A COMPUTER-AIDED METHODOLOGY FOR DIRECT AND INDIRECT MONITORING OF THE LEARNING PROCESS

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Abstract: Learning is a complex process that needs to be carefully taken under control by assessing its outcomes (direct monitoring) and by identifying the factors that might affect them (indirect monitoring). A large number of well-documented assessment techniques is available, but they are heterogeneous in nature and they are independently applied even within the same institution, so that they produce results which are not suitable for comparison and cross-processing. This paper presents an integrated computer-aided methodology that makes use of a comprehensive set of questionnaires (monitoring tools) administered within a unified framework (software assessment tool) in order to gather coherent data sets on which advanced statistical analyses can be performed. The applicability of the approach is demonstrated on a real-world case study.

1 INTRODUCTION

Educational market is becoming more and more competitive, thus imposing to universities to keep pace with recent trends and to improve the services they provide. As a consequence academic institutions have to bend their efforts to carry out direct and indirect monitoring. The former is aimed at measuring students' performance both during the courses (*formative evaluation*) and at the end of the courses (*summative evaluation*) (Gardner, 2005). The latter is aimed at evaluating the set of factors which affect students' performance. This kind of analysis provides information both to instructors and staff members for improving courses (*classroom assessment*) (Joyce *et al.*, 1996) and to students for enhancing their cultural and social growth (*course-embedded assessment*) (Farmer & Donald, 1993). Addressing monitoring issues entails the development and application of suitable assessment methodologies.

This paper presents an integrated approach to carry out direct and indirect monitoring of the learning process under a unified framework. Notice that this work is not aimed at introducing a new software tool. Rather, it is aimed at proposing a comprehensive methodology for computer-aided monitoring and assessment, pointing out the distinguishing features that must be provided by any software platform used to implement the methodology.

The main objective of the proposed methodology is to make available to the academic institution a coherent set of data to be used not only to evaluate specific indicators, but also to conduct advanced correlation analysis and to identify causal relationships to be used for improving the learning process. The reliability of the data set is guaranteed both by the scientific validation of the questionnaires used as monitoring tools (taken from literature), and by the adoption of a common computer-aided framework to administer all of them.

The work is organized as follows: in Section 2 we outline the methodology; in Section 3 we discuss the application of the proposed approach to a blended MS degree program used as a case study; in Section 4 we draw conclusions.

2 METHODOLOGY

The proposed methodology is based on three pilars:

- using questionnaires taken from literature as a recognized assessment tool;
- performing advanced statistical analyses of all available data;

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- adopting a common software platform for addressing all computer-aided assessment needs.

2.1 Direct Monitoring

Questionnaires are often used for direct monitoring in higher education to verify student achievements in learning: written exams are made of different types of questions to assess the level of students' final knowledge on specific topics of the courses (*summative evaluation*); self-evaluation tests are delivered througthout an academic program to make students aware of their progress in learning (*formative evaluation*).

LCQ. *Learning curve monitoring* (LCM) has been recently proposed as an advanced form of direct monitoring based on a questionnaire (called LCQ) covering all the topics of the degree program and administered periodically (Pigliapoco & Bogliolo, 2008). The LCQ is composed of questions prepared with the contribution of all the instructors, and it provides two main direct indicators: the *learning value*, which is the score obtained in a particular administration, and the *learning rate*, which is the slope of the learning curve between two subsequent administrations. Each student becomes acquainted with his/her own learning values and with the average learning values of the population (i.e., the cohort) he/she belongs to. The comparison between individual and average values provides both summative and formative self-evaluation opportunities. Since LCQ is periodically administered over the study program, each result provides a summative feedback if referred to a single period (e.g., the last academic year), and a formative feedback if considered as a single observation of a long-term process (e.g., the degree program as a whole). Finally, the last point of the learning curve, taken after completion of the study program, provides summative information about the overall achievements.

2.2 Indirect Monitoring

Indirect monitoring identifies the factors impacting on student performance. In particular, students are characterized by different attitudes towards teaching and learning, different responses to the services they benefit from, and different emotional involvement in academic context. Literature suggests exploring all these aspects by means of specific questionnaires focusing on: *learning styles* (LSQ), *customer satisfaction* (SQ), and *psychological sense of community* (PSoC).

LSQ. Learning styles are "characteristic cognitive, affective, and psychological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Keefe, 1979). Several models have been proposed over the years. A classification can be suggested according to the different definitions associated with the phrase "learning style" (Sadler-Smith, 1997) which can be considered either as a *cognitive personality element* (e.g. Witkin et al. 1977; Riding & Rayner, 1998), or as an *information-processing style* (e.g. Kolb, 1984; Honey & Mumford, 1992), or as a set of *approaches to studying* (e.g. Entwistle, 1998), or as a set of *instructional preferences* (e.g. Riechmann & Grasha, 1974). According to the second definition, Felder & Soloman (1999) developed a model based on a psychometric instrument called *Index of Learning Styles* (ILS), which consists of a 44-item questionnaire and a scoring sheet to be used by the students to self-evaluate their own information processing styles as *active vs reflective*, *sensing vs intuitive*, *visual vs verbal*, and *sequential vs global*. ILS is widely recognized (Zywno, 2003; Felder & Spurlin, 2005) and it can be applied to: *i)* diagnose and predict probable difficulties experienced by some learners (Khaled & Baldwin, 2003), *ii)* increase the support for learners having different individual preferences, *iii)* tailor the teaching methodology (e-learning, blended learning, face-to-face learning) to learners' approaches to study, and *iv)* provide support for effective instructional design.

SQ. Customer satisfaction is typically sounded out by means of questionnaires. Some studies (Wiers-Jenssen *et al.*, 2002) examine how overall student satisfaction can be broken down into several components referring to broader aspects of students' learning experience. It has been demonstrated that students who are satisfied with the pedagogic quality of teaching, with the organizational and administrative aspects of courses, and with the physical infrastructures of institutions, not only have better opinions about the academic program, but they also have better performance in learning.

PSoC. Psychological sense of community is "a feeling that members have to belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together" (Mc Millan & Chavis, 1986). Several approaches have been proposed over the years to investigate PSoC by

means of questionnaires (Rovai, 2002; Pigliapoco & Bogliolo, 2007).
Rovai (2002) introduced the so called *Classroom Community Scale* (CCS) which uses a 20-item test. The questionnaire takes into account the four dimensions of PSoC which are *spirit* (friendship, cohesion, bonding among learners), *trust* (credibility, benevolence, confidence among learners), *interaction* (honesty in feedback, trust, and safety among learners), and *common expectations* (commonality of the same goals, that is learning). The answers to questions range in a [0-4] interval corresponding to "strongly agree, agree, neutral, disagree, and strongly disagree". CCS distinguishes between *CCS connectedness* (which represents the feelings of the community of students regarding their cohesion, spirit, trust, interdependence, and social presence) and *CCS learning* (which represents the feelings of community members regarding the construction of understanding through discussions and the sharing of values and beliefs) (Rovai, 2002).
Pigliapoco & Bogliolo (2007) elaborated two alternative indicators: *Membership* and *SCITT (*which stays for the dimensions of *Spirit, Commonality, Interaction, Trust granted* and *Trust received*) expressed in a [0-10] interval. Membership corresponds to the score of the following direct question asked to students: "How much do you feel a member of a community?". SCITT is an indicator obtained from five questions asked to investigate the dimensions of PSoC summarized in its acronym.
Recent studies have shown that PSoC felt by students plays a key role in affecting their performance (Picciano, 2002), satisfaction (Johnston *et al*., 2005; Shea *et al*, 2002), and persistence (Carr, 2000; Frankola, 2001) in academic degree programs.

2.3 Statistical Analysis

The core of the proposed methodology is based on the statistical analysis of collected data. To this purpose we define a *domain* as a set of data gathered from a sample the members of which share a common feature. For instance, a domain can be represented by the data collected from a group of students belonging to the same cohort where the academic year of enrollment is the feature shared by all the members. Similarly, the distinguishing feature of the data belonging to the same domain could be the teaching methodology (e.g., e-learning, face-to-face learning, blended learning). Notice that the definition of domain given so far is completely general, in order to be possibly tailored to any parameter of interest.

Both for direct and indirect monitoring, the collected data can be processed in three different ways called: *i) intra-domain* analysis, *ii) inter-domain* analysis, and *iii) cross-processing*.
Intra-domain analysis makes it possible to evaluate the average trend and the variations of a particular phenomenon within a single domain. For example, given a set of LCQs filled in by students belonging to the same cohort, it is possible to evaluate the average learning trend of the cohort (by plotting the average learning values over time) and its intra-cohort variations (by computing standard deviations within the cohort). In the same way, considering a single topic of a course as the common feature of a given domain, the intra-domain analysis can be carried out to evaluate subject-specific learning (by averaging the scores of all questions referred to the given topic) or knowledge retention (by comparing the scores achieved on the same topic over time).
Inter-domain analysis makes it possible to point out differences/similarities between two or more domains. For instance, in case of two domains discriminated on the basis of the teaching methodology, inter-domain analysis highlights the differences between face-to-face students and distance-learning students by comparing the average values computed over the two different domains.
Finally, cross-processing allows us to capture correlations between two or more phenomena taken into consideration either in intra- or in inter-domain analyses. For example, cross-processing can be used to cross-validate two different assessment systems (by computing correlations between LCQ results and exam grades) or to point out the relationship between different classes or subjects treated during the course (by computing correlations between subject-specific learning values).

2.4 Software Requirements

A software platform supporting the implementation of the assessment methodology described so far should provide specific features to enable: the creation of any type of questions, the administration of any type of questionnaires, the performance of all the statistical analyses outlined in Section 2.3, and a flexible management of access rights and ownerships.

2.4.1 Questionnaires Creation

The software tool must allow privileged users (i.e. tutors, instructors, and administrators) to create their own sets of questions (such as open-text,

single/multiple choice, true/false, cloze, Likert-scale, …) possibly organized in MxN matrices in order to capture multi-dimensional phenomena. Questions must be stored in a relational database organized into hierarchical sub-sets. Each set of questions could be arbitrarily associated to an entire course, to a single didactic module, or to a particular lesson. Once question sets have been created, it should be possible to define meta-questionnaires made up of questions randomly or deterministically taken from different sets.

2.4.2 Questionnaire Administration

Privileged users should be able to administer a questionnaire by setting up a call which is characterized by the meta-questionnaire to be administered (a new *instance* of the questionnaire will be generated whenever a new user opens it), and by the following administration options:

- supervised/unsupervised administration;
- anonymous/personal filling-in;
- evaluated/self-evaluated/not-to-be-evaluated result.

In case of supervised administration, the tool should provide a mechanism to ensure that the filling in of the questionnaire can be made only upon explicit authorization given by privileged users. Moreover, in case of anonymous filling in (such as for customer satisfaction questionnaires and LCQ) the software must guarantee that all the users, included privileged users, can not explicitly reveal students' identities even if encrypted IDs are managed by the database in order to provide support for correlation analysis, as outlined in the following subsection.

2.4.3 Statistical Processing

A set of statistical tools should be provided by the assessment software in order to conduct data analysis. First of all, the processing tool should be able to calculate the score obtained on each question both automatically and manually (i.e., with or without instructor's involvement). Moreover, the processing tool should be flexible enough to allow intra-domain, inter-domain, and cross-processing analyses. For this reason, the data structure used to represent question answers should contain a reference to the corresponding question, to the set the question belongs to, and to the user who gave the answer (such a reference will be kept blind in case of anonymous filling in).

2.4.4 Rights and Ownership Management

The management of data ownership and access rights should enable the system administrator to carefully decide who can: create questions, use questions to create meta-questionnaires, set-up administration calls, fill in a questionnaire instance, evaluate a questionnaire report, access the results, and perform statistical analysis.

3 CASE STUDY

The proposed methodolody was applied to a European MS degree program in Urban Comparative Studies, (hereafter denoted by *E-Urbs*) organized by the University of Urbino, Italy, together with 7 European academic institutions. E-Urbs was delivered in a blended way which included a face-to-face (F2F) summer school (lasting 3 ½ weeks, corresponding to 15 credits); 9 online (OnL) courses (lasting 26 weeks, corresponding to 27 credits); an internship and a thesis preparation (lasting 10 weeks, corresponding to 18 credits). The 24 students who enrolled in the program came from 14 countries with different cultural backgrounds.

A *Feedback Management Tool (FMT)* was purposely developed by the University of Urbino to meet all the requirements outlined in Section 2.4. The FMT was implemented in Java and added as a plugin to the e-learning management system adopted in E-Urbs, in order to be used for the case study.

The application of the proposed methodology entailed: *i)* the identification of well-known questionnaires taken from literature to be used as monitoring tools; *ii)* the implementation of the monitoring tools of choice within the FMT; *iii)* the data processing in terms of intra- and inter-domain analysis; *iv)* the cross-processing of all the available data. The four phases are detailed in the following subsections, while some conclusions are drawn from the case study in Subsection 3.5.

3.1 Implementation

Direct monitoring was carried out by means of exams, self-evaluation tests and learning curve questionnaire (LCQ); indirect monitoring was performed by means of a learning styles questionnaire (LSQ), a satisfaction questionnaire (SQ), and a psychological sense of community questionnaire (PSoC).

Exams were prepared by tutors and instructors as online tests made up of multiple-choice and open-

text questions. The tests were administered at the end of each teaching activity to evaluate students' preparation.

Self-evaluation tests were prepared by tutors and instructors and made available to students among the resources associated with each lecture of each course. All self-evaluation tests were compliant with the same format adopted for final exams.

LCQ was made up of questions covering all the topics of the master, prepared with the contribution of all the instructors. Each instructor was asked to prepare a thematic set of questions on the topics covered by his/her own lectures. The questionnaire was made up of questions randomly taken from each set. The learning-curve questionnaire was administered 3 times during the master (at the beginning, at the end of the summer school, at the end of the online courses) in order to build a learning curve by plotting the average results as a function of time/credits (ECTS).

LSQ was used to infer the learning style of the students in order to make them aware of their learning attitudes and to give them advise on how to take advantage of the teaching activities of the master. The Felder-Soloman's model was applied to the case study.

SQs were administered three times to monitor the satisfaction of the students and the suitability of the proposed teaching methodology at the end of the summer school, at the end of the on-line courses, and at the end of the master. Customer satisfaction questionnaires were administered anonymously, although students were requested to authenticate in order to make sure they submitted the questionnaire only once.

PSoC was sounded out according the CCS (both CCS Connectedness and CCS Learning) and SCITT/Membership. The questionnaires were administered twice, at the end of summer school and at the end of the on-line courses.

3.2 Organizational Aspects

From an organizational point of view, the application of the methodology required:

- the administration of all questionnaires to be scheduled in advance, according to the timing diagram reported in Figure 1;

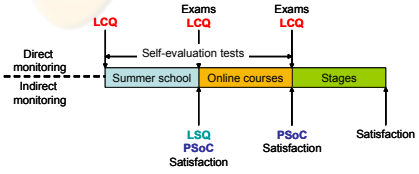

Figure 1: Administration planning.

- a common template to be developed and adopted for all questionnaires;
- a tutor to be appointed to provide guidelines and assistance during question/questionnaire preparation and management;
- all instructors and tutors to be involved in question preparation by means of constant online interactions;
- all questions to be gathered and organized in thematic sets before the beginning of teaching activities;
- a face-to-face meeting to be organized in order to make students, instructors and tutors aware of the purposes of the methodology.

3.3 Intra and Inter Domain Analysis

For space limitations, in this subsection we present only the most relevant results provided by the direct and indirect monitoring tools applied to the case study.

Direct Monitoring. The graph of Figure 2 shows the average scores obtained by students in the LCQ at the beginning of the master (LC1), after the face-to-face summer school (LC2), and at the end of the master (LC3). Both the overall added value of the learning process and the individual contributions of face-to-face and online activities can be easily evaluated from the graph.

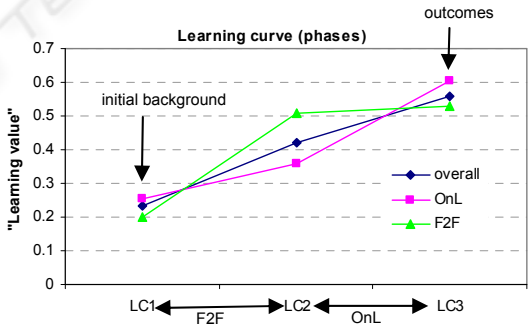

Figure 2: Learning Curve – Phases.

The blue diamonds refer to the results of the overall questionnaire, while green triangles and pink squares refer only to the scores of the questions covering the topics of the face-to-face and online courses, respectively.

As expected, the green curve grows much faster in the first part, while the pink curve grows faster in the second one. Notice, however, that there was a non-negligible "crosstalk" effect between online and face-to-face courses, so that face-to-face learning activities provided a sizeable increase of the

knowledge on the topics covered by the online courses, and vice versa. This can be explained both in terms of induced learning and in terms of correlation between the topics of the courses. Figures 3 and 4 show the same learning curves, plotted as functions of time (expressed in weeks) and of credits (expressed in ECTs). Looking at curve derivatives we observe that face-to-face activities are more efficient than online activities in terms of added knowledge per time unit, but the efficiency of the two phases is similar if evaluated in terms of credits.

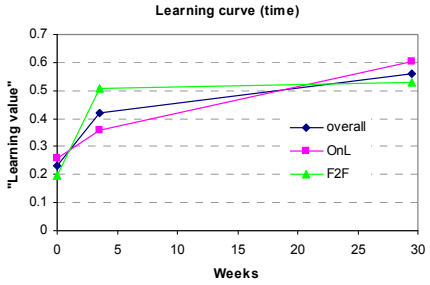

Figure 3: Learning Curve – Weeks.

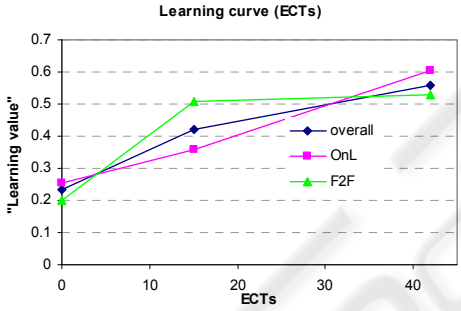

Figure 4: Learning Curve – ECTs.

Indirect Monitoring. The results of the LSQ were self-evaluated by each student by means of a scoring sheet that allowed the user to determine his/her own position in a 4-dimensional space. The axis of the learning-style space are active/reflective (ACT/RLF), visual/verbal (VIS/VRB), sensitive/intuitive (SNS/INT), and sequential/global (SEQ/GLO). According to the position in the space, the model suggests how to take maximum advantage of the learning activities. The sample under study was not characterized by a common dominant LS, since students revealed heterogeneous tendencies to different styles. All the students were provided with the scoring sheet reporting the suggested activities to be carried out in order to compensate their personal lack of balance among the 4 dimensions.

SQs allowed each student to express his/her own opinion on several aspects of the master program, and to assign a score to each course based on interest, usefulness, difficulty, objectives, instructor's accessibility, instructor's competence, instructor's clearness, readings, exams, study effort and overall satisfaction. All the average scores were above 2 in a 0-4 Likert scale.

Figure 5 shows two tables that report the values of the PSoC indicators computed after the summer school and at the end of the online activities.

PSoC indicators

Variables	After Summer School		After OnL courses	
	Mean	St. Dev.	Mean	St.Dev.
Membership (1)	**7,40**	2,64	**6,15**	2,95
Spirit	7,45	2,21	7,42	2,1
Interaction	7,19	2,27	7,05	2,42
Trust granted	7,73	3,47	7,15	3,29
Trust received	7,73	1,56	6,42	3,05
Commonality	6,85	2,81	5,63	3,24
SCITT	***7,39***		***6,73***	

CCS indicators

Variables	After Summer School		After OnL courses	
	Mean	St. Dev.	Mean	St.Dev.
CCS	**2,64**	0,49	**2,45**	0,56
CCS Conn	2,80	0,87	2,55	0,93
CCS Learn	2,48	0,46	2,35	0,67

Figure 5: Psychological Sense of Community indicators.

We can observe that the Summer School was very useful for the development of a strong sense of community among students. Most students pointed out this aspect also in the free-comment field of the SQ:

"The building of community between people of different backgrounds is very good";

"Main strength is the opportunity to discuss, interact, and meet the other students";

"Strength: multidimensional group, age, origin, educational background".

"Opportunity to create a lively network with many brilliant people of similar interests and goals".

PSoC slightly decreased during online courses since geographical distance affected transactional distance (Moore, 1993).

Standard deviation is quite small if compared with sample averages, meaning that students experienced quite uniform feelings.

3.4 Cross Processing

The correlations between learning styles and learning curves were computed in order to find out the learning styles providing the best performance in face-to-face and online courses.

Correlation LCQ vs LSQ types

	RFL	ACT	SNS	INT	VIS	VRB	SEQ	GLO
LC F2F	**0,31**	-0,32	-0,17	**0,29**	**0,38**	-0,35	-0,01	-0,06
LC OnL	-0,12	**0,34**	**0,22**	-0,13	-0,14	**0,12**	-0,36	**0,31**
LC Overall	0,01	-0,03	**0,38**	-0,41	0,17	-0,27	0,16	-0,08

Figure 6: Correlation between LSQ and LCQ.

Figure 6 reports the correlation coefficients computed for each learning style against three different learning rates obtained from LCQs: F2F (computed only on questions related to the summer school), OnL (computed only on questions related to the online courses) and Overall (computed on the average of all questions).
Interestingly enough, the most effective learning styles in OnL courses are the opposites of the most effective ones in F2F courses: RLF, INT and VIS for face to face activities, ACT, SNS, VRB and GLO for online activities. Finally, SNS resulted to be the most effective style for learning persistence. The correlation between PSoC indicators and learning styles was studied in order to understand if the learning style might have affected the psychological sense of community. The only significant result obtained from the available data was a positive correlation between CCS and RFL, SNS, VIS, SEQ. Interestingly, such correlation was independent of the teaching method (F2F and OnL). Psychological sense of community is considered to play an important role in students' performance. This general statement was confirmed by the positive correlation (0.26) between CCS and learning rates.

3.5 Discussion on the Case Study

The most critical aspects of the proposed methodology that emerged from the case study were the adoption of a common template for the questions prepared by all tutors and instructors for exams and self-evaluation tests, and the need for having all question sets prepared before the beginning of the courses. Facing these criticalities required a huge coordination effort at the very beginning of the activities and imposed to the instructors to think about the evaluation criteria for their courses much earlier than they expected.
On the other hand, this kind of methodology provided the key advantage of enabling a uniform and comprehensive monitoring of the learning process and induced a better planning of the teaching activities.
Another issue was the statistical significance of the results provided by the feedback tools. In fact, the sample composed of the 24 students of the master was sufficient to guarantee the significance of intra- and inter-domain first-order statistics, while it was too small to guarantee the significance of cross-processing second-order statistics.
Nevertheless, the case study demonstrates the applicability of the proposed approach, its adaptability to specific assessment needs, the added value of the integration of all monitoring tools within a unique framework, and the possibility, for the academic institution, to take advantage of the overall methodology. For instance, in a future edition of the Master, *ad hoc* activities could be organized to encourage socialization among students and enhance PSoC, additional support could be provided to students according to their LSs, didactic periods could be rescheduled according to the results of LC and SQ.
In conclusion, not only student perfomance could be increased by taking under control both the outcomes and the factors impacting on them, but a generalized improvement of the educational process could be pursued by academic institutions.

4 CONCLUSIONS

In this paper we have presented a comprehensive assessment methodology that makes use of questionnaires to address both the direct and indirect monitoring needs of a learning process, in order to make available to the educational institution a coherent set of data to be used for conducting advanced statistical analysis.
The proposed methodology is general in nature, in that it can be applied in any context to address any monitoring need for which a suitable questionnaire exists or can be conceived. The generality of the approach has not to be confused with the generality of the results it produces. In fact, if the flexibility of the methodology is fully exploited to address context-specific monitoring needs, then the results could not have necessarily a universal validity, in spite of their significance within the targeted application field.
The proposed methodology has been described in detail by pointing out its distinguishing features, by outlining the requirements of the software tools to be used to implement it, and by underlying the scientific value of questionnaires used as monitoring tools in education. The applicability of the approach has been demonstrated by means of a real world case study.

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