What and how to monitor complex educative experiences. Toward the definition of a general framework.

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Abstract. A result of re-considering educative processes as "experiences", i.e. multidimensional processes of high complexity and flexibility, is a decrease in the predictability of processes' outcomes. As consequence, a natural transition from evaluation approaches (produced by a deterministic view) to monitoring practices is needed and expected. Such transition requires to invest a quite considerable effort in design and development of new and more powerful monitoring strategies, methods, tools and environments. In this paper, using appropriate examples, we present and discuss possible strategies that can be adopted to achieve the goal. We also present a parallel participatory strategy that can be adopted whenever tools to monitor specific dimensions of the educative experience are not yet available.

Keywords: Educative Process Monitoring and Assessment, Education as Experience, Experience styles, Organic Process, P^{3}BL, Design Inspired Learning, Trace Detection and Analysis, Emotional Interaction and Analysis, Automatic Text Analysis, Concept Maps, Participatory Grading, LIFE.

1 The framework of reference

We believe that, with the exception of situations where educational and testing procedures are operationalizable, it makes little sense to discuss about assessment of complex educative processes if such discussion is not preceded by the description of the pedagogical-methodological "vision" and of the framework that lie behind and support it.

The focus of our "vision" is the *realization of the person*, a person that learns how to tame the complexity and to design her/his own personal learning trajectory, made up of a succession of experiences [1,2]. Consequently we have identified a model of process - the organic process [3] - sufficiently flexible to be adapted to all context and situations and integrable into a bigger picture, that of the *human experience*, see fig. 1 [4]. Then, we have also identified the *design literacy* as the cornerstone of present and future education and the design inspired P^{3}BL (*problem, process and project-based* *learning*) as the most suitable methodological approach for our framework [5]. Accordingly we have designed and developed an on-line environment, *LIFE* [6], suitable to flexibly accommodate the variability of learning experiences and personal characteristics (*experience styles*), etc..

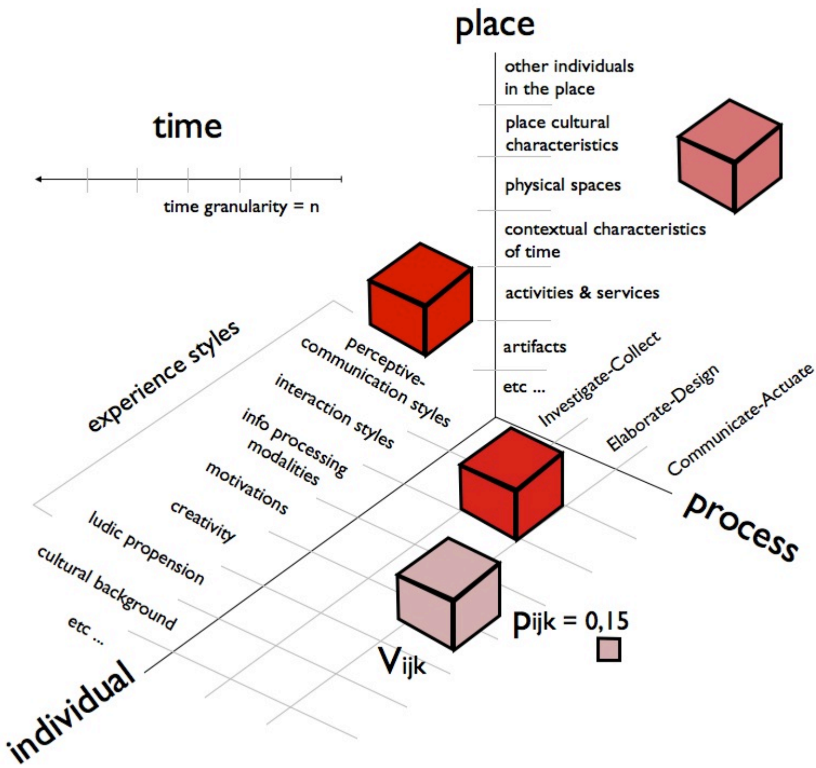


Fig. 1. Experience's model: 3D static space of representation plus the time dimension. Filled cubes are examples of meaningful voxels, V_{ijk}, for a given experience at a given time of its evolution; the color saturation is proportional to the weight/density/relevance, p_{ijk}, associated to a given voxel. More details on the experience's model can be found in ref. 4.

Such complex and flexible framework, inevitably raises the question of *what and how to evaluate the educative experience with respect to the person, the environment (including technology), the process*.

We believe that, according to the focus of our vision, it is very important to develop the expertise needed to monitor how learners progress into the acquisition of the ability:

- to operate within, design and flexibly readjust on-the-fly educative open processes;

- to use relevant methodologies and approaches (critical thinking, problem setting, collaborative team working, etc..)
- to contribute significantly to the cultural evolution of the society (i.e. to use with creativity her/his own personal characteristics and the cultural DNA of the context in which one operates to produce innovation [7]).

We would like to stress that focusing on such abilities does not imply a reduced consideration for other basic skills - like literacy, numeracy and digital literacy [8] - but in this context we take for granted the possession of adequate levels of such skills. Their evaluation is out of the focus of this paper, though some of them can be acquired through open learning processes like those considered here [3-5].

According to experiential framework described above [3,9], monitoring the acquisition and/or transformation of learners' abilities in complex educative processes, would require to monitor all the relevant qualities of learning experiences and, as well, the perception that an individual has of such experiences with respect to the specific learning context and her/his own experiential styles, with particular reference to the maintenance of a good level of motivation [10, 26] and a sufficient tensional state [11] (flow [12]) .

It is worthwhile to note that in such experiential framework technologies act as mediators of the educational process and, thus, should not impose filters or restrictions of any kind but, rather, offer new opportunities and open new paths (*technology enhanced educative processes*). The need to identify any form of constraint that could be imposed by the technology and to contribute to its removal is so obvious to us that we prefer not to deal with this issue here and dedicate the following paragraphs to the discussion on new strategies and methods of measurements that may enable us to monitor the evolution of a complex educative process.

The great challenge would be, thus, *the design and development of a system able to monitor skills, motivation, tensional level and quality of the experience in a non-intrusive manner and to provide individuals with tools and know-how to self-evaluate their behavior and, as well, progresses of the process*. Unfortunately, at present this is not a easy goal to achieve, although it is a valuable one to strive for.

At the present, in fact, the non-intrusive monitoring of all dimensions of learning experiences is not possible, simply because all necessary methodologies and technologies have not yet been developed.

Very often, in fact, one has to use more "direct" tools like tests and questionnaires; for some experience's dimensions, then, even these latter do not exist yet. They must be designed from scratch and validated through procedures, often, rather complex, being aware that the use of more "direct" tools could sometimes affect the ongoing process and, therefore, introduce possible bias. Awareness, in any case, may help in minimizing such danger.

In addition one has to consider that *the ability of individuals to self-assess can not be taken for granted*. As demonstrated in the literature, in fact, it is an ability not always available at all age, at all level of competence and for all domain of knowledge [13]. The ability to self-assess, therefore, is a skill that has to be acquired, gradually, learning experience after learning experience. This fact justifies, hence, the effort in developing intermediate methodologies (like the one described in par. 6) that can help the learner to develop such self-assess ability.

One complementary and equally important issue, transversal to the previous ones, is the unavoidable *transition from products assessment to the monitoring and quantitive/qualitative evaluation of activities carried on during the process*. However, despite of the attention that is increasingly paid to traces left by the players of an educative process, we are not yet equipped to carry out a fully analysis of all meaningful traces, nor are we able to correlate such traces to all experience's dimensions and/or individual's capacities we are interested in. It follows that, waiting for further developments of this domain, at present, we have to find a suitable balance and integration between traces' monitoring and products evaluation.

Faced with so far-reaching needs and a so open domain of research, here, we can only limit ourselves to indicate some possible strategies, illustrating them with examples taken from our experience.

As for non-intrusive analysis of the experience's dimensions one can proceed by:

1) direct extraction of indicators from traces recorded during the educative process;

2) indirect extraction of indicators from traces recorded during the educative process, thanks to markers identified and validated separately from the process.

As for monitoring approaches that uses tests one can proceed by:

3) development and administration of tests allowing for a direct extraction of meaningful indicators;

4) development and administration of tests allowing for an indirect extraction of meaningful indicators, through correlations with external tests, not easily reproducible in situ during the process.

If the above strategies would not be powerful enough to lead to the identification of methods and technologies suitable to monitor acquired skills, experience's qualities, motivational and tensional level of the experience, then, we are left with the need to:

5) involve the learners in participatory grading and/or monitoring activities.

In the following we show an example for each of the strategies listed above, and then draw conclusions.

2 Monitoring the Experience - strategy 1: direct determination of indicators from traces recorded during the educative process

One example of monitoring and direct determination of indicators is the analysis of traces left in a forum during educative processes. Two the sub-strategies that can be adopted to work out interesting information on the individual styles:

i) analysis of the absolute value of selected parameters, or their combinations, normalized to the time window selected for observations - eg. number of accesses, number of post that have been red, number of new thread opened, etc ... - followed by a mapping of such value onto given behavioral styles;
ii) analysis of the temporal variation of selected parameters to measure their dynamics and, thus, possible deviations of individual behaviors from average behaviors of the group under observation.

Fig. 2 shows an example of results obtained by following sub-strategy i). The level of *responsiveness* is determined by the ratio "number of posts sent/number of posts red"; *informativeness* is associated to the number of post red; *proactiveness* to the number of the new threads that have been opened. The white straight lines are drown in correspondance of the mean values of the indicators considered and define four quadrants: in the quadrant closest to the origin of the axes are located the *sleepers,* in the bottom right area we find the *lurkers,* at the top left th*e narcissi* (hyper-players) and hyper-responsive (large circles), on the top right, finally we find the individuals that are likely to actively contribute to the development of the learning community [14]. The position of each individual on the plot is certainly related, at large, also to the her/his personal ability to communicate and interact socially, although it is not possible to work out detailed indications only on the basis of this representation.

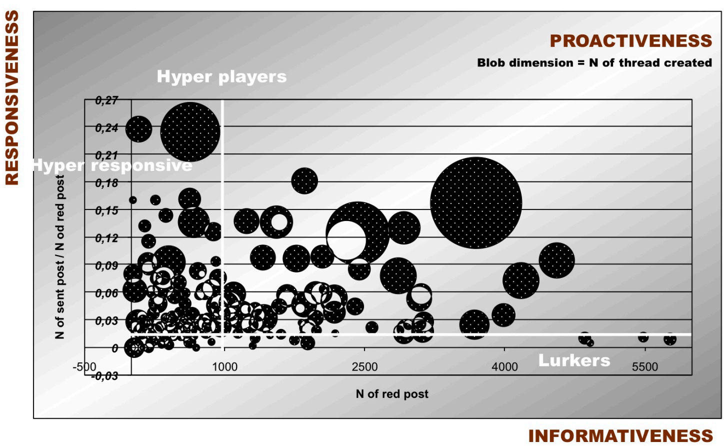


Fig. 2. Example of 2D and half space of representation of individual behavior.

As example of the sub-strategy ii) let's discuss the analysis of a set of traces recorded during a Master course on Technology Enhanced Learning (TEL) attended mainly by high and secondary schools' teachers and carried on fully on-line. Fig. 3a shows, on the same timeline, the number of new threads that have been opened (red line), the number of replies (blue line) and comments to portions of text (yellow line) that have been sent from all members of the community participating in the learning process.

Fig. 3b shows the same traces for a learner whose interaction pattern is fairly in line with the one of fig.3a (it is not by chance that s/he got an excellent score in the final examination). In the beginning s/he appeared hesitant to use comments, while then s/he used them with an intensity equivalent to that of the post replies. Fig. 3c illustrates the case of a learner who has worked in a very discontinuous way, whose interaction pattern is very far away from the average one; not by chance s/he failed to pass the final examination. Fig. 3d shows that, despite the opportunity to comment on portions of text has met a considerable favor among the learners, there are still some, a very small number indeed, who prefer to interact mainly by post reply.

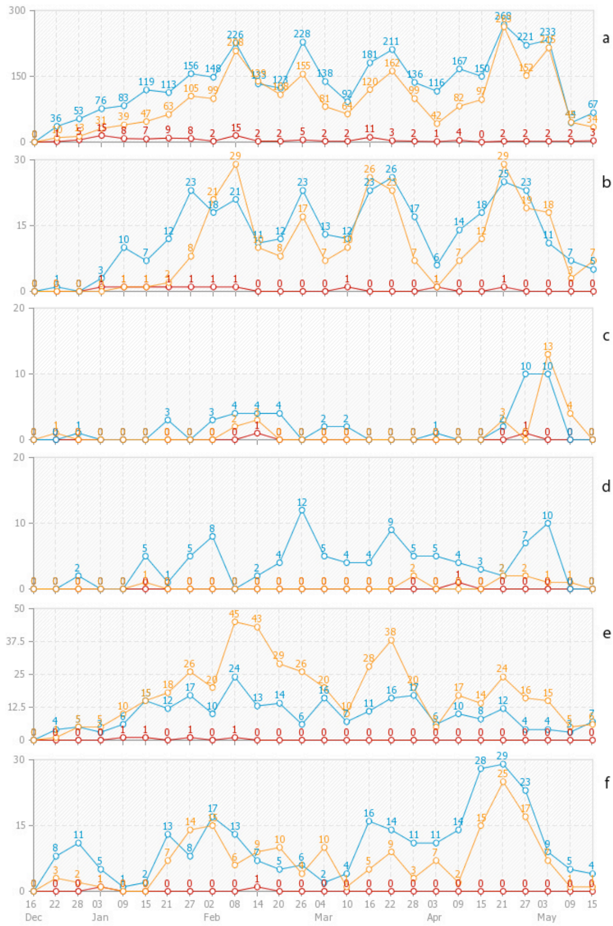
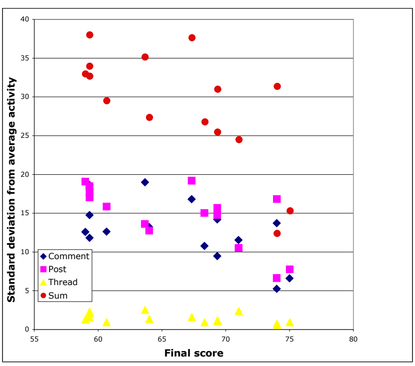


Fig. 3. Forum activities' vs. time: thread opened (red line) post replies (blue line), comment to text (yellow line); a) average activity of the learning community as a whole, b) to d) examples of learners' pattern of activities, e) and f) tutors' pattern of activities

Fig 3d and 3e show the emergence of different styles of tutoring. The tutor of fig. 3e, in fact, uses much more comments and was more present in the early stages of the P³BL (problem, project, process based learning) process, during problem setting and brainstorming. On the other hand, the tutor of fig. 3f, while making a balanced use of both modalities, has a slight preference for replies and was more present in the final stage of the process, namely the design phase.

Starting from the data of fig. 3, one can operate a comparison between the individuals' behavioral patterns (i.e. those reported in fig. 3b-d) and the mean behavioral pattern of the group, fig. 3a (paying attention to subtract the amount of activities produced by the tutors). The calculation of the sum of the standard deviations for the three relevant activities considered here - open threads, send replies, send comments - was found to be, as an example, 0.6 (thread), 6.62 (post), 5.24 (comments), all together 12.46, for the learner of fig. 3b, and 1.87 (thread), 28.64 (post), 25.61 (comments) that add up to 55.61 for the learner of fig. 3c. It is important to note that such a calculation could lead to high values of the standard deviation both in case of a low level of activity and in case of very inhomogeneous distribution of the activities which not synchronize with the trend of the process (strictly speaking high values of the standard deviation may be provoked also by bunch of hyperactivity, but it is highly improbable situations in learning processes like the one we are dealing with; we observed only few limited periods of hyperactivity generated by anxiogenic states and/or by the improbable attempts to recover the lost time).



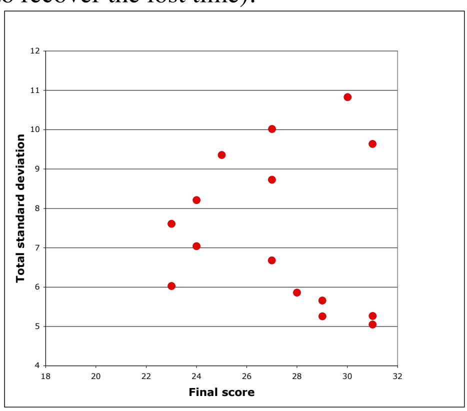


Fig. 4. Standard deviation of the student activities with respect to the mean activity of the whole group integrated over the whole duration of the process vs. the score reported during the final examination. Left: Master; right: ISM 2009

In Fig. 4, the overall standard deviations are shown vs. the mark obtained by the students during the final examination for two different processes. In the case of the Master in TEL, i.e. a process carried on completely on-line, we observed just a inverse correlation between the two quantities [15]. In the case of a P³B blended bachelor course on Interface and Multimodal Systems (ISM) we observed a more curious behavior, two diverging trends: the first one, similar to that of the Master, indicates that a group of students benefits from on-line social interaction, while the second one, opposite to the first, shows that a second group of students prefers a lower level of "social" exposition (we remind that blended courses allow also off-line interactions). This to indicate the existence of measurable "design" styles.

Overall, this second example shows that the traces' "dynamics" can be used also to predict the final result and, thus, to self-evaluate the on-going activity; although in the case of blended courses it should be integrated, probably, with other methods and tools able to detect the "social" propension of the individuals. We would like to underline that traces' "dynamics" could be used, in principle, also to monitor the motivational-tensional state of the process.

3 Monitoring the Experience - strategy 2: indirect determination of indicators from traces recorded during the educative process, making use of meaningful markers defined out of the process.

Texts are the most copious kind of traces left by the individuals during TEL processes. Standard automatic quantitative analysis of texts (number of words used, length of the sentences, etc.) may certainly provide insights about the characteristics of learners but texts, often, contain much more informations of what is usually worked out, informations that can be very useful to monitor several dimensions of an educative experience. To extract such useful information, however, it is necessary to develop new strategies and methods and make use of data that cannot be straightforwardly derived from the text itself.

This is the case of the extraction of the emotional state of individuals from texts. The emotional states can be derived from the text only if one is able to identify meaningful markers, i.e. a corpus of words that convey emotional states. To identify such emotional corpus in a natural manner (i.e. according to a bottom-up procedure) one has to select a quite large sample of candidate markers and then set up a test procedure that allow people to indicate the emotion/s conveyed by each single word according to a given model of emotions (in our case the Plutchik model [16]). Once that the histograms of the emotions conveyed by each marker has been obtained one can extract the average distributions of emotion conveyed by all texts written by students and tutors. As an example, the first strip of histograms in fig. 5) refers to the Master on TEL and shows how after an initial transient, the emotional state of the group stabilized and remained unchanged over time, reflecting a process that has been kept under control and that was carried on without major problems.

The situation of the bachelor course in ISM was somewhat different. The average emotional state of the group was much less stable and showed peaks of negative "mood" in the proximity of the deadlines for deliveries or oral presentations. Among the three ISM processes the more problematic one was that held in 2007.

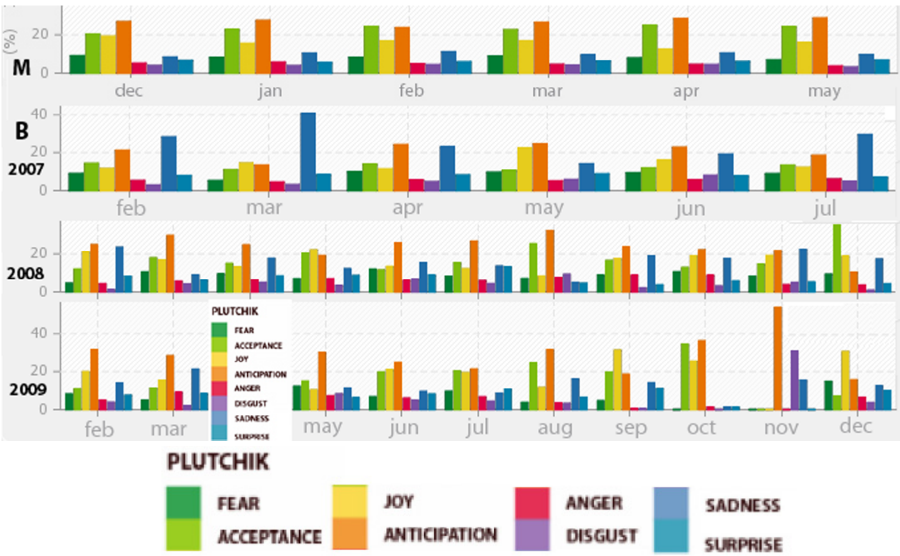


Fig. 5. time evolution of the distributions of the average emotions, as detected by means of automatic text analysis, for the four educational processes described in the text;

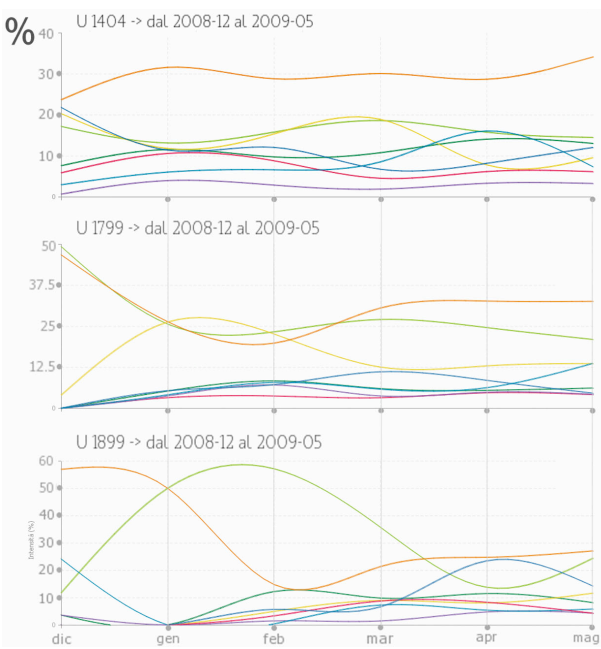


Fig. 6. time evolution of the distributions of the average emotions.

As far as individuals are concerned, the top plot of fig. 6 shows how the emotional pattern of the main tutor (ID 1404) was dominated by the 'anticipation' (central emotion of one of the petals of the Plutchik flower that integrate also 'vigilance' and 'interest') which can be translated into a constant presence and encouragement to the needs of the learners and to the schedule of the process. The central plot shows the case of learner ID 1799 that after a cautious approach, stabilizes her emotional profile, aligns with the process and get a very good final score. Finally, in the bottom plot is shown the case of learner ID 1899, that deserved very little interest in the process at the beginning (hence the emotional instability of the distribution) and that did not pass the examination; it is not by chance that toward the end sadness, fear and anger reached a significant proportions before to fall down again during the "take leave" phase where reappeared a higher level of confidence for the future.

The system allows also for a more detailed, day by day, analysis, but its description is beyond the scope of this article, like the discussion on the possibility to measure the social emotivity [9], by integrating the emotional analysis with the Social Network Analysis [17].

4 Monitoring the Experience - strategy 3: design of tests aimed to the direct derivation of relevant indicators.

An example of such strategy is represented by the quantitative evaluation of concept maps designed starting from a seed concept i.e. a stimulus that identify a given domain of knowledge or a part of it. Once that maps have been realized one can proceed with their quantitative analysis: a) by comparing the concepts used with their classification into categories; b) by looking at the relationships between first neighbors concepts [18]. If the test is repeated several times during the process, the analysis of the maps allows to monitor the evolution of the cognitive status of the students with respect to a given domain of knowledge.

Fig. 7 shows pairs (top-bottom) of radar graphs, or cognitive fingerprints (CF), obtained from the analysis of conceptual maps drawn by four students at the beginning (top row) and at the end (bottom row) of the first year of a bachelor degree course. The concept seed proposed was “communication”. One can immediately notice that the space of representation - size and axis - may differ from student to student and that it evolves over time; this is because the representation emerges naturally from the analysis of the conceptual map and it is not imposed a priori by default.

The average over many individual CFs provides an insight on changes induced by a given educative process. The graphs in fig. 8, worked out as average of CFs shown in fig. 7, puts in evidence that the average students’ perception of the context "communication" has been enhanced with respect to the categories “communication”, “information technology” and “media industry” and has impoverished with respect to the categories “language” and “content”, in agreement with approach and objectives of the bachelor curriculum in Media Science and Technologies.

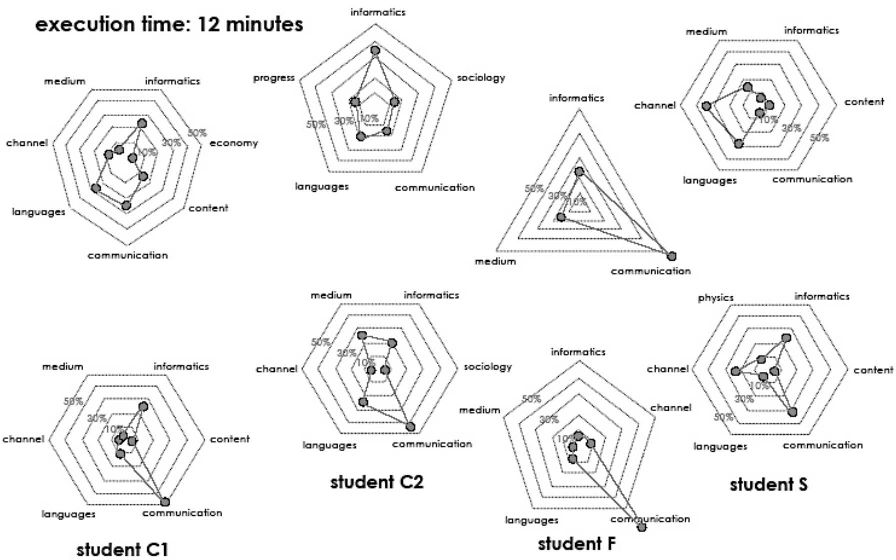


Fig. 7. Examples of "cognitive fingerprints" and their evolution during the year

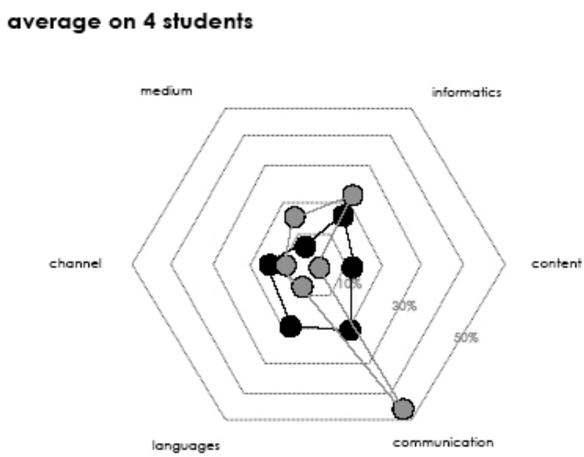


Fig. 8. "Cognitive fingerprints" obtained by averaging those shown by fig. 7

Not to go far away from the demonstrative purpose of the present paper we do not get into too many details, but it is certainly worthwhile to mention that by integrating the transformation of the maps occurred during the learning process we were able to workout self-consistently an indicator that correlated with results obtained during a summative test, based on multiple-choices questionnaire, carried out at the end of the process considered [19].
The quantitative evaluation of the concept maps, designed starting from a concept seed, is a very powerful method but certainly cannot be considered non-intrusive. A possible step forward in this direction will be the extrapolation of concept maps from selected textual traces left by the individual during the educative process.

5 Monitoring the Experience - strategy 4: design of tests aimed to derive indirectly relevant indicators thanks to correlations with data not easily recordable during the educative process.

Sometimes there are information on individual's styles that are not easy to detect during the development of standard educative processes taking place in standard on-line environments. The same information, however, can be extracted quite straightforwardly by means of sophisticated, and often off-line, techniques. In this case the goal is to find a correlation with a monitoring strategy or a test procedure that, then, can be applied on-line within the standard learning environments.

This is the case, for example, of the visual exploration strategies that are strongly related to all visual tasks and to the way individuals profit of the information contained in images. We have shown [20] that such exploration strategies can be identified by means of an eye-tracker and that they can be correlated with visual memory tasks, i.e. the ability to recognize images that have been modified respect to those shown in a previous run. At the same time we were also able to show that tests on the learning styles, like the Felder-Silverman's one [21], did not show any meaningful correlation with the outcomes of the visual memory and recognition tasks.

The overall result is that we have designed and developed a new on-line test that can be used to detect in a simple but indirect manner individual visual strategy and propensity, probably more useful than information on global and visual propensities derivable from tests on learning styles.

6 Monitoring the Experience - strategy 5: participatory grading

Despite all efforts described in the previous paragraphs there are abilities whose acquisition is difficult to assess and, as well, experience's dimensions that are difficult to monitor. Waiting for the design and development of more powerful methodologies and tools, since two years we started to explore a different strategy aimed at involving “learners” in the monitoring and assessing procedures. Preliminary tests on such participatory approach were conducted on the assessment of intermediate tests of selected bachelor courses: *participatory grading*.

The participatory grading, unlike the peer grading [22], takes into account also the opinion expressed by the teacher. We consider this approach particularly suitable and useful in all situations in which students have no special familiarity with the peer review process, nor with the content of the course, like in the case studies considered here.

In detail, the final evaluation of the tests is determined by three factors:

a) the teacher's grade;

b) plus the difference between the teacher's grade and the average grade of the peer reviewers (usually three) time a suitable weighing factor, w;

c) minus the sum of the distance between the grades assigned by each evaluator with respect to the teacher's grade (in unities of standard deviation of the statistical distribution of such distance).

In practice, factor c) counteracts unjustified contribution deriving from factor b): if a peer-reviewer would assign particularly unjustified grade to her/his peers (too high or too low) s/he would move consistently away from the teacher's grade with the result to get a negative correction to her/his own grade.

To further stimulate the objectivity of the assessment we have introduced a reward mechanism for those whose distance from the teacher's grade was below a given threshold. Obviously the teacher's grades are not known to students, who are aware only of the mechanism used to determine the final grade. Moreover we have also introduced a penalty to discourage the non-delivery of the revisions.

The intermediate tests considered for participatory grading consists in open questions/problems (4 mandatory questions plus an optional question and the sketch of a concept map, optional too). Students were not given specific guidelines for revision; we just asked them to evaluate the correctness of the response on a percentage scale ranging from 0% to 100%.

Table 1 synthesizes the results of the participatory grading that took place during a a course in Physics of the academic years '09-'10 (30 students on average) and '10-'11 (20 students on average). In the academic year '09-'10, the participatory grading has been carried on without the help of the online environment. The student works were photocopied and delivered to peers for the evaluations (three for each peer) without obscuring the name of the author. After the collection of ratings, data were entered in a standard spreadsheet and analyzed using the statistical tools made available by the software. In the academic year '10-'11, to study the possibility of using the participatory grading as part of on-line processes, we have integrated such grading method into the test module of our on-line learning environment, LIFE [6]. The transfer of the participatory grading on-line allowed us, among other things, to assign the revisions randomly and anonymously. It is worthwhile to note that in the case of tests based on open-ended questions, students were provided with a copy of their work and were asked to insert the answers into an on-line form to make them available to peer reviewers (of course after a check on the correspondence with the original text).

Table 1. Legend: C = mean value of the quantity [(peers' grade – teacher's grade)/teacher's grade] for the compulsory part of the test; O=as C but for the optional part of the test; OA=as C but for the whole test; M = mean value of the distribution of the distances between peer reviewers' and teacher's grades (in points); SD = standard deviation of the distribution of the distances between peer reviewers' and teacher's grades (in points); Stud% = percentage of students that obtained a reward for their "objective" grading (see body of the paper).

	C	**O**	**OA**	**MD**	**SD**	**Stud%**
09-'10 test I	63%	62%	63%	2/12	1,3	30%
09-'10 test II	12%	8%	12%	0,4/12	1,4	67%
09-'10 test III	5%	-30%	-2%	0,5/12	2,1	69%
'10-'11 test I	54%	75%	54%	0,67/6	0,54	42%
'10-'11 test II	26%	23%	25%	0,54/6	0,4	44%
'10-'11 test III	20%	26%	21%	0,47/6	0,85	78%

It comes out that, on average, the students tend always (with the exception of test III of the academic year '09-'10) to evaluate the works of their peers more generously, 12% to 63%, than the teacher [see also ref. 23] (this observation suggested us to assign a value of 0.2 to w). Going into the details, the two cohorts showed similar trends, although characterized by different intensities: the students, in fact, after a particularly generous evaluation of the outcomes of the first test, improved greatly their performance as peer reviewers on the occasion of the second test and continued in such trend on the third test too (students's evaluations of the '09-'10 cohort became, on average, even lower than those of the docent). At the same time teacher's and peers' grade distributions became compatible within one standard deviation, and the number of students who received a reward increased (because the average distance between their grade and the teacher's grade were less than one standard deviation). The higher standard deviation observed on occasion of the third test is mainly due to the difficulties encountered with fluids and thermodynamics.

We didn't observed significant differences that can be ascribed to the modification in the participatory grading procedure we adopted during the academic year '10-'11: on-line vs. off-line procedure, anonymous vs. manifest author. This proves that the participatory grading can be seamlessly integrated within a design process carried out in blended (or on- line) configuration and that the counteracted mechanism through which the final grade is worked out is robust enough not to be affected by the knowledge of the authors.

We have no enough room here to discuss into details the results of the questionnaire administered to the students of the '10-'11 cohort with the aim to collect their opinion on the participatory grading, but certainly the results obtained so far encourage us to enlarge the involvement of the students in a more general and constant action of *participatory monitoring* aimed at assessing all relevant dimensions of an educative experience (see fig. 1) that cannot detected by other means.

7 Conclusions

Resuming, we have shown that monitoring/assessment strategies and methodologies cannot avoid to be strongly anchored to a well defined pedagogical and methodological vision. In fact, is this latter that determines the design and development of more or less complex technologies and online environments -, including those we need to monitor open and flexible educative experiences [1-5, 24, 25].

To develop technologies anchored to an open and multidimensional vision of the learning processes is not an easy task but it is not an insurmountable task too, as not insurmountable is to correlate the emergences derived from traces' analysis with performances of the learners and qualities of the experience.

Somewhat more complex is the fostering of an adequate self-assessment competency in the learners. This is, however, a very important issue that also challenge us to design and develop suitable strategies and methodologies aiming to induce the acquisition by the learners of adequate abilities. In fact self-assessment:

a) may help in evaluating those dimensions of the educative experience that can not be yet assessed by means of non-intrusive (or intrusive) technologies;

b) allow for a more conscious design of her/his own learning trajectory (and, as consequence, foster the need of more open environments and processes).

Of course all this has to be built on top of our knowledge and ability to make tools and environments more usable.

In conclusion, more open pedagogical and methodological visions require us a breakthrough in design and development of monitoring and assessment tools ... we need much more imagination, ability to integrate already existing methodologies and to design new ones.

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