Re-engineering of collaborative e-learning systems: evaluation of system, collaboration and acquired knowledge qualities

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Abstract. This paper relates an experimentation of a collaborative e-learning system. In this kind of system, tracks arising from communication tools allow to build useful indicators for all system actors. We show how tracks are analyzed and how this analysis is useful for reengineering purposes.

1. Introduction

The desynchronization of the two major teaching roles – course design and tutoring – in distance education, penalizes iterative optimization of the system quality by not taking into account uses with a reengineering objective. That's why in [1] we have proposed an extension of IEEE-LTSA (Learning Technology Systems Architecture) meta-architecture model [2]. This proposition explicitly integrates a step dealing with the observation and comportment analysis of distance learning systems and the learning process actors in an iterative process, guided by design intentions. We underline, in particular, the need for a formal description of the design point of view of the scenario, called prescriptive scenario, as well as assistance in uses analysis by comparing descriptive scenarios (an a posteriori scenario that effectively describes the learning situation's sequence [3]) with the predictive scenario. This produces information, significant for designers from a pedagogical point of view, when they perform a retro-conception or a reengineering [4] of their systems. In the framework of REDiM (Reengineering Driven by Models) project, we are particularly interested in supporting the implementation of those designers two main roles: (i) to establish the predictive scenario of a given learning situation, and (ii) to anticipate descriptive scenario construction by defining situation observation needs allowing the effective evaluation of the learners' activity.
In this paper, we will focus on a particular collaborative e-learning system: Symba. More precisely, we will observe the effective use of a pedagogical scenario in the context of a collective activity supported by collaborative tools. Our experiment thus consists of a project management collective activity, and more specifically, of a web-project management activity (specification and implementation of a web project). From our pedagogical reengineering point of view, many interesting information can arise from this experiment. In particular, we can be interested in comparing descriptive scenarios with predictive ones. Nevertheless, in a collaborative context, another interesting advisability is to compare roles emerging from activity to those anticipated by designers. In our experiment, desirous of putting ourselves in a normalization context, we have used pedagogical model arising from IMS consortium' Learning Design [5] in order to describe learning activities and to explicit pedagogical

scenarios. Nevertheless, we only use IMS LD as a means for designers to express their intentions, and not in an implementation perspective.

2. Presentation of *Symba* experiment

We have used an experimental CSCL support environment called SYMBA [6]. This environment is a Web-based system, developed by the LIUM laboratory in the framework of a Ph.D. study, in order to support Collective Activities in a Learning Context. It was designed following a double objective: (i) allowing students to explicitly work on their organization and (ii) providing tailorability [7] features allowing students to decide about tools and resources they want to be accessible in order to achieve tasks they have defined. Students have to develop a dynamic web-site using previously taught web project management methodology. According to our theoretical framework, students have first to collectively work (and agree) on project organization (such as what to be done, who does what, when tasks have to be finished, which tools are necessary for a particular task…) before beginning the second step, consisting in collectively performing tasks they have defined, according to their organization.

2.1 Presentation of actors

This experimental system is used by four distinct categories of actors. First category is made of fifty-six ***learners*** in higher education, from the Laval Institute of Technology, University of Maine (France). They were associated in small groups of 5 and they where working either at the University center or at home using tools offered by *Symba*. Those proposed tools are centered about description, organization and perception of the activity, but learners must also use the environment in order to explicit organization of their work, with a sharable plan and tasks editors. Activity proposed to the learners lasts for four weeks (35 working hours per week) and a predictive pedagogical scenario implying a collaborative learning was proposed, even if students are free to adopt or modify it. One can notice that this predictive scenario may involve concepts that are not yet taught to learners.

The second category of actors is made of ***instructional designers***. They specify the predictive pedagogical scenario and the uses of the learning system to be observed, they also analyze effective use of the Learning System in order to improve it (reengineering process).

A third category is made of three kinds of ***tutors***. We have *moderator tutors* whose role is to monitor activity within the learning session and to fill reports to evaluating tutors (i.e. *assessor tutors*) in charge to evaluate learners' activity in order to measure knowledge they have acquired. Lastly, *domain experts* are in charge of assisting learners in their tasks by helping them to solve specific problems connected to their expertise domain.

The last actors category is made of two kinds of ***analysts***. *Observed uses modelers* are building tracks with collected raw data, either from the Learning system or not, whereas *observed uses analysts* are analyzing the observed uses in order to synthesize information.

2.2 Different motivations in data analysis

In our experiment, some actors want to (and are interested in) analyze data. *Instructional designers* want to verify if roles they have predicted are well taken by learners and to detect unforeseen new roles. They are also interested in understanding the effective progress of a session in order to discover inconsistencies in it, for reengineering purposes. *Observed uses modelers* are interested in finding new techniques in order to improve their analysis abilities,

whereas *observed uses analysts* are interested in finding new patterns in order to improve their analysis abilities.
A part of *moderator* tutors job is to make reports for assessor tutors on learners abilities to collaborate and to work in group. *Assessor tutors* want to evaluate knowledge acquired by learners in Web projects management by verifying if produced organization is coherent with taught method during web project management courses. Lastly, *domain experts* are also involved in analyzing data, whilst they do not currently analyze data since this analysis cannot be done during the learning session (manual analysis), but they would be interested in analyzing data in order to understand what learners have done previously when they ask them for help.

2.3 What kind of data is being analyzed?

From a reengineering perspective, we will use some raw data (either recorded by the learning system or not) in order to generate some new data that will be useful for system actors. We will also need some additional data, such as the predictive scenario for the activity, and content data, that is, outcomes produced by learners during their activities. We will now detail most important data helping us to formalize emerging roles arising from learners activity.

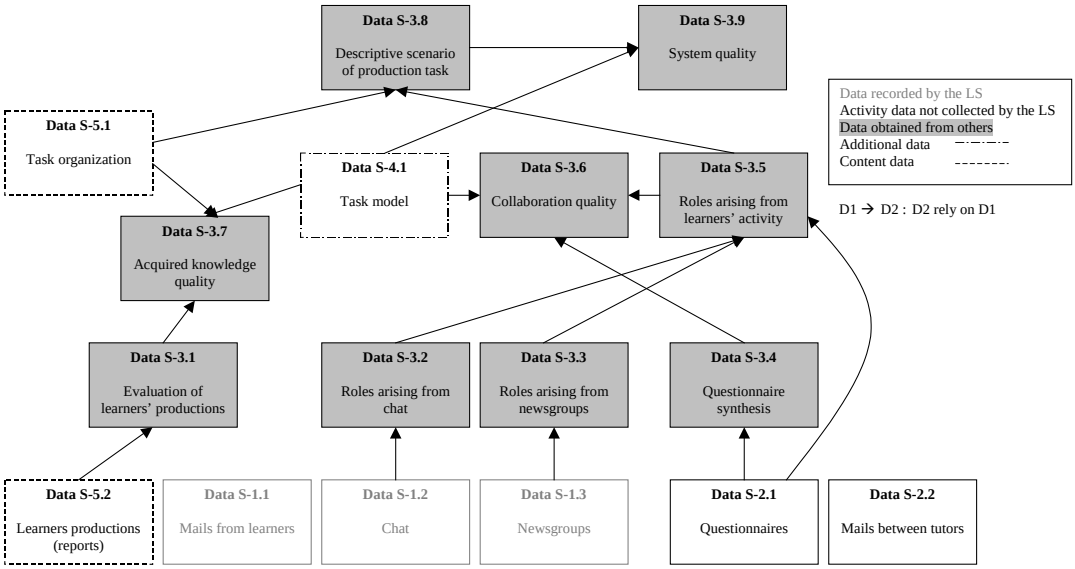

Figure 1. Dependencies between data

In this paper, we will focus on role emergence and we will not detail comparison between descriptive scenario and the predictive one. We will first detail raw data, either recorded by the learning or not. Please note that many of our raw data deal with communication tools tracks. In original tracks messages are written in French, they have been translated into English for insertion here.
Data S-1.2 (data arising from chat) corresponds to the transcription of all communications exchanged between learners via the chat service. A partial transcription of such messages can be found in Figure 2.

02/06/2004
10:45:33 *Arnaud* : I accept to begin working on functional guidance, but I will need some help.
10:46:02 *Myriam* **:** Yes, all going well, I should have finished soon and I would help you after that.
11:10:59 *Arnaud* **:** Do you need some help for the database ?

Figure 2. Excerpt of messages exchanged on the chat service

Data S-1.3 (data arising from newsgroups) corresponds to the transcription of the entire set of messages posted on newsgroup services. An example of such a message can be found in Figure 3.

41
31/01/2005, 17H43
Myriam
noemail
Re : IMPORTANT : WORK DISTRIBUTION
I agree to make the graphical charter, but I rather would work with *Arnaud* since I have already began this work with him and it will be simpler to continue together rather than with another people. Moreover, we are in the same class group and therefore it is easier to meet ourselves.

Figure 3. Excerpt of a message exchanged on the newsgroup tool

Data S-2.1 (data arising from questionnaires) consists of questionnaires, whose main goal is to evaluate group functioning by measuring some parameters such as participation, collaboration, organization… Answers to questionnaires are measured with a Likert scale, graduated from 1 to 5 (strictly disagree, disagree, not agree nor disagree, agree, completely agree). An example of such a questionnaire can be found in Figure 4.

I- PARTICIPATION

1- You always felt yourself integrated in your team because you were widely sharing information.

Completely agree: from a functionality viewpoint, as well as from a graphical viewpoint, we always concert all together before taking a decision. Discussion was therefore always privileged.

2- You always felt yourself integrated in your team because all decisions were taken after considering all opinions.

Completely agree : we have always take into account everyone's positions in order to make project progress in the good direction, with a good collective spirit.

Figure 4. Excerpt of a completed questionnaire

We will now detail data obtained by combining other data (either raw data or more synthetic data).

Data S-3.3 (data related to collaborative communication tools, i.e. *role emergence from newsgroups)* is derived from the transcription of all communications exchanged on newsgroups. Emerging roles are extracted from communication tracks using pragmatic markers [8] (see Figure 5 for an example). This data consists in a list of roles arising from observed communications. One can notice that those roles can be identical to those arising from other communication tools (e.g. chat service, data S-3.2) and are expressed using IMS/LD (see Figure 6 for an example).

Arnaud
So, I propose the following planning for the project:

June 3 -> legal aspects
June 3 to June 4 -> XHTML and PHP structures definition
June 3 to June 12 -> Overall, we can do the following : conception, content structure

[…]

June 23 : final tests and presentation preparation

Myriam
Re : Project Planning
I approve your project planning

Figure 5. pragmatic makers identifying a 'functional leader' role in newsgroups

Data S-3.2 (data related to collaborative communication tools, i.e. *role emergence from chat)* is derived from the transcription of all communications exchanged with chat service. Emerging roles are extracted from communication tracks using pragmatic markers [8] (see Figure 5 for an example). This data consists in a list of roles arising from observed communications. One can notice that those roles can be identical to those arising from other communication tools (e.g. newsgroups, data S-3.3) and are expressed using IMS/LD (see Figure 6).

```
<imsld:roles>
   <imsld:learner identifier="R-learner">
   ...
      <imsld:title>Learner</imsld:title>
      <imsld:learner identifier="R1-learner">
         <imsld:title>Socio-affective leader</imsld:title>
      </imsld:learner>
      <imsld:learner identifier="R2-learner">
         <imsld:title>Debate participant</imsld:title>
      </imsld:learner>
      <imsld:learner identifier="R5-learner">
         <imsld:title>Debate opener</imsld:title>
      </imsld:learner>
   </imsld:learner>
```

Figure 6. roles arising from chat analysis

Data S-3.4 (data related to questionnaire synthesis) is made of answers to questionnaires (data S-2.1) synthesized in percentages and reported with an evaluation grid summarizing this information for each question.

Data S-3.5 (data related to new roles arising from learners' activity). Study of interactions done with Symba communication tools (data S-3.2 and data S-3.3), as well as answers made to questionnaires (data S-3.4), allow to evaluate collaborative process from a cognitive and socio-affective viewpoint. Then, as for data S-3.2 and S-3.3, observed roles in a learning session are transcribed in an IMS/LD formalism.

```
<imsld:learning-activity identifier="LA25">
   <imsld:title>Integration</imsld:title>
   <imsld:learning-objectives>
      <imsld:item identifierref="" identifier="LA25-obj">
         <imsld:title>
            To know integrating all previously made pieces to the Web site
         </imsld:title>
      </imsld:item>
   </imsld:learning-objectives>
   <imsld:environment-ref ref="S2-mail-service" />
   <imsld:environment-ref ref="S3-chat" />
   <imsld:environment-ref ref="S4-newsgroups" />
   <imsld:environment-ref ref="LO18-outcomes-ress-detailedConception.zip" />
   <imsld:activity-description>
      Consists in integrating all previously realized pieces
      (graphical design, videos…)
   </imsld:activity-description>
   <imsld:complete-activity>
      <imsld:user-choice />
   </imsld:complete-activity>
</imsld:learning-activity>
```

Figure 7. Predictive task organization (excerpt)

Data S-3.6 (collaboration quality) corresponds to an evaluation of the quality of the collaboration between learners. This evaluation is made by comparing emerging roles from activity (data S-3.5) to predicted roles presupposed by designers (data S-4.1) and consists in a textual report.

We will lastly describe one additional data which is used in order to highlight synthesized data.

Data S-4.1 (task model specified by instructional designers) corresponds to the task model as anticipated by designers. That is, an indication of the activity sequence that learners are supposed to produce using organization workplace from Symba. This task model is expressed

using IMS Learning Design (and, technically, it is an XML file conforming to IMS/LD XML-Schema definition, see Figure 7 for an example).

2.4 Who analyses data, how and when?

Analysts, and sometimes tutors, analyze data in order to synthesize information they contain. This analysis then produces new data (obtained from others) that can, in turn, be analyzed in order to produce new data.

Moderator tutors analyze data S-3.6 (*collaboration quality*) at the end of a learning session. Their analysis is made using report from the analysis sub-system (data S-3.5) and the task model produced by designers (data S-4.1) in order to verify the concordance between predicted roles and observed ones (at a per learner level).

All other analysis are made by the observed uses modelers (analyzing raw data) and observed uses analysts (making analysis from analysis reports made by observed uses modelers). We will first detail analysis made by *observed uses modelers*.

Analysis of data S-1.2 (*data arising from chat*), that is, tracks produced by learners, by way of their interactions through chat system is currently done manually, at the end of a learning session, using pragmatic markers [8] in order to identify emerging roles. This analysis will be automated in a next step. Analysis of data S-1.3 (*data arising from newsgroups*) is very similar: tracks are produced by learners, by way of their interactions through newsgroups. Currently, those data are manually analyzed with pragmatic markers [8] at the end of the session, and this analysis will also be automated in a further step.

Analysis of data S-2.1 (*data arising from questionnaires*) is made at the end of a learning session. Answers to questionnaire are synthesized in percentages and reported with an evaluation grid. Currently, this analysis is done manually, but will be automated in a next step. Since data S-2.1 contains detailed answers to questionnaires, it can be also used in order to make an analysis report concerning collaboration inside the group. This report is made at the end of a learning session and consists in a textual report.

Analysis of data S-3.2 (*role emergence from chat*) is made at the end of a learning session. Roles identified by pragmatic markers are formatted under an IMS Learning Design format. Currently, this analysis is done manually, but it will be automated in a next step. Analysis of data S-3.3 (*role emergence from newsgroups*) is done in a very similar way: at the end of a learning session, roles identified by pragmatic markers are formatted under an IMS Learning Design format. Currently, this analysis is done manually, but will be automated in a further step.

We will now detail analysis made by observed uses analysts. Analysis of data S-3.4 (*data related to questionnaires*) is made at the end of a learning session. Synthesis of questionnaires is analyzed by the human analyst in order to highlight collaboration quality (through a report on learners abilities to collaborate and to work in group). Questionnaire answering allow to evaluate variables such that: participation, collaboration, communication, work atmosphere, leadership, …

Data S-3.5 (*data related to new roles arising from learners' activity*) is produced by analysis sub-system, relying on data S-3.2 and S-3.3, relative to communication tools tracks and data S-3.4, relative to learner behavior obtained by analysis of questionnaires. Those three data are merged in one data, roles arising from multiple sources are reported only once. This unified data is then analyzed in order to find a matching between new roles and learners. Currently, this data originates in a manual analysis initiated at the end of a learning session. A computerized tool is under development, and should allow data analysis during a learning session.

2.5 Who uses the results of the analysis, how and for which kind of action?

Results of the analysis are used by many actors of our e-learning system. Analysts use them in order to produce new analysis, tutors use them in order to evaluate learners and designers use them in order to improve their predictive scenario (in a reengineering cycle).
We will first detail how analysts (both observed uses modelers and observed uses analysts) use results of previous analysis in order to build new data. First, *observed uses modelers* are in charge of formatting roles identified by analysts using pragmatic markers on chat messages (data S-1.2) and newsgroups messages (data S-1.3). They format those analysis results using an IMS/LD formalism. This is currently a manual transformation, that will later be automated.

Those two IMS/LD XML files then constitute, respectively, data S-3.2 and data S-3.3. Which, in turn, are used in order to produce data S-3.5 by merging those two XML-file in one containing emerging roles (editing out doubles). The last task for observed uses modelers is to format data arising from analysis of data S-2.1, i.e. questionnaires (percentages calculated by analyst) using a synthesis grid. This work is manually done at the end of a learning session and will be automated in a second step.
The textual report on learners abilities to collaborate and to work in groups arising from analysis of data S-2.1 (questionnaires) is then used, at the end of a learning session, by *observed uses analysts* in order to update learner binding to new roles and to clarify collaboration problems. This is a manual use.
We will now evoke uses made by tutors, and more particularly by *assessor tutors*. Their interest in analysis results is to attribute a grade to learners. They are therefore interested in moderator tutors reports made for data S-3.6 (evaluation of collaboration quality). They use those reports in order to attribute a grade concerning collaboration to learners.
Lastly, *designers* are also interested in using result of analysis. From a reengineering point of view, they are particularly interested in result of analysis of data S-3.5 (related to new roles arising from learners' activity). After a learning session, they use those analysis results in order to evaluate training that is bind to learner's collaborating capacities. It mainly consists of verifying that designer's predicted roles are well taken by learners and detecting new roles coming to the fore. When our analysis sub-system will be automated, those data would eventually be used by moderator tutors during a session, in order to regulate project progress (by adjusting role definition or pushing learners to adopt presupposed roles).

3. Conclusion

In a collaborative e-learning system, tracks arising from communication tools allow to build useful indicators for all system actors. Indeed, some indicators like 'collaboration quality' (data S-3.6) can, at once, be used by tutors in order to evaluate learners, by analysts in order to build other indicators and by designers in order to evaluate relevance of their pedagogical scenarios. From this last point of view, we have shown, in this paper, that considering emerging roles arising from communication tools tracks can be useful for reengineering purposes. For example, in our experiment, we have unfolded a first reengineering cycle, and this first cycle had allowed us to enrich predictive scenario made by designers by adding socio-affective roles arising from learning session tracks analysis. Role emergence was one key point of our reengineering process, and was in keeping with comparison of predictive scenarios and descriptive ones enriched with emerging roles.
Another interesting point is that proposed indicators can be used in a more general framework than the one of our experiment. Indeed, role mining from communication tools tracks can

help to enlighten effective use of the collaborative system and to push collaboration quality indicator forward, whatever the collaborative experiment may be. Moreover, in order to support production of such generic indicators, we have defined software tools [9] that, once developed, will allow the analysis of the collected data depending both on the predictive scenario and the formal description of elements to be observed. They will produce formal representations of user comportment, based on observation needs, and thus form a useful help in order to implement reengineering process.

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