex questions*, what usually happens in the traditional system, without associating them with the addressed contents, hinders the identification of the learning gaps, that is, it is not favorable for a back-tracing in the sense of identifying accurately the contents that are blocking the student's learning improvement.

The assessment grading process (attribution of measures) could be automatic in *objective questions* or semi-automatic or manual when it comes to open questions. The automatic assessment

grading is an open research field and deserves special attention since it consumes a long time of teachers' job. Moreover, assessment-grading makes room for certain subjectivity. However, this is not included among the objectives of this paper.

The adaptive assessment submodule should generate suitable assessments to the cognitive and metacognitive student profile. The traditional educational system assesses all students in the same way, not considering the student's current knowledge level. Concerning formative assessment, it is necessary to take the student's current knowledge level into account and assess him accordingly, in order to contribute for his learning improvement.

To create adaptive assessments, the system will take into account the student's previous performance, stored in *Student Module*, besides attributes like: difficulty level of the assessment unit and contents relationship. According to the student's performance, the system will select suitable assessment units, with a lower or higher difficulty level, or will approach simpler or more complex contents. For additional information about computerized adaptive assessment generation techniques, see (Goncalves, 2004), (Cura, 2005) and (Lagos, 2005).

As important as the data collection, in this module, is the treatment of these data in order to generate a set of simplified information that allows a human analysis or a *computational analysis* to support the decision-making. In this sense, the data-mining submodule should apply pattern-recognition algorithms to discover new knowledge in the assessment data. This submodule will supply information to the accompaniment module.

Accompaniment Module

This module could be accessed by students and teachers in order to monitor the student's knowledge and learning improvements by means of cognitive and metacognitive measures gathered from assessments.

The feedback generated by the assessment grading process (automatic or manual) and the information provided by data-mining tasks will make it possible for teachers and students to accompany the learning process.

Some decisions related to educational objectives could be taken from the information stored in this module, such as: to issue certificates and indicate the next instructional process stage based on the student cognitive and metacognitive level.

The cognitive measures will indicate the student's actual performance in the assessments. The possibility of selecting *time periods* will make it possible to track the student's evolution. The unstable student performance in some contents (high and low) could indicate that these contents are not adequately sedimented, while a continuous unsatisfactory student performance in some contents could indicate that this content is critical for the student to advance to the next step. In other words, the environment besides presenting results, will also allow for the *Educational Users* to verify the critical learning contents in individual level as well as in collective level.

Another important point in learning accompaniment in this work is continuity. Thus, having a unique or an interconnected knowledge database for several domains will make it possible to use it in several modules, courses or even in several education degrees. This would be an ideal situation: to monitor the student knowledge level continuously.

The metacognitive measures are a differential in this work. The metacognitive accompaniment, mainly by the student, will offer him conditions to realize his actual level of knowledge. It is considered that metacognitive measures could be used in selecting the next instructional step and mainly in choosing the level of complexity of the next assessments. For example, the indication of a metacognitive *pessimistic* profile can suggest that the environment should select more com-

plex contents for next assessments, besides keeping constant dialogue with the student to make him aware that his knowledge in fact is wider than he thinks.

The environment should not only show results to the student, but also compel him to hold a dialogue with it by selecting options, filling the gaps etc, in order to *force him* to read his results and in a certain way, to get his agreement.

Environment Inputs and Outputs

By drawing an analogy between this environment and a factory, we now introduce the necessary inputs to its perfect operation, i.e., the assessment planning, as well as the final products, i.e., assessment outcomes, as shown in Figure 3.

Assessment Planning

The Management Module and the Knowledge Module will be like an engine for the whole process, since each assessment planning will derive from them, starting with the recording of the assessment units associated with the learning objectives that in turn will be connected to the knowledge and the cognitive processes to be assessed.

In this stage the purpose of the assessment is established and so are the instruments to be implemented (tests, questionnaires, portfolios etc), the indicators and criteria to measure the student's performance in activities. Moreover, the way of recording and informing, showing or exhibiting the current student's state to teachers, parents and students themselves, and their integration in the teaching-learning process must also be defined.

In a second moment, some stages of the assessment planning could take place in automatic or semi-automatic ways by using the previous results, or rather, by using the current cognitive and metacognitive student profile.

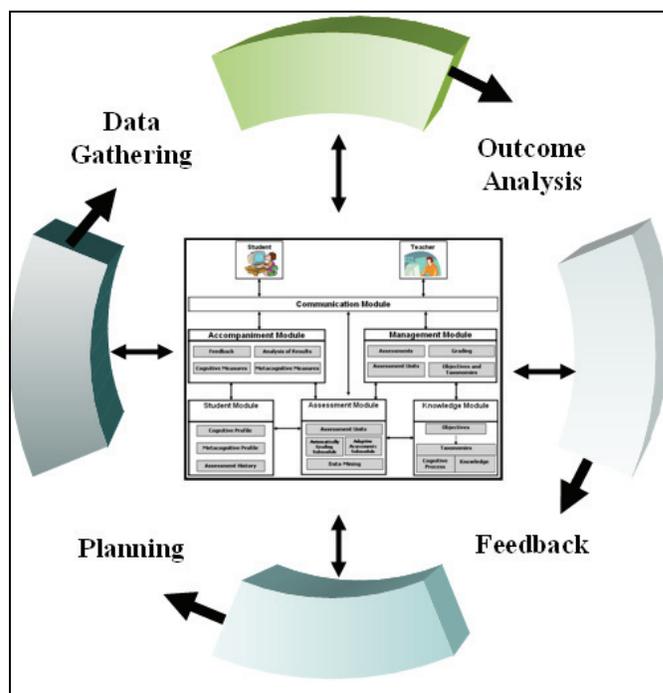


Figure 3: Cycle of Inputs and Outputs

Data Gathering

The Assessment Module is the heart of the environment, since students will achieve the assessments through it. The data gathered in each assessment will update the cognitive and metacognitive student's profile. The teacher or even the system will choose the most suitable assessment to the student's current profile.

Several variables could influence this stage, for example: the moment, the place, the time length, the space setting (one or more students), the research sources, answering-sharing, the questions, the discussion etc.

At any rate, in a computer environment, all these variables could be input into the system so that they can be considered for updating the student's profile.

In this stage, rough data will be gathered and they should be processed before being analyzed by Educational Users.

Outcome Analysis

As previously discussed, the data volume generated by a continuous assessment process requires the use of automatic or semi-automatic tools to assist in the result analysis and interpretation.

This work considers the use of (KDD) techniques to reduce the volume data and to make results interpretation easier for teacher and student alike.

Data mining can be considered a way to discover knowledge in large databases (Rud, 2001; Wang 2003). The purpose of data mining techniques is to generate automatic tools to investigate and extract information from databases. The extracted knowledge is finally presented in terms of models and rules among variables.

In this work, we are previewing the application of data mining on the students' performance, data that was obtained from assessments. The basic idea is to prepare the data collected from a student's several assessments, in each item of the ontology (subjects) and relate them (cross over) by using their hierarchical organization, in order to find new knowledge about the student learning by using data mining tools.

In this phase the data will be transformed into information and new knowledge and can be either used manually by the teacher or automatically by the system in selecting the next step. The outcomes of this stage will determine what kind of *feedback* the system will supply the student with, in the next phase.

Feedback

The implications of the assessment results, that is, the way they will be reinvested in teaching and learning and transmitted to students are important aspects that must be equated in this stage, or, in other words, it matters to know how the results will provide the environment with Feedback.

In this phase, the teacher can judge the adequacy of the assessment instruments used and change them. The system itself can *take decisions* in order to lead the assessment process as close as possible to the cognitive and metacognitive student level.

It is not enough to indicate to student if his answer is *right* or *wrong*. The environment must delimit the content items at which the student's performance is insufficient, not just once, but in a sequential series.

In a certain way, the environment will also indicate *what* can be assessed in agreement with the current student profile. It's a waste of time to insist on consecutively assessing contents that the student has already made it clear he does not know.

Being digitally stored, these data make it possible to get a knowledge photograph of the student extending for a long period of time. In this way, one can check the student's performance dynamic in a continuous time, not just at some few moments, as is the practice in the current system. This will certainly assist teachers when taking decisions about approvals and certifications, but mainly in identifying the student's learning gaps.

Final Considerations and Future Works

The major part of Computational Learning Environments hides the assessment process or does not take into account the value of assessment inputs and outputs.

The environment architecture proposed in this article brings the assessment to the center, in such a way that assessment can act as a learning engine, gathering data that could identify precisely the student's knowledge level, and use this information to improve the learning process. We suppose that the metacognitive measures will make it possible for the student himself to self-monitor his learning. Moreover, the outcomes will help teachers and other persons involved in the Educational System to decide about next steps to improve the System as a whole.

The architecture described and discussed above makes it possible either to develop a new Computer Learning Environment or to extend an existing one, including the proposed features.

As future work, besides the environment implementation, we are investigating a pedagogical architecture for application in an actual classroom context. We have already conducted some case studies but only half applying these ideas, supported by some computer assessments prototypes.

To conclude, we see the use of mobile front-end devices as potential devices in Education, mainly to gather information from student's knowledge in anywhere through assessments and, for this reason, this will be considered in our following studies.

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Biography



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