TrAVis to Enhance Students' Self-monitoring in Online Learning Supported by Computer-Mediated Communication Tools

Madeth May[1], Sébastien George[2] and Patrick Prévôt[3]

[1] Industrial Engineering Department, INSA-Lyon, University of Lyon
21 Jean Cappelle, Villeurbanne F-69621, France
madeth.may@insa-lyon.fr

[2] Computer Sciences Department, INSA-Lyon, University of Lyon
21 Jean Cappelle, Villeurbanne F-69621, France
sebastien.george@insa-lyon.fr

[3] Industrial Engineering Department, INSA-Lyon, University of Lyon
21 Jean Cappelle, Villeurbanne F-69621, France
patrick.prevot@insa-lyon.fr

Abstract: **This paper presents TrAVis (Tracking Data Analysis and Visualization Tools), a Web-based system that assists the students in visualizing their communication activities in distance learning situations. While most of the existing systems in the same genre are exclusively dedicated to the teachers, TrAVis is objectively designed and implemented for both teachers and students. In particular, TrAVis is considered a "reflective tool" that helps students analyze and evaluate their own activities in relation to those of others. This paper focuses on how TrAVis provides the students with new ways to monitor in real-time their individual and group activities. It also discusses the experiment in an authentic learning situation along with students' feedback on the usability and utility of TrAVis.**

Keywords: tracking data, Computer-Mediated Communication, data analysis and visualization, data indicator.

I. Introduction

Researches in E-learning are involved in improving learning environments by the use of technology [1]. As we progress, we witness a big change of research interests in E-learning toward the learning process and the participants. More attention has been paid to the improvement of technologies that better support participation and interactivity [2]. Those technologies include Computer Mediated Communication (CMC) tools, which are employed to extend the content and interaction of a class because of their advantage in providing users with a great variety of ways to communicate between them. In fact, communication has undoubtedly always been an important part of the learning process. Whilst it usually creates opportunities for learning to take place, it also enables the sharing of information, the confrontation of ideas and thoughts which contribute to learning [3-6]. More evidence to back up such an argument can be found in the research effort of Morreale & Osborn [7] along with a thorough study of nearly one hundred articles, which emphasizes the importance of communications in various contexts, from the contemporary life to the specific learning situations.

In distance learning, communications are made on CMC tools and can be called Computer-Mediated Communication activities (CMC activity in short). Making CMC activity is not only to increase interaction between student and teacher, or interaction among students, but also to compensate the lack of face-to-face interaction. Berge & Collins pointed out that CMC tool is recognized as an essential element in distance learning and is strongly recommended for both teachers and students [8]. Many research results have proven that using CMC tools allows the participants to achieve a better learning performance [9], overcome many traditional barriers of distance and times [10] and gain flexibility in learning [11]. However, if we take a closer look at the use of CMC tools in distance learning, CMC tools alone do not always enable the participants to fully control their activities in the way they do in a traditional face-to-face learning situation. As a matter of fact, the interactions between the participants are not person to person, but computer-mediated and online, which makes it difficult, for example, for the teachers to supervise the students' activities. As for the students, they could easily encounter difficulties regarding self-monitoring if CMC tool is the only support they have for conducting their learning activities. This is due to the fact that CMC tools, from a technological standpoint, were not originally built to allow students to self-monitor.

Acknowledging the practical issues related to using CMC tools, we put our research efforts into providing technical solutions to the students in terms of self-monitoring during and after the online learning process. This paper presents a part of our research work that places an emphasis on TrAVis,

which is designed and developed for real-time analysis and visualization of users' tracking data on Web-based CMC tools (i.e. discussion forums, chat, blog, wiki, etc.). It is structured as follows. Section II covers our research context and discusses some related works. The third section gives an overview of TrAVis. Some examples of tracking data analysis and visualization are given in the fourth section to demonstrate how students can use TrAVis to monitor their own activities and those of others. The experiment of TrAVis in an authentic learning situation is presented in the fifth section along with a discussion on the feedbacks we received from the students.

II. Research Context and Related Works

A. Tracking students' CMC activities

Online learning through CMC requires a significant investment of resources, and involves considerable effort from various participants. For instance, the teachers usually seek for effective pedagogical concepts and strategies to foster the learning process via CMC tools. The students, on the other hand, often request technical support to enhance their learning experiences, such as being able to observe their own activities and to analyze them. But instead, the support they obtain still strongly rely upon their teacher's commitment and are usually constrained by other factors related to distance and time. Meanwhile, with the current support of CMC tools that are often limited to communication means, the students are compelled to neglect some important facets of learning, such as self-monitoring when they are in a distance learning situation. It is needless to remind how crucial self-monitoring is to the students in increasing more appropriate behaviors in the classroom, boosting completion of homework assignments, improving both academic performance and social skills, and reducing disruptive behaviors [12-14].

Having studied these issues, we addressed the importance of tracking CMC in learning situations for the benefits of tracking data to online tutoring and learning enhancements. The findings from our previous work revealed that the concept of using tracking system is recognized as a contributing factor to the high quality education in terms of teaching enhancement and learning guidance. Also found in [15], a review of a variety of systems that make use of learning tracking data to assist the students in mirroring their activities and to guide them throughout the learning process. Further evidence can be found in the research works of [16-20].

In our previous work, an explicit tracking approach has been proposed for the implementation of tracking systems for a great variety of CMC tools. It focuses on a tracking mechanism capable of observing different types of user action and interaction on CMC tools. We discussed in detail this research effort in [21]. Later, we pursue our research by focusing on exploiting the collected data to design graphical "data indicators" that support students in terms of gaining awareness and making assessment of their learning activities, outcomes, effectiveness, etc.

Data indicators refer to a piece of information, generally presented in a graphical form and may feature the process of the considered "cognitive system" learning activity, the characteristics or the quality of the interaction being performed on a technology-based learning environment [22]. Obtaining data indicators is a complex process. It involves many phases, among which the design of each data indicator at the conceptual level. Later in this paper, we discuss about the data indicators that serve for self-monitoring, how we design and visualize them.

B. Some existing tools

Data indicator gives considerable assistance to the participants in the learning process. It provides means of abstracting, synthesizing, inferring and viewing the information that it features. Found in the existing research works and presented in table 1, there are three main types of assistance: awareness, assessment and evaluation. Each of the three types is correlated to the nature of data indicator and the system that computes it. We describe below some systems that are particularly devoted to the visualization of CMC activities, and that are the most relevant to our research.

ARGUNAUT [23] is an awareness tool that provides data indicators of online discussions between users (i.e. students and teachers). Its main objective is to support the teachers in their endeavor to increase the quality of synchronous discussion in collaborative learning situations. The original indicators of users' discussion were first seen in the research work of [24]. They displayed the links of discussions in a tree form, giving an awareness of the discussion dept and how users interacted among each other. Later, we have seen iHelp [25], another awareness tool that aims to improve the user collaboration throughout their communication activities. For example, iHelp assists the teacher in supervising the communication process between students.

Regarding assessment tools, they are dedicated to the analysis of various aspects of a communication activity. As seen in [26] and [27], to assess the productivity of a student in a group discussion, the teacher can analyze the participation level of that student (e.g. number of messages posted in a discussion forum). In the same context, [28] suggested a tool that offers means to analyze the temporal and spatial dimensions of students' discussions. The proposed data indicators are illustrated in a form of activity map, allowing teachers to observe and assess communication characteristics such as the degree of participations of a student.

Beside gaining awareness and making assessment of student activities, evaluating students is also needed. From a teacher standpoint, the evaluation, in the context of CMC, can be carried out based on the communications made among the students and the results of the communications. Mazza & Dimitrova [29] suggested CourseVis to the teachers who wish to visualize the social aspect of student discussion. Not too far from CourseVis in terms of information visualization, DIAS (Discussion Interaction Analysis System) of [30] is a Web-based system that supports the teachers in analyzing students' interactions on a discussion forum. Data indictors computed by DIAS mainly serve for the evaluation of the social dimension of each student. Last but not least, GISMO, is a Graphical Interactive Student Monitoring tool, developed by [19].

Nature of indicators	Tools/Indicator concepts	Target users	Authors
Awareness	Trace-Based System (SBT-IM)	Researcher	Djouad et al. (2010) [31]
	ARGUNAUT	Teacher	De Groot et al. (2007) [23] Van Diggelen et al. (2008) [32]
	iHelp	Teacher Student	Brooks et al. (2006) [25]
	Discourse structure analysis	Teacher	Gerosa et al. (2004) [24]
	Mining groups' activities	Teacher Student	Reyes & Tchounikine (2005) [33]
	DIAS	Teacher Student Researcher	Bratitsis & Dimitracopoulou (2005) [30]
	Newsgroup Crowds	Researcher	Viegas & Smith (2004) [35]
Assessment	Temporal participation indicators	Teacher	Dringus & Ellis (2005) [36]
	DIAS	Teacher Student Researcher	Bratitsis & Dimitracopoulou (2005) [30]
	Automatic Message Assessment	Teacher	Wu & Chen (2006) [37]
	MTRDS	Teacher Student Researcher	Gibbs et al. (2006) [28]
	Assessing online discussion	Teacher	Shaul (2007) [27]
	PeopleGarden	Researcher	Donath et al. (1999) [38] Donath (2002) [26]
	i-Bee	Student	Mochizuki et al. (2005) [39]
Evaluation	Tatiana	Researcher	Dyke et al. (2009) [20]
	CourseVis	Teacher	Mazza & Dimitrova (2004) [42]
	DIAS	Teacher Student Researcher	Bratitsis & Dimitracopoulou (2005) [30]
	Evaluation of groups' activities	Teacher Student	Barros & Verdejo (2000) [40]
	DAT (Discussion Analysis Tool)	Researcher	Jeong (2003) [41]
	Discourse structure analysis	Teacher	Gerosa et al. (2004) [24]
	GISMO	Teacher	Mazza & Botturi (2007) [19]

Table 1. A compilation of existing tools for visualizing communications activities

GISMO visualizes behavioral and social data of students' activities on a discussion forum. Its objective is to help teachers evaluate the involvement of the students in the communication process during the course activities on a learning platform (e.g. Moodle).

Our primary observation regarding the existing tools is that most of them are exclusively dedicated to the teachers. While recent systems were explicitly developed for researchers, only a few are accessible by the students. Moreover, students are usually allowed minimal access to the tools due to their restricted user rights, as well as their roles in the learning process. As a result, students always receive less support in visualizing and analyzing their CMC activities. This is not to mention that most of the existing tools were not intentionally built to enable students to perform self-monitoring.

Other observation is relevant to the assistance of the data indicators proposed by each tool. It is worth mentioning that a communication activity consists of a variety of user interactions and contents exchanged over a CMC tool. Therefore, it needs to be described with adequate and pertinent information to help students identify the level of interactions of their communication activities. In this regards, the proposed systems must be equipped with a friendly graphic user interface (GUI) components, allowing users to manipulate the tracking data and particularly to compute graphical data indicators, which are representative and easy to view. However, some existing systems provide only the overview of users' activities and often in a unique form. Such deficiency might turn data visualization and analysis into a time consuming task and less effective.

Regarding self-monitoring from a student perspective, we are suggesting that it should start with acquiring an awareness of the activities being carried out at different levels, recognized as individual or group activities (discussed further in section III). Indeed, it would make more sense for the students to observe, assess or evaluate their own activities in relation to others.

To sum up, the study on the existing tools leads us to propose TrAVis, which is objectively designed not only for the teachers but also for the students. Plus, TrAVis is distinguished from the existing tools by its capacity in

computing substantial data indicators, allowing students to efficiently self-monitor and analyze both the process and the product of an activity (i.e. how an activity is carried out and what the output is).

III. TrAVis: Design Approach

A. Overview

TrAVis is a technological solution that enables users to directly access the tracking data repository via a Graphical User Interface, to compute the data indicators, and to visualize them in different visual forms and scales. To support student self-monitoring, TrAVis offers three tools to monitor in real time the ongoing communication activities. More particularly, TrAVis is also a "reflective tool" or in other words, a guide giving students an insight on their interactions with others, thus allowing them to make assessment of several aspects of both individual and group activities (e.g. social, cognitive, behavioral aspects). For instance, TrAVis allows the students to acquire an overview of their personal learning progress, their participation rate in social interactions, or other statistical data from their communication activities.

The development of TrAVis is guided by a number of rules that lead to an achievement of good quality engineering process in relation to the architecture design and the evolution of TrAVis for further usage. While TrAVis is an independent platform, designed to be applied to a wide range of CMC tools, it is also built upon multi-component architecture. The significant advantage of such architecture is that each component can be individually modified. Moreover, it is practical for us to be able to add extra features or new functions to improve a particular component without having to alter the whole architecture of TrAVis. Further information regarding TrAVis' architecture can be found in [43].

For the reasons of flexibility and accessibility, TrAVis is developed with Web-based technologies. Our main objective is to share TrAVis with the E-learning community, a part of which regularly seeks additional technological solutions to enhance tracking data analysis and visualization practices. On top of that, TrAVis is carefully designed to be accessible by non-computer specialists who often request technical support in using a particular tool to make use of tracking data. Thanks to Web-based technologies, the interface of TrAVis is flexible, allowing users with limited technical skills to easily

manipulate it. For example, users have choices between manually filling the visualization parameters and selecting them from a preset list. Figure 1 shows a screenshot of a visualization tool, among others, currently available to TrAVis users.

B. Proposing data indicator for self-monitoring

Having adopted a mixture of iterative and participative approaches in the design of TrAVis, several changes have been made to the latter during the progress of our research. Each version of TrAVis was built to improve the data indicators at a conceptual level, their graphical forms and their visualization techniques.

In respect of the conceptual level of data indicators, we referred to the research efforts of [44] and [45] that focused on different levels of user interactions during CMC activities in learning situation. More precisely, these research efforts distinguished the four levels of interaction – *aggregation, discussion, cooperation and collaboration*, which reflect the form or the modality of a communication activity. For instance, while the aggregation level refers to the activities of an individual user, the collaboration level refers to the collaborative activities of a small group of users. It is worth mentioning that the challenge we faced was to propose different sets of data indicators to support the analysis of each level of interaction. Accordingly, we identified at first the significant information describing the latter and how it is represented in a visual form easily interpretable by the users.

Another crucial aspect of data indicator design at the conceptual level is that every single indicator from the inferior levels can be reused in the superior levels (cf. figure 2), thus enabling TrAVis to compute additional indicators.
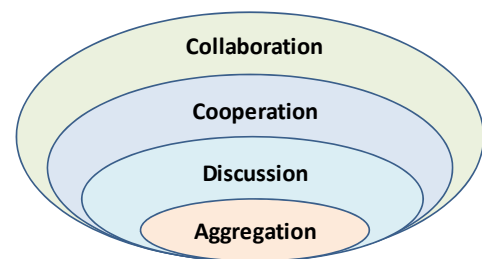

Figure 2. Four suggested levels of data indicator
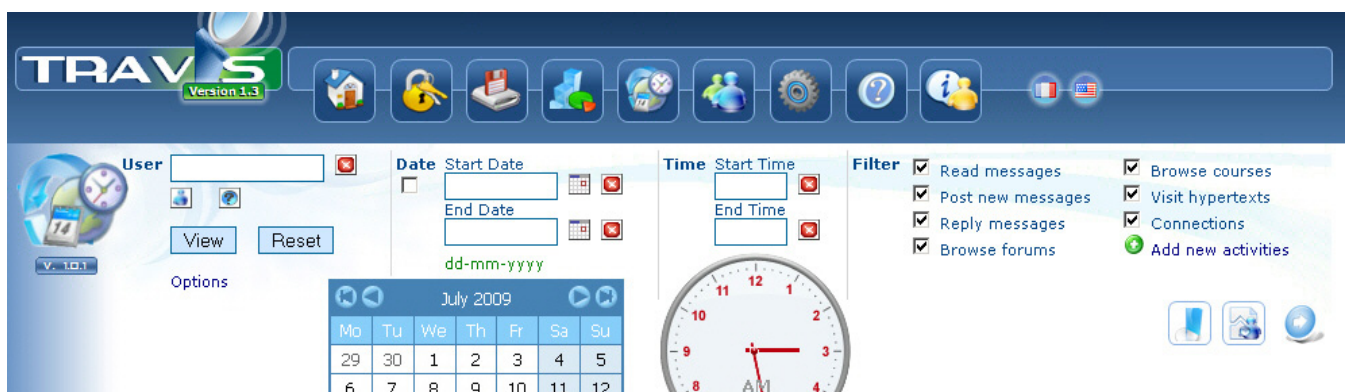

Figure 1. A screenshot of a visualization tool of TrAVis

For example, every indicator in the *aggregation* level is found in the *discussion* level and the combination of indicators from both *aggregation* and *discussion* levels are included in the cooperation level; and so on. We present in section IV.B some proposed data indicators with example of visualization.

Regarding the visualization techniques in TrAVis, our main goal is to provide users with flexibility in constructing the visual forms of the indicators. Hence, we choose to render as many indicators as possible in a form that varies from statistical data in tabular format, to synthetic information in graphical representation. Talking about flexibility, we also add visualization variables that allow the transformation of the indicators, depending on their type, from one visual form to another. For instance, the "user" variable enables indicators of an individual user, or multiple users, to be visualized either separately or together. Plus, an indicator can also be viewed with a specific date and time or even within a period of time (i.e. an interval of time). Having such flexibility in TrAVis is to provide students not only ease of control in formation visualization, but more importantly an efficient way to self-monitor.

IV. TrAVis to Enhance Self-Monitoring

In this section, we give some examples of data indicators dedicated to support self-monitoring on a discussion forum. It should be noted that discussion forum is a reference CMC tool that has been used in our case studies and experiment. Nonetheless, our research covers a variety of CMC tools, both synchronous and asynchronous.

A. Real-time monitor a student's activities

One of the three visualization tools of TrAVis is called "Time Machine" due to the technical capacity of retrieving the information from the tracking data repository and computing

data indicator on the fly. This makes it a particularly efficient tool for users who wish to observe in real-time the ongoing activities on the discussion forum.

Figure 3 illustrates the view screen of Time Machine with the list of the activities of a user (Tdelille). With this view, we can move up and down the activity list (A) and update it in order to get the most recent activities performed by Tdelille. Each activity is represented as a horizontal bar and in a unique color. When we select an activity by clicking on a bar, the detail information of the activity is displayed at the right part of the screen (B) with an "extra menu" (C), allowing us to view other activities that are related to the current activity.

In figure 3, we are viewing an activity of Tdelille while reading a message "Outils et modes de collaboration" in the forum "Scénario de communication". From that view, we choose to display who else read the same message that Tdelille is reading (D). Each sphere shown in portion (D) of figure 3 represents an activity of displaying a message and the diameter of the sphere is proportional to the time spent by each user reading the message. The distance between two spheres represents the time gap between two different readings. The color of the sphere indicates if a message has been displayed, read partially or entirely. For instance, the green sphere notifies us that the user read the message by having moved the vertical scrollbar downward to the end of the page.

Regarding self-monitoring, Time Machine supports students in navigating among the past and the current activities with or without a specific time slot. It can be used as a "User Control Panel" that enables students to access to other types of indicators. As shown in figure 4, an indicator that features the statistical data related to four other different activities on a discussion forum. Time Machine is useful for students to monitor very closely their activities and their interactions with the rest of the group. It gives a quick
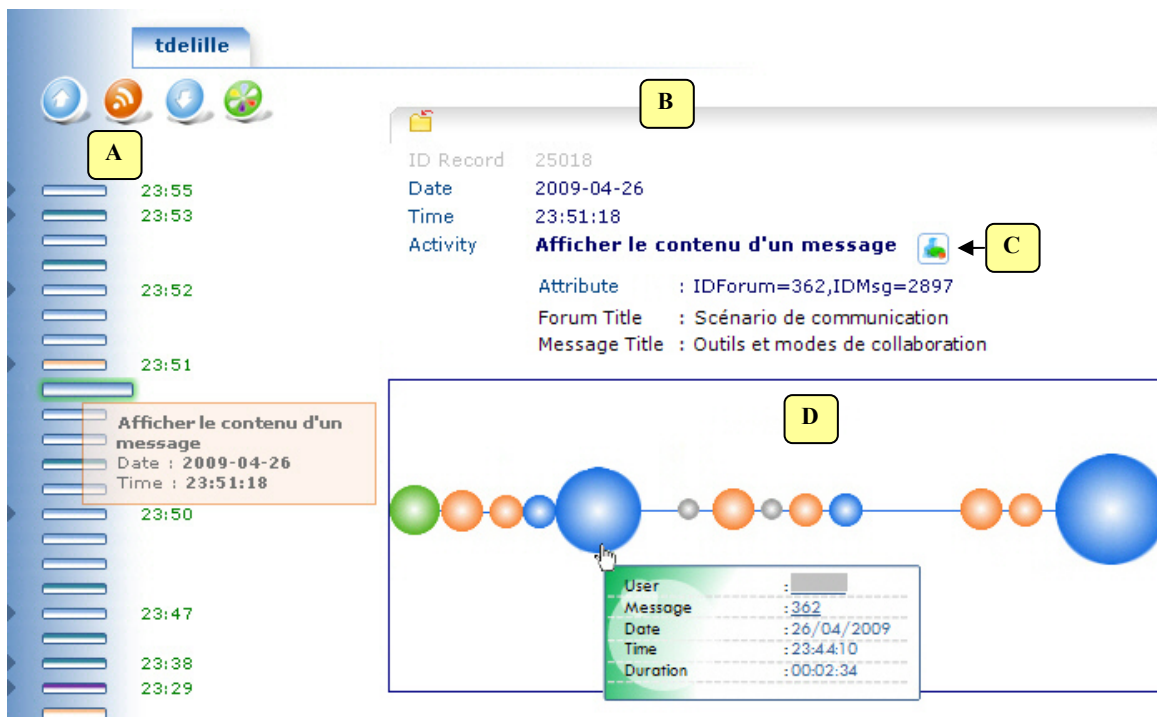

Figure 3. List of student's activities displayed on Time Machine view screen

perception of their individual ongoing activities, which also enables time-dependent analysis of several aspects in relation to their personal progress and participation in the discussion with other students.
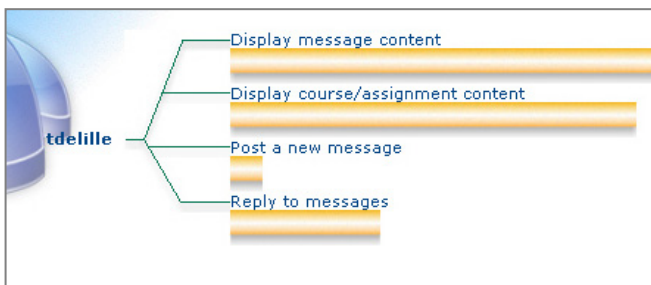

Figure 4. Overview of a student's activity on a discussion forum

B. Analyze students' levels of interaction

Earlier in section II.B, we suggested that self-monitoring can be carried through an analysis of different levels of interactions among the students. In this regard, TrAVis provides tools to compute data indictors for students to analyze their levels of interaction from an individual and a group perspective. Presented in a radar graph, each indicator can be restricted to one single user (figure 5) or extended to multiple users (figure 6).

1) Aggregation level

Figure 5 gives an example of aggregation data indicators of a user Tdelille. The five data points of the radar graph summarize the following activities: connection frequency, threads started, messages posted, message replied, and message quoted.
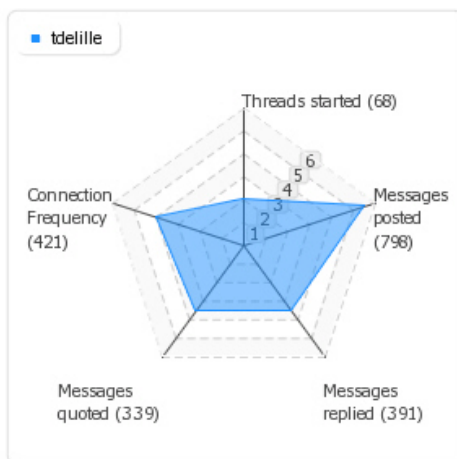

Figure 5. Data indicator for aggregation level

The spoke of radar graph is marked by a number from 1 to 6, representing the magnitude of the data points. The magnitude value is automatically calibrated according to the number of data points and their corresponding values. The numbers figured right under the label of each data point represent the quantitative data of each activity. For instance, the label "Threads started (68)" refers to the sixty-eight discussion threads started by Tdelille.

The aggregation data indicators shown in figure 5 reflect the students' activities being performed for mutual benefit. They are commonly used to describe the activities of each individual student but in the context of pooling the resources in the discussion group.

2) Discussion level

The data indicators at the discussion level refer to quantitative information regarding user interaction (e.g. number of messages posted in a discussion forum) and to the content exchanged throughout the communication activities (e.g. message content, document exchanged among users, etc.).

In practice, analyzing the discussion indicators leads to an identification of the level of social interaction and the activeness of each student in the group. For example, from figure 6, the number of forums a student participated could reflect the interest of the student in making discussions in the forums, which belong to other groups or are dedicated to other discussion topics. Meanwhile, the number of messages a student read and posted in the forum could reveal how active the student was in interacting with others.

3) Cooperation level

More interestingly, the visualization of users' communication activities is not limited to a single activity, a single user or a single group of users. Data indicators at the cooperation level feature group activity being carried out to reach a common goal. They are most useful for students to identify the part of their contribution comparing to the rest of the group.

Via figure 7 that illustrates data indicator for cooperation level, we give an example of analyzing the cooperative aspect of group activities. The analysis can be done based on a group of users' perspective where we are interested in how users cooperate with one another. To do so, we attempt to identify each user profile in relation to the rest of the group. For instance, we can observe in figure 7 that the fourth user (Tdelille) is a lot more active than other users in "almost" every aspect. Moreover, judging from the total number of postings, it appears that Tdelille is also the most significant contributor. In this way, Tdelille, in relation to the group, has a profile as the leader and who initiates most of the discussions (see indicators Thread started and New messages) as well as animates them (see indicators Quoted messages and Replied messages). As yet, the important aspect of the cooperation level can be then determined by the divergence between user profiles – e.g. the larger difference between users' activities in terms participation and contribution means the lower cooperation level among the group. Having that said, the analysis of the cooperation level can still be done in different manners according to user analysis perspective.

4) Collaboration level

Data indicators at this level focus on the product of group activity within a defined time span. Due to this condition, the analysis of collaboration level of students' activities is time-dependent and usually realized from a group of users' perspective. Figure 8 gives an example of collaboration level of two groups of students on three forums that have the same structure, dedicated to the group discussion to perform the same collaborative task. Each radar graph, filled in with a
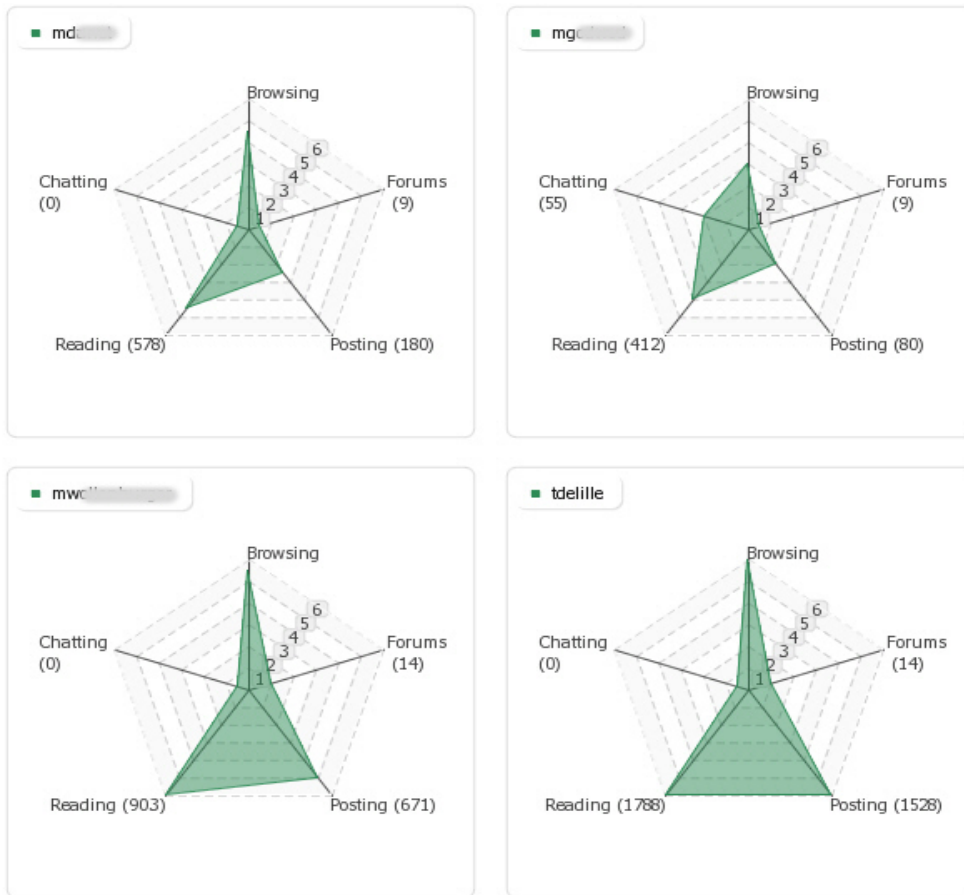
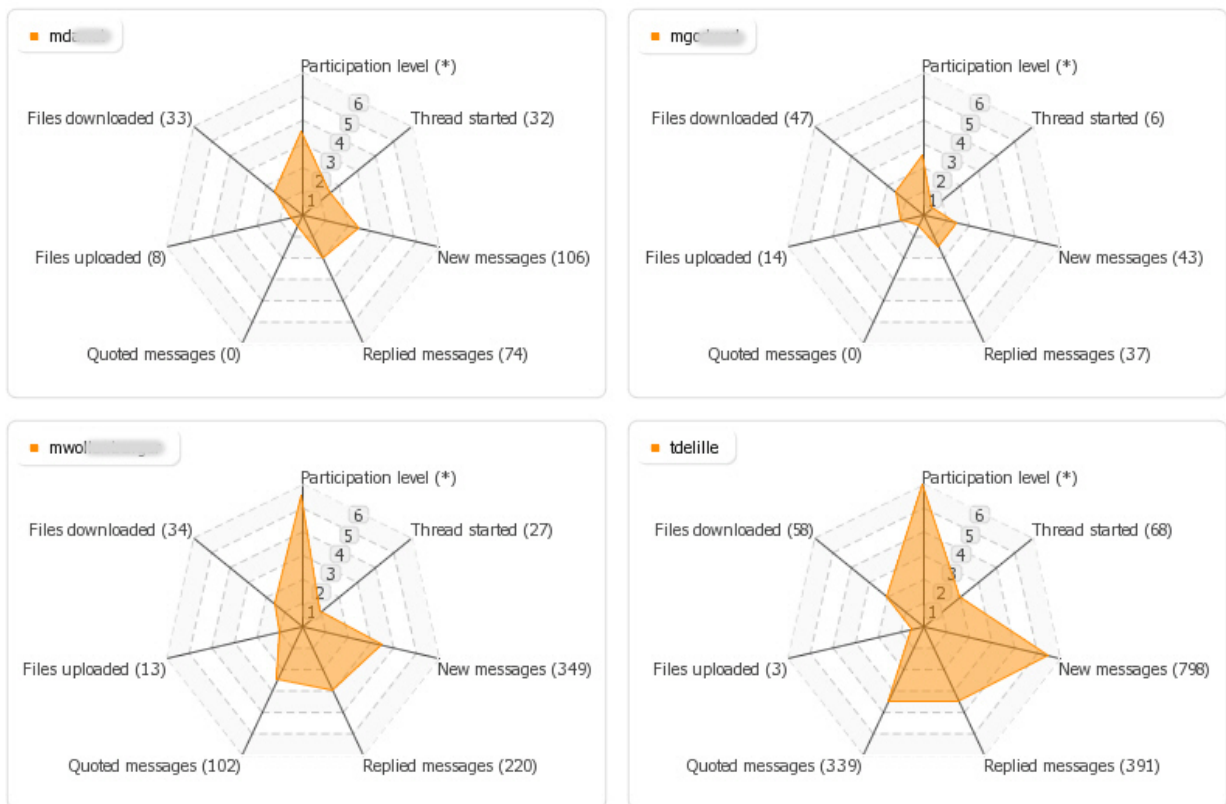**Figure 6.** Data indicator for discussion level

Figure 7. Data indicator for cooperation level

distinct color, gives a quick perception of the forum and its access frequency, number of threads, files, messages, etc.

In practice, the analysis of interactions among group discussion leads to an evaluation of various aspects of the

collaboration level of each group. For instance, figure 8 shows that group A has more intense interaction than group B in almost the three forums. Thus, it can be used to (i) compare the participation rates of both groups during the collaborative task or (ii) to evaluate the productivity rates of one group in relation to another, according to the number of messages posted or files created and shared.
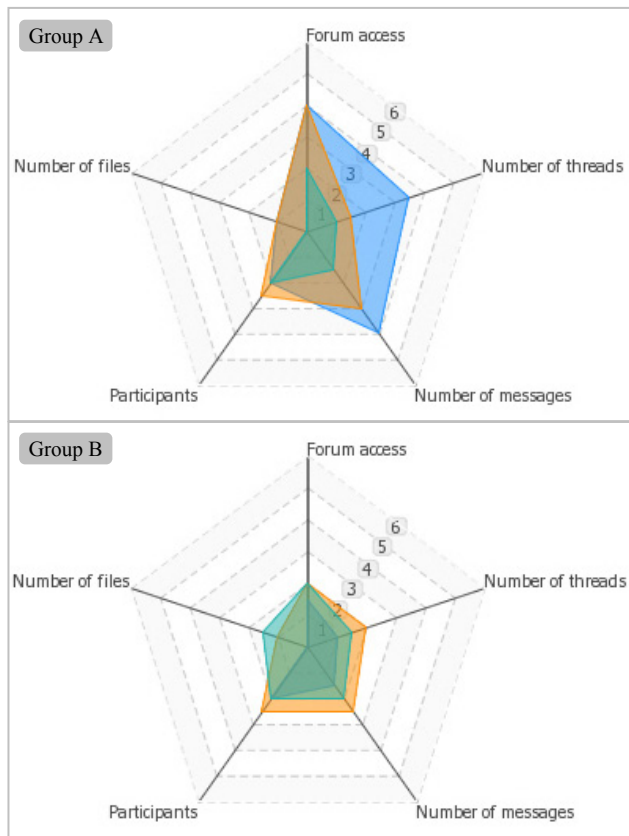

Figure 8. Data indicator for collaboration level

Thus far, we would like to emphasize that TrAVis offers means to the students to self-monitor by visualizing data indicators of CMC activities in different manners. However, the interpretation of each data indicator is still reliant on each student's personal point of view and analysis objective.

V. TrAVis in Authentic Learning Situation

A. Experiment set-up

Beside the three case studies we have conducted since 2007 [21], an experiment in an authentic learning situation with the participation of both tutors and students of FFL (French as Foreign Language) from Stendhal University of Grenoble III, has been successfully carried out in late 2009. 13 students and 3 tutors have participated in the experiment, which lasted for three months. It is worth mentioning that FFL is a two-years-professional-master course to train learners to be tutors, specialized in French language teaching.

Our experiment took place with one of the course modules, titled "Creating Pedagogical Scenario" during which the students worked together with the support of Moodle and

discussion forums to create a learning scenario for a French class. Separated into groups, the students were supervised by tutors. Each group had several learning tasks undertaken by group discussions in a collective manner – e.g. the discussion on the organization, negotiation and distribution of the tasks among the group members, etc. At the end of the course, the students were evaluated by their tutor as a group and individually. Throughout the experiment, the tutors used TrAVis to monitor the interactions between the students and to evaluate different aspects of the students' communication activities. The students, on the other hand, used TrAVis to visualize their progress in the group activities and to compare their profiles with the rest of their group members.

The main objectives of our experiment are to (i) evaluate the functional level of TrAVis from the point of view of the tutors and students, and (ii) study the impact of TrAVis in an authentic learning situation like FFL. Thus, at the end of the experiment, we used a questionnaire to study the feedbacks of the participants regarding the usability and the utility of TrAVis in the context of FFL.

B. Discussion on students' feedback

In this section, we present some data from the experiment and the result analysis of the questionnaire. First, we look at table 2, which summarizes the quantitative data of the communication activities of the three groups of students.

Number of discussion forums	28
Number of discussion threads	330
Number of messages	2804
Number of files	92

Table 2. Quantitative data of the communication activities from the experiment.

Table 2 reveals a very interesting aspect related to the intensity of the communication activities of the students. Notably, within three months, 330 discussion threads were created in 28 forums and over 2804 messages were exchanged among the students. It shows that, on average, 36 new messages were posted per day and each user posted around 215 messages throughout their learning activities.

Regarding the questionnaire of TrAVis, we received 7 responses (1 tutor and 6 students) despite several invitations we made. While statistical data from the questionnaire are interesting, users' comments are the most significant and beneficial to the qualitative analysis of the usability and utility of TrAVis.

1) Usability of TrAVis

Despite the fact that most of the students are non-specialist computer users, they find TrAVis easy to use, as mentioned in the comments below:

"The tool is very handy. I can instinctively use it from the beginning and without a user's guide."

This comment is very interesting as it points out that even without a user's guide, the student could easily operate TrAVis. From a developer standpoint, it is important for us to ensure TrAVis the most practical to the users so that they will

not have to spend time exploring how to use it, but start to exploit immediately its functionalities and services. Some other students expressed in a few words to give their appreciation on TrAVis interface design. As found in the two following quotes:

"I found the interface very cheerful and colourful. There are many buttons but they all seem to be necessary to enable the information searching at a specific point."

"The interface is very pleasant to use."

Besides the good evaluation scores and positive comments on using TrAVis, some minor difficulties were also stated as follows:

"Even if I appreciated the interface, and gave it a good score, it took me a while to understand the functionality of the project (TrAVis)."

"At the beginning, I had a little difficulty understanding the purpose of each tool."

In spite of having created a technical guide to assist the users in maneuvering different tools of TrAVis, we recognize that some practical issues might eventually occur when users get to experience TrAVis for the first time. From the experiment, we found out that the difficulties students had were commonly not related to using TrAVis, but to the unfamiliarity of the graphical data indicators and the associated analysis concepts.

2) Utility of TrAVis

In terms of evaluating the utility of TrAVis, we focus on the design approach of the proposed data indicators and their visual forms. Below, we quote some comments, reflecting how students perceived the utility of the data indicators and the impact of using TrAVis in their online learning practices. It is important to mention that some of the students have already been practicing their teaching activities alongside their FFL training courses. As yet, their comments, as presented below, describe their appreciation on TrAVis from both student and teacher standpoints.

"It allows the teacher to analyze and evaluate dynamics and practices of his students. Besides the frequency of connections, the 4 indicators (aggregation, cooperation, discussion, collaboration) allow the online tutor to evaluate the engagement and the learning motivation of each participant."

"TrAVis allows visualizing the trajectories of practices so the tutor can proceed to an instructional adjustment in a realistic situation."

"I am positive about the innovative learning approach that the use of TrAVis may imply… It gives me a whole new perspective on practice, learning, identity dynamics and motivation."

Such comments drew our attention to one crucial aspect regarding how the four levels of data indicators actually help the teachers not only to identify the different levels of interaction among the students, but mostly to evaluate the engagement and the learning motivation of each student. Another student had been a little more specific on the use of the data indicators from a student perspective.

"From the perspective of a learner, but also of a tutor, we can technically observe a group of learners and their activities on the tool (i.e. forum) as well as monitor the participation of each individual."

"When we manage a group, taking into account the participation of the group is difficult, which can be a contributing factor to the failure of the project. Therefore, a tool like TrAVis could quickly become interesting and certainly essential."

The evaluation of TrAVis also reveals some issues related to the representation of the data indicators. As expressed in the following comments, the visual forms of some data indicators cause some difficulties in the information interpretation, which obviously require the users to spend more time on the visualization.

"I would say that it is not obvious at first glance. It took me quite a while, and I need some practice and concentration to figure out what I could make use of each functionality."

"Some graphics, such as indicators for collaboration, are for me a little difficult to understand (having said that, I only spent a few minutes to visualize those indicators and I have not actually used them)."

To sum up, the evaluation we made on TrAVis turned out to be very positive. The data from the questionnaire showed good appreciation of the students on TrAVis. In fact, the students particularly appreciated the technical capacity of TrAVis in computing graphical data indicators with significant information related to the communication activity. Additionally, both students and teachers provided us with significant feedback on the issues related to TrAVis they encountered during the experiment, which are most helpful for the improvement of TrAVis in both technical and practical aspects. However, they did not provide us with information to evaluate whether or not the proposed data indicators reflect the reality of the CMC activity.

VI. Conclusions

The major contribution of the research work presented in this paper focuses on TrAVis, a technological solution to enhance self-monitoring processes. Comparing to the existing systems, two distinctive characteristics of TrAVis are the accessibility and the production of data indicators. Indeed, TrAVis is not only dedicated to users with different backgrounds and experiences in using computerized systems, but also customizable to users with limited technical skills. Furthermore, while most systems are only built for the

teachers, TrAVis is objectively designed for both teachers and students.

In regard to self-monitoring, TrAVis provides a new experience of visualizing tracking data in multiple visual forms and in different scales. Various set of data indicators are suggested to increase the ease of use in analyzing CMC activities. More importantly, they reveal an original concept of analyzing in real-time the levels of interaction (i.e. aggregation, discussion, cooperation and collaboration) of an individual or a group of students. The examples of data indicators given in section IV illustrate how TrAVis offers to students support beyond basic "information visualization", but mostly "information interpretation" from different perspectives.

The experiment we conducted has been a valuable opportunity for us to put TrAVis into an authentic learning situation. We were able to demonstrate to the participants the benefits of using TrAVis in their actual practices.

Our future work places a special focus on the improvement of TrAVis at the functional level. We are particularly interested in implementing a new tool in TrAVis, called "Editor of data indicators", to enable the users to compose new series of data indicators by using the existing ones. This means that instead of having one single indicator describing a unique CMC interaction; users can combine multiple indicators to compute new types of indicators, which are beneficial to the analysis of a large sequence of CMC interactions. From a personal standpoint, such tools can be of practical help to users, not only to customize the data indicators to match better their needs, but mostly to create visualization that serves their specific analysis. Another significant advantageous of this tool is that it allows users to perform an analysis of CMC interactions in different manners by just changing the combination of data indicators.

Conducting new case studies always helps us gain a broader perspective on how TrAVis contributes to online learning activities. We are strongly interested in investigating both the positive and negative impact of TrAVis when being used for self-monitoring enhancement. For example, we are studying whether or not, when using TrAVis, the learners change their behaviors in their group activities. We are currently working with other research colleagues from other disciplines to conduct an experiment in which TrAVis will be used to analyze more complex users' interactions. We are also expecting that the upcoming experiment will help us explore how TrAVis can really be beneficial to online teaching and learning enhancement.

Acknowledgment

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Author Biographies

Madeth May has a PhD in Computer Sciences and specializes in Technology Enhanced Learning and Serious Games. He is currently working as Assistant Professor at the department of Industrial Engineering of INSA Lyon, France. He has strong research interest in Technology Enhanced Learning, Serious Game, Human-Computer Interactions, Web Intelligence and Knowledge Management.

Sébastien George is Associate Professor in the Department of Computer Sciences, INSA Lyon (National Institute of Applied Sciences, Engineering University in France). He is a member of the LIESP Research Laboratory. He received his Doctoral Thesis from the University of Maine in France in 2001. There he designed and developed an environment dedicated to distant project-based learning. Then he did a postdoctoral fellowship at the Tele-University of Quebec in Canada. He joined INSA Lyon in 2002. He has been qualified as HDR (Habilitation thesis) in 2010, an accreditation to supervise PhD students. His major fields of interest are Human-Computer Interactions, Computer Supported Collaborative Learning, Computer Mediated Communication, Assistance to human tutoring in distance education and serious gaming.

Patrick Prévôt is Professor in the Industrial Engineering Department, INSA Lyon in France. Graduate Engineer, he has a doctorate in Science and is member of the LIESP Research Laboratory. He is the founder of Industrial Engineering Department (Engineering University) in 1992, European Journal of Automation in 1996 and a Research Team about E-learning and Serious Games building in 1995. His major interest topics are: Serious Game building, Author environment, Collaborative learning, Computer Human Interface, Cognitive psychology, Knowledge Management. He is author or co-author of fifteen serious games about Industrial Engineering.