Learners Monitoring Based on Traces in CSCL System

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Abstract. In this paper, we propose to use traces in order to facilitate the process of learners monitoring in collaborative learning context, where the interactions between the human actors are very voluminous and very heterogeneous. These traces concern the entire pedagogical activities of the actors as well as the use of the system resources. Hence, first of all, these traces must be collected and filtered. Then, they must be analyzed to assist or support the tutors in their tasks. For facilitating their use, these traces are distributed into two main classes, which depend on the pedagogical activities (learning, assessment and collaboration) and on the system use. The collected traces are used by a collaborative learning system called SYCATA (SYstème pour la Collecte et lAnalyse des Traces dApprentissage collaboratif). For facilitating the learners monitoring process, a set of tools are offered to tutors (trace visualization, advice management, etc.). Furthermore, SYCATA has an assistant system of the tutor, which is based on the collected traces and a set of indicators calculated from theses traces. Our system was implemented and experimented with a sample of university students where good results have been obtained.

Keywords: CSCL, Trace, Learners monitoring, Indicator, Trace visualization, Assistant system.

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1 Introduction

Many works on learners monitoring take place in the context of open and distance learning (whether individual or collaborative) where the need for monitoring the learners is particularly strong. Indeed, the context of distance learning raises many problems, such as the risk of abandonment of learners, the lack of motivation and the difficulty for the tutor to have an adequate perception of the activity of learners [13][18][19][22]. In Computer-Supported Collaborative Learning (CSCL), other than the cognitive aspect, the learners monitoring must take into account their behavioural aspect. In other words, the interactions between the learners should be analyzed to know the content of the exchanges and their nature. This analysis allows the tutor to know the deadlocks in the functioning of each group of learners, to follow the progress of the behavioural profile of each learner and/or each group, to motivate isolated learners and lazy groups, etc. [20]. All these advantages allow an adequate assistance and evaluation of each learner and each group. This implies that the tutor must have a representation, as accurate as possible, of the activities carried out by the learner (these activities can be individual or collaborative, cognitive and/or behavioural) and should view these activities to facilitate their interpretation. The representation of these activities can be done by using the traces.

In the last few years, trace analysis has been developed and new research fields have emerged concerning the nature and especially the structure of data, models, methods and techniques to analyze and visualize indicators in order to foster learning [5]. These traces are often used for re-learning scenarios [17], to help under-

standing the users behaviour [23] or his learning style, to support the creation of intelligent help tutorials [15] and to monitor the learners or to modify their profiles.

In this work, we propose to use the traces to assist the tutors in a CSCL environment and provide feedbacks on various activities/tasks of learners. In collaborative learning context, the traces left by the learners are very diverse and very heterogeneous since they concern all their activities carried out throughout the period of the system use. That makes the task of viewing these traces very tedious especially for the tutors. The difficulty is not limited to this; it also concerns the exploitation and analysis of this large amount of data mass.

The goal of this paper is to study the use of traces for learners monitoring in a CSCL system baptized SYCATA (SYstème pour la Collecte et lAnalyse des Traces dApprentissage collaboratif, which can be traduced as: a system for collecting and analyzing traces of collaborative learning). This system is implemented and tested with University students where good results were extracted. For facilitating the learners monitoring, SYCATA possess an assistant system of the tutor, which is used to advise and support the tutor in his tasks.

The rest of this paper is organized as follows: in Section 2, we present a state of the art on related works where we give some learning systems that used the traces. Section 3 is devoted to the presentation of the means of learners monitoring in SYCATA. We present in Section 4 the results of an experiment conducted at the level of the University. Finally, section 5 contains the conclusion and the future work.

2 Related works

2.1 Trace-based learning systems

There are currently several points of view on what could be the definition of a trace. According to Jermann and his colleagues [16], a trace is an observation or a recording of the learners interaction with a system for analysis.

In the same vein, J-P. Pernin [31] defines a trace as an indicator of actors activity in a learning situation, whether it is instrumented or not. In a slightly different way, P-A. Champin [3] talks about a sequence of states and transitions representing users activity, "the time sequence of objects and operations mobilized by the user when he uses the system is called trace of use" (extracted from [14]).

The researchers of TRAILS project (Personalized and Collaborative Trails of Digital and Non-Digital Learning Objects) [35] consider traces of use in hypermedia as a sequence of actions, and use them to identify the overall objective of the user. As for Choquet and Iksal [6], they consider as trace any data providing information on a learning session broadening the definition given by the researchers of the TRAILS project. In our research, we adopted the definition given by Settouti and his colleagues [33]. They consider as a numerical trace a "trace of the activity of a user who uses a tool to carry out this activity, saved on a numerical medium".

Many learning environments used traces for learners monitoring. We can cite APLUSIX [4], which is a help environment for learning algebra using the learning traces in order to help students solving exercises. This tool lets students solve exercises and check (by using traces) that the solutions are correct and complete.

The tutor in REFLET [9], ESSAIM [8] and FORMID [12] can see the traces of the learners activities. All these tools display the progress of the work of each learner. CourseVis [25] is used for 3D visualization of traces stemming from the WebCT platform. The objective is to make visualization from the calculation of indicators and statistical measures. CourseVis is used for the tutors to provide a kind of a dashboard of a learning activity (group monitoring) [10]. Some systems are used for the trace visualization. We can cite Gismo (Graphical Interactive Student Monitoring System for Moodle) [24][26] which outlines the activities of learners using Moodle. Gismo displays traces in a graph by representing the number of access to different Moodle resources by different learners. In order to analyze the traces, we can mention ColAT (Collaboration Analysis Tool) [1] and LISTEN [29]. ColAT is a learning traces analysis tool which is independent of any learning system. It is used to analyze every step of the learners activities within a collaborative learning session [37].

In the LISTEN project, the researchers have developed an intelligent tutor which is capable of listening and interpreting the oral products of learner in his learning to read English. They have developed a set of knowledge on collecting and analyzing traces, and then sought to formalize this know-how as software architecture and methodological recommendations [28].

Finally, JCachesim[2] is a simulation environment of the operation of a computer. It enables learners to observe the functioning of the Central Processing Unit (CPU) and the invisible tasks during the execution of a program and in particular operations of reading and writing. The tutors can follow the learners traces by viewing the log files where all interactions are recorded.

2.2 Traces used in learning environments

In this section, we present a list of traces used in some learning systems. This list is not exhaustive, but reflects

the main traces kept in these systems. We can notice that the descriptions of these traces are very diverse and often related to each other

Table 1: List of traces used by some learning systems.

$Environment$	$Traces$
In the LISTEN project [28]	- The studied text - The time of the study - The number of access to this text - The traces of communication between learners - Frequency, volume and messages recipient
In the CourseVis tool [24][25]	- Connection time to the system - History of the visited resources - Marks of success in tests and questionnaires - Actions performed on the system
In CSCL tool developed by Siebra and her colleagues [34]	- Interaction traces: number of sent messages - The number of read messages - The quality of the interaction itself
In JCachesim tool[2]	-The recording of actions done by the learners on the tool. -The recording of response time to the solicitation of the system. -The origin of access to a resource - The role assigned to a user - The requests for aid or assistance

2.3 Discussion

We have presented some trace-based systems as well as a list of traces that are used in these systems. In this section, we give some remarks about the limits of these systems.

First of all, the majority of the cited systems focus on only one activity of the trace usage (analyse, visualization, collection, etc.). Also, in the existing systems, we note some limits:

- The tutors dont have enough tools to filter this great mass of data. Moreover, they can not understand the significance of such data.
- The lack of tools for keeping the traces concerning the actions carried out by the tutors (sending of messages or advice, organization of virtual meetings, etc.).
- The novice tutors can encounter problems related to the learners monitoring process. They must have assistance.

To eliminate these limits, we have developed a system (SYCATA) which can take into account: the collection, analysis, visualization and interpretation of traces. In addition, it allows filtering the collected traces, and managing messages and advice sent to learners. Finally, it assists the tutors in their work by providing them an assistant system.

3 Learners monitoring in SYCATA

3.1 Presentation of SYCATA

SYCATA is a collaborative learning environment, which has most of the features found in CSCL systems. It can be used by four human actors:

- $theauthors$ are responsible of the creation of the learning objects that will be presented to $learners$,
- $thetutors$ can follow-up all the activities of learners, and
- $theadministrator$ is the first responsible of the system management.

An important feature of this system is the ability to manage a set of traces representing the different interactions between the different actors. In our work, the collected traces are distributed into two main classes. The former itself is distributed into three sub-classes, which depended on the pedagogical activities of learners. The latter contains two sub-classes, which are related to traces of use of communication tools and system resources (detailed in the following section).

For facilitating learners monitoring, SYCATA has an assistant system of the tutor. This system uses a database of rules initialized by the experts in the tutorial field and a set of indicators based on collected traces. This system offers to the tutor a set of actions for each selected learner (sending messages, setting an appointment, programming a virtual meeting, etc.).

3.2 Taxonomy of traces

To process the treatment on these traces, it seems necessary to build a traces taxonomy to thereafter define the corresponding treatment to a similar type of traces. Also, traces taxonomy will regroup the different approaches for the processing of traces in the same structure [14].

In literature, we found traces of learning that are used by several researchers, traces of interaction [3][7] [30] [32] [34] and traces of use [3][6][21][27][35]. Gwenegan [14] has identified four groups of traces: the footsteps information (personal information and technical information related to the used medium (system version, IP address, ...)), traces related to the exploitation of a resource (name, reference resources, access number, ...), traces associated with the learning activity (the

quality of a production, response time, test results.) and the traces attached to the communication activity (number of messages sent and read in a forum, message content, ...).

To exploit better the traces collected by our system, we suggest some classes of traces. To facilitate their interpretation, we join to each trace a symbol. The proposed classes are:

a. Activity traces:

i: **Learning traces:** concern the access to educational material content in SYCATA and corresponding consultation time (date, duration, designation of learning object, etc.). They are represented by rectangles.

ii: **Assessment traces:** : concern the assessment tests (exercises, marks, etc.). They are represented by lozenges.

iii: **Collaboration traces** : concern all the collaborative activities such as replies to the forum, acceptance of collaboration request, collaboration tool, collaboration date, etc. They are represented by ellipses.

b. Traces of using communication tools and system resources:

i: **Communication traces:** they concern the interaction between the learner and the other actors or between the learners themselves outside of the collaborative activities (i.e., there is no explicit request for collaboration). They are represented by circles.

ii: **Traces of use:** : include information on the access to the system (date, frequency), the access to system resources (courses, test), access to the collaborators search engine (it is a tool that allows searching a collaborator, verifying some criteria [19]) and communication tools (chat, forum, e-mail). These traces are represented by squares.

Compared to those types of traces previously mentioned, we have retained and adapted traces of learning, use and communication to be used in our collaborative learning environment. We should also mention that there are few researchers who used the three types of traces at the same time. Depending on their scope, they used only one type of these traces.

3.3 Main architecture of the system

Figure 1 gives an overview of the overall architecture of SYCATA. It consists of four main interfaces, which are associated with each of the following human actors: administrator, learner, author and tutor. In addition, it contains a traces manager which is made up of four components: traces collector module, indicators calculator module, traces visualization system and assistant system of the tutor.

The Traces Manager (TM) allows managing all collected traces (addition, deletion, filtering, etc.) and all the indicators that can be used by the visualization system or the assistant system. It includes the traces preservation process and the rights of displaying these traces.

The Traces Collector Module (TCM) allows the collection of learners traces and their classification into different classes (cited in the previous section). The collected traces are used by the Indicators Calculator Module (ICM), which allows calculating the indicators that concern the learners activities. The indicators are used during or after the learning activity and represent a variety of information such as the number of access to a resource, the time spent on each exercise or the success rate [33]. We consider an indicator as a variable that is calculated from a trace or a set of traces.

The traces managed by the TM are used either by the Traces Visualization System (TVS) or by the assistant system of the tutor. The TVS gives to the actors statistical and graphical representation of traces (sectors, stick diagrams, etc.). The visualization is the representation (temporal data) of all collected and converted traces during the learning period of the learner.

The TVS executes a set of steps for doing its task. The visualization process of these traces is the following:

1. After filtering the traces, the user (tutor or learner) must choose the viewing period (the current day, any previous day, any past week or also a well determined period).

2. Next, the user must choose the mode of viewing traces: graphical, numerical or mixed.

3. After showing all the traces, the user can choose any trace class for more details.

4. For each class, a set of information that characterize the type of traces will be displayed.

The last component of the TM is the Tutors Assistant System (TAS). Its role is to assist the human tutor in his task of monitoring learners. In other words, it can send advice in the form of a message to learners requiring assistance. These advice are the results of the execution of a series of tutorial rules. These rules are updated by field experts. The assistant system uses a set of indicators (calculated from the traces left by the

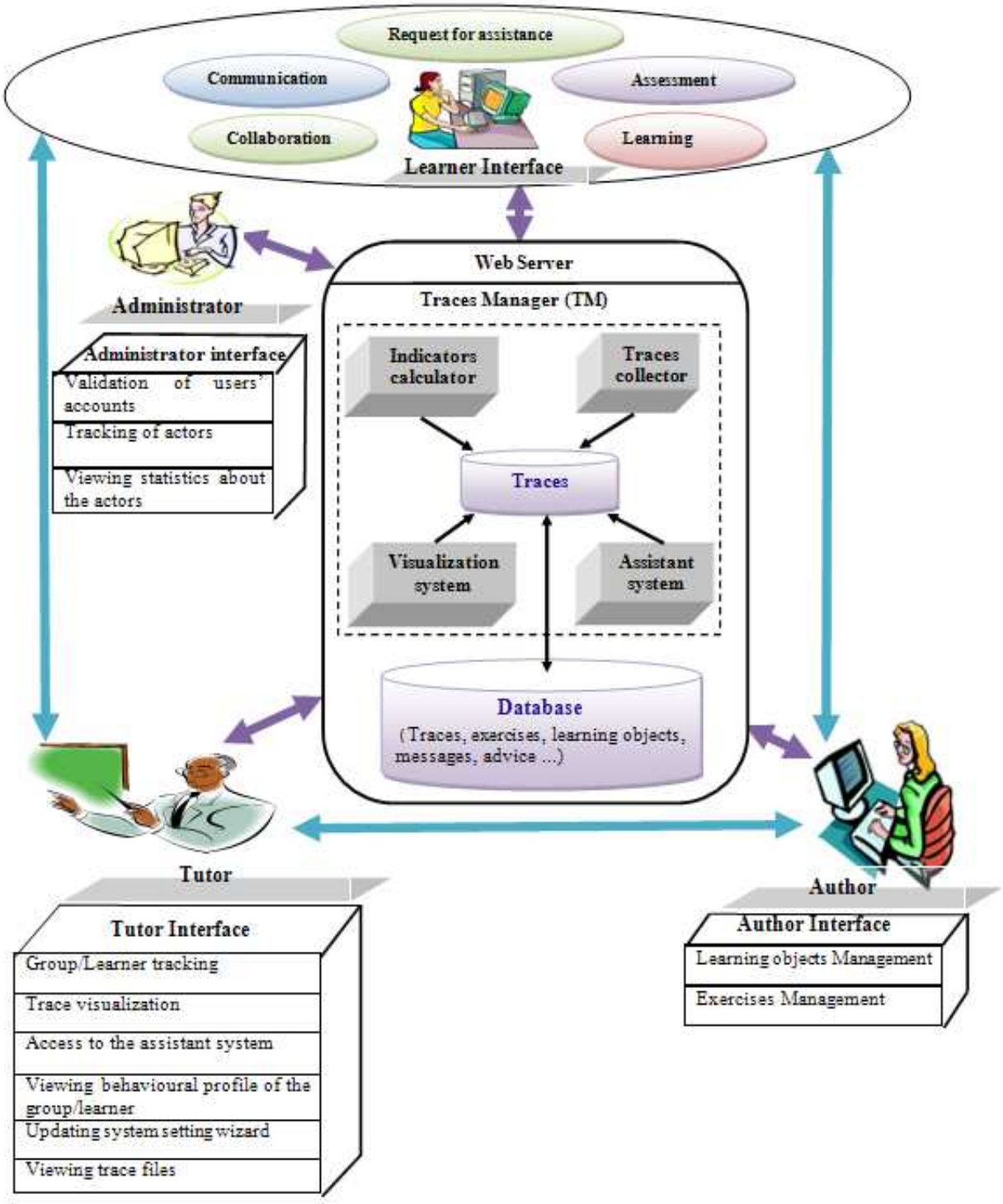

Figure 1: Architecture of SYCATA

learners) and basic tutorial rules (established by the experts). Furthermore, this system, which resembles an expert system, has an inference engine that reasons using a database of rules and facts (initialized when registering a new learner) to deduce the advice.

Finally, the architecture of SYCATA contains a data -base including all necessary information on the system actors and the interactions done between them, and a web server that provides navigation.

3.4 Means for learners monitoring

In SYCATA, several tools are available to tutors to monitor the progress of their learners and all their activities throughout the period of the system use.

a. Trace visualization

One of the difficulties of using traces is their visualization. Indeed, registration of a given datum from the learners activity is very easy, but how it will be reproduced and in what form it must be displayed in order to not lose its importance? There are traces that will be more significant with the graphical mode, while others will be more significant with the numerical mode (statistics). In our work and in order to better reproduce the traces (for maintaining its importance), we offered the following visualization modes: graphical, numerical and mixed.

This visualization is very interesting for the learner in order to improve his knowledge as well as his cognitive and behavioural profiles. The visualization of his traces promotes his educational activities and constitutes a good reflexive tool. As for the tutor, the visualization allows him to know information on the progress of every learner as well as his attitudes of work in regular time intervals. This offers him the opportunity to intervene and provide assistance to learners who are in trouble.

The tutor can see the traces of all his learners, whereas the learner can only see his own ones. The users of these traces have the opportunity to choose the viewing time of these traces:

- **Traces of the current day:** they can see all traces of the activities done during the current day.
- **Daily traces:** they can see traces of any previous day.
- **Weekly traces:** this option allows them to see all traces of the current week (see figure 2).
- **Traces of a given period:** SYCATA offers the users the opportunity to see the traces done during a given period (month, biannual, annual, etc.).

Figure 2: Weekly traces visualization

b. Viewing more details on each traces class

For each activity, the learner or the tutor can find a detailed plan with all information on each trace, such as:

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The tutor can see the traces of all his learners, whereas the learner can only see his own ones. The users of these traces have the opportunity to choose the viewing time of these traces:

- Activity designation.
- Starting date/Completion date of this activity.
- Starting time/Completion time of this activity.
- Other information according to the type of each activity. For example, in the case of collaboration traces, we can found: receiver of collaboration request, object of collaboration request, date and time of the collaboration request, appointment of collaboration, collaboration tool, duration of collaboration, etc.

To see these details, the tutor/learner can click on the image associated with each traces class (see figure 3).

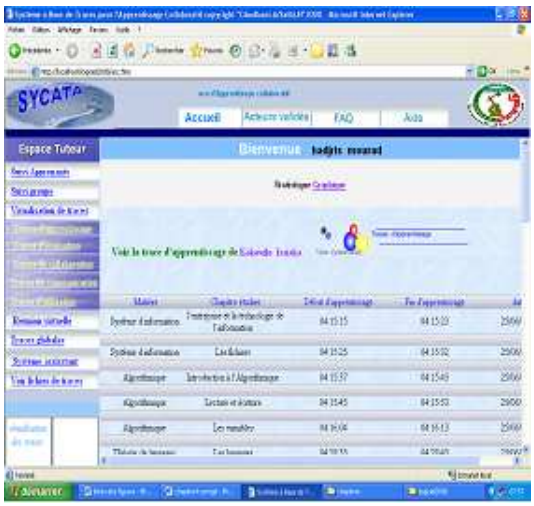

Figure 3: A detailed description of learning traces.

c. Trace analyze

To better enjoy the collected traces, means for their analysis are provided. This analysis allows to:

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The tutor can see the traces of all his learners, whereas the learner can only see his own ones. The users of these traces have the opportunity to choose the viewing time of these traces:

- See the progression of cognitive or/and behavioural profile of each learner during a definite period (one week, one month, etc.).
- Reconstruct the path of the learner to show his progress in a learning session. This allows explaining the background that led the learner to perform an action or to obtain a particular outcome[11].
- See the list of isolated learners or too solicited ones.
- Calculate the rate of an activity, frequency of sending messages of each learner.
- See the frequency of using every available tool: search engine of collaborators, communication tools, etc

The trace analysis is done thanks to the assistant system of the tutor, which can replace the tutor in the case of absence. It sends messages to learners based on indicators calculated from the colleted traces. For example, according to the value of the indicator "cognitive profile", there will be a piece of advice to be sent to concerned learners. If its value is Very weak, a message requesting the learner to consult the concepts of the corresponding learning objects and to collaborate with his colleagues is sent to him. Finally, we remind that each indicator is associated with a set of advice to send to the concerned learners.

Figure 4 shows a set of updated production rules of the assistant system. Each production rule contains a condition about an indicator and the action to do if the condition is true. The action is usually sending a message to the learner or an invitation to a virtual meeting.

To see these details, the tutor/learner can click on the image associated with each traces class (see figure 3).

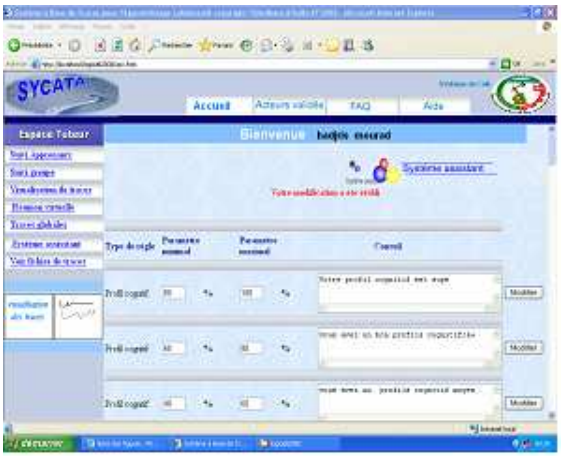

Figure 4: Advice update of the tutors assistant system.

d. Consultation of learners profiles

As indicated previously, the tutor can see the traces of any learner of his groups as well as the progress of cognitive and behavioural profiles of learners, and behavioural profile of his groups during well determined periods of time (a week, a month, etc.). The same formulas used in SACA system [19] are taken into account for the calculation of these profiles values. Figure 5 shows the visualization of the group behavioural profile.

e. Support for the isolated learners

As indicated previously, the tutor can see the traces of any learner of his groups as well as the progress of cognitive and behavioural profiles of learners, and be-

Figure 5: Weekly group behavioural profile.

havioural profile of his groups during well determined periods of time (a week, a month, etc.). The same formulas used in SACA system [19] are taken into account for the calculation of these profiles values. Figure 5 shows the visualization of the group behavioural profile.

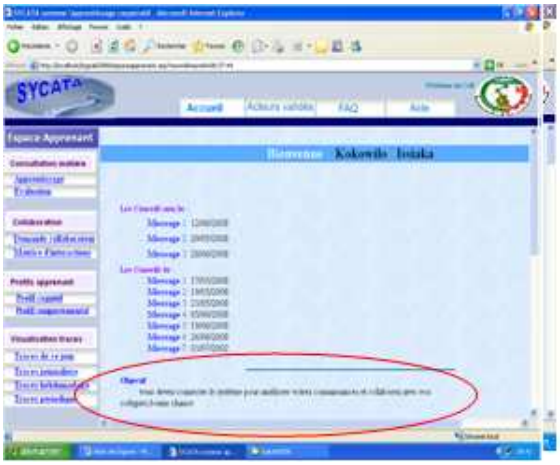

Figure 6: Messages sent by the tutor using the assistant system.

4 Experiment

4.1 Methodology

We conducted an experiment in computer science department at Guelma University (Algeria), with fifty six students from 3rd year licence degree. The learnt subject was: "Compilation". It was designed by two teachers of the computer science department and including about one hundred fifty concepts and assessment exercises.

The participants are divided into two groups (at random). The first group (control group) follows a system prototype without the trace visualization functionality, while the second (experimental group) uses SYCATA system with all its features. All the learners were organized in groups (four students per group) that followed-up by ten human tutors of computer science department. The students access the system using the Intranet of the University.

At the end of the experiment (after two months May-June 2008), a questionnaire (about the learnt subject) is submitted to the learners of both groups. The questionnaire is constituted of a set of exercises established by the same teachers who created the learnt subject.
Our hypothesis is that trace visualization increases the cognitive level of learners.

4.2 Results and discussion

To verify our hypothesis, we have compared the means of control group and experimental group. To know if the difference is significant between the two means we have used paired samples t-test (student t-test). After using R software [36] which is a free software environment for statistical computing and graphics, we have obtained the following results with 95

Table 2: t-test statistics.

N	Mean of control group	Mean of experimental group	t_{score}	Degree of freedom	P value
28	9.036	10.79	-2.57	27	0.0129

From the table of t-test, t0.975 = $\pm 2.04, so, t_{score} < t0.975(-2.57 < -2.04)$.

The difference was very significant, the hypothesis is proved and we can affirm that trace visualization can increase the cognitive level of learners in collaborative learning system. At the end of the experiment, a questionnaire containing multiple-choice questions is submitted to the learners that used SYCATA (experimental group). It concerns the functioning of SYCATA and its features. During this experiment, we observed that the students were very satisfied with this system. The visual appearance of several traces with its different forms was the most admired element. This last point has attracted the attention of many students who think that the possibility of showing the learning pathways in detail is very useful to increase the capacity of knowledge memorisation and the followed path. According to students, these

traces find out the weaknesses and the strengths of each one of them. In addition, these students believe that the tutors intervention is very useful to direct or encourage them.

Concerning the faced problems, the learners cited:

1. lack of opportunity to save the displayed traces,
2. lack of tools for storing conversations made between them (i.e. learners),
3. refusal by some learners of collaboration requests,
4. no possibility to send parts of the courses or exercises from learning space, and
5. knowledge assessment tool is less efficient.

a. Learners answers on questionnaire questions
We present in Figure 7 the responses from learners (who used SYCATA system with all its features) to some questions of the questionnaire (n=28).

b. Tutors answers on questionnaire questions
Regarding the tutors, they appreciated the use of this system, especially the trace visualization. In addition, more interest has been given to the assistant system. However, these tutors found some gaps on the graphical representation of some traces in particular those of communication traces (by sectors), the lack of possibilities for knowing the online availability of a learner (who belongs to tutoring groups) and the process of updating system setting wizard is too long (tutors want to have assistance).

For knowing the appreciation of the tutors, we submitted to them a questionnaire related to the functioning of SYCATA and its features. The obtained results are the following (n=10) (Figure 8).

5 Conclusion and future work

Many interactive systems are now available on the Web and most of these systems use collected information on their usage to improve their quality. In human learning field (individual or collaborative), we note that there is a number of tools used to capture traces and produce data, which is ready for interpretation. This type of tools is developed in order to give teachers and tutors opportunities to understand the interactions within the learning platforms and can act directly on the design of learning environments, to make them actually closer to the learners needs or to modify the existing ones.

The aim of our research is to develop tools for the collection, analysis and interpretation of traces in a CSCL environment. These traces can be used for facilitating the learners monitoring in a CSCL environment and the assistance of all the environment actors. Currently, we have implemented a system (SYCATA) that collects and analyzes the traces of the learners. This system is based on traces of activities produced by learners during their collaborative learning as well as the traces of using the different resources of the system and the available communication tools.

In this paper, we presented some tools that facilitate the process of learners monitoring in collaborative learning context. All these tools are based on the collected traces of the learners activities or the set of calculated indicators. A very important component of SYCATA is the assistant system of the tutor. It can assist the tutor by managing a set of advice to be sent to the learners having difficulties in each of the suggested pedagogical activities: learning, assessment and collaboration.

As a prospect to our research, we plan to study the relevance of the advice sent by the assistant system, and the proposed tools for facilitating the learners monitoring process. Finally, we intend to conduct another experiment with a larger sample than the first one.

N	Question	Proposed Choices			
1	Did you understand the concept of "Trace"?	Yes, perfectly	Yes, in general	Not so	Not at all
		12	**13**	**3**	**0**
2	How do you see the traces of learning?	Very helpful	Helpful	Unhelpful	Not helpful
		16	**11**	**1**	**0**
3	How do you see the traces of assessment?	**12**	**12**	**4**	**0**
4	How do you see the traces of collaboration?	**18**	**8**	**2**	**0**
5	How do you see the traces of communication?	**10**	**15**	**2**	**1**
6	How do you see the traces of use?	**6**	**16**	**5**	**1**
7	How do you see the interventions of your tutor?	**20**	**7**	**1**	**0**
8	How do you see the importance of the trace visualization?	Very important	Important	Unimportant	Not Important
		18	**9**	**1**	**0**
9	How do you see the quality of trace visualization?	Very well done	Well done	Badly done	Very boring
		7	**20**	**1**	**0**

Figure 7: Experiment results: the answers of the learners.

N	Question	Proposed Choices			
1	Did you appreciate the use of SYCATA?	Yes, perfectly	Yes, in general	Not so	Not at all
		2	**7**	**1**	**0**
2	How do you see the traces of learning?	Very helpful	Helpful	Unhelpful	Not helpful
		6	**4**	**0**	**0**
3	How do you see the traces of assessment?	**3**	**7**	**0**	**0**
4	How do you see the traces of collaboration?	**6**	**4**	**0**	**0**
5	How do you see the traces of communication?	**2**	**7**	**1**	**0**
6	How do you see the traces of use?	**1**	**7**	**2**	**0**
7	How do you see the use of the assistant system?	**4**	**6**	**0**	**0**
8	How do you see the importance of trace visualization?	Very important	Important	Unimportant	Not Important
		8	**2**	**0**	**0**
9	How do you see the quality of trace visualization?	Very well done	Well done	Badly done	Very boring
		2	**4**	**4**	**0**
10	How do you see the difficulty of the assistant system setting update?	Very easy	Easy	Difficult	Very difficult
		0	**5**	**5**	**0**

Figure 8: Experiment results: the answers of the tutors.

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