Open platform to model and capture experimental data in Technology enhanced learning systems

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ABSTRACT

We are working in the context of our research team (multidisciplinary with numerous and various TEL systems), on the design and implementation of an open platform to collect, save and share experimental data drawn from the interaction with TEL systems as well as to build, save and share the analysis processes executed on these traces. From our point of view both data and analysis processes are worth to be stored and shared, and moreover have to be joined in a unique repository to get the whole picture. This communication presents the data part of the project.

An analysis of contemporary platforms shows the lack of solution for a repository of data joined to the analysis processes in the domain of TEL systems, and points out the limitations of current platform dedicated to TEL data. Hence a general, simple and customizable model of TEL systems interaction traces is proposed. It put emphasis on the users (learners, teachers) and allocates a reasonable weight to the pedagogical situation. This is implemented in a web platform, on one side connected to one (or several) TEL systems (via http protocol and javascript API) for the collection of the traces, and on the other side linked to pre-defined databases to save the data. Another added-value of the platform is to allow to share the data. The final part of the communication demonstrates several real use cases taken from our research team work.

1. INTRODUCTION

Early research in TEL have produced results related to models and systems to enhance learning but the data, the analyses and very often the systems couldn't be reused by others researchers. The effort to build experimental situations (ie real situations in different domains and different levels where data are collected) but also the research for replicability and the work of comparison between some equivalent models or systems show the necessity to share data, process treatments, analyses, results and benchmarks.

The rapid expansion of the use of technologies in supporting learning and the data produced by these usages allow two new research areas in TEL: learning analytic and educational data mining. In addition, classical researches propose processes to evaluate their models or systems. Like we will show in next section, in the last decade some platforms have appeared to share data. These platforms propose mainly repositories to share data and sometime some treatments. In some cases the data is linked to a learning paradigm, thus the data schema is also close to the paradigm. For example, if the platform analyses learner's knowledge, the log data has to contain knowledge evaluation. Others platforms propose to mutualise some kind of learning data but the treatments and the analysis are outside the platform. This kind of platform is useful to evaluate replicability but not to perform the comparison between equivalent models or systems.

Our objective is to mutualise experimental research in TEL System, i.e. to mutualise data but also the process to capture and analyze this kind of data. In this paper we will focus in the first part, i.e. specify and implement an open platform for modelling and capturing experimental data for TEL and will try to show how the others phases (treatment and analysis) have an influence in the choices to design these first part. In this paper, we consider the context of experimental research in TEL and therefore, in the following, data and processes are always mentioned in this context.

2. FRAMEWORK AND RELATED WORKS

This project is built in the framework of a multidisciplinary team (MeTAH[1]) who works in various scientific learning domains (mathematics, physics, biology, chemistry, medicine) and in different fields of TEL (student models, learning design, feedback models, inquired learning, didactics ...).

Traces, coming from the interaction between the users (learners but also teachers) and the systems, don't have the same schema and format. Also the process and used tools could be different [1].

As our objective is to mutualise learning and teaching traces, and their process, it is necessary to design a model to collect traces in order to obtain TEL data.

Like written by Setoutti et al [2], providing a single, common and extensible model conceptually compatible with common trace exploitation processes seems desirable. But they argue that designing common trace schema and format requires a standardized model with precise semantics and it could be too soon for TEL community to try it because it needs an agreement of semantic level.

Some platforms propose TEL schemas to share data. For example DataShop [3], which is an open repository of learning data, proposes a schema centred on learner transaction with a system, in particular intelligent tutor systems like cognitive tutors. "The DataShop logging model is represented by the following constructs: Context message: the student, problem, and session with the tutor; Tool message: represents an action in the tool performed by a student or tutor; Tutor message: represents a tutor's response to a student action" [3], p5. The DataShop web application provides several tools to assist the analysis and

[1] https://metah.imag.fr/?lang=en

visualisation of repository data. In order to take benefit from these platform functionalities (like for example calculate the learning curve) the trace has to contain in the tutor message the tutor evaluation (correct or incorrect) of the student behaviour.

The platform Mulce (MUltimodal contextualized Learner Corpus Exchange) [4] proposes also a repository. They defined a Learning & Teaching Corpus (LETEC) as a package containing the data issued from an online course, the contextual information and metadata, necessary to make these data visible, shareable and reusable. Their objective is to better describe the context of the data. Indeed, they made an effort to describe this context (users, learning domain, technology, communication language, learning scenario, interactions phenomena) and the type of the corpus (global, distinguishable, pedagogical scenarios) and the descriptions of the analyses tools used for the data corpus. These analysis tools are described but externalised.

Both authors' platforms emphasize the necessity of making connection with analysis tools.

Our project is to mutualise, in an open and flexible platform, TEL data but also tools to process and analyse it. This choice, i.e. connect data and the TEL analysis tools in the same platform, guides our choices for designing the platform and also the definition of the preliminary phases like model and capture data TEL. Also, because we are interested by various learning and teaching paradigms we would like to leave the possibility to share data and tools coming from several TEL paradigms.

3. TRACES FOR TEL

Whatever the situation, an exercise, a complex pedagogical situation, some student's resolution, the current state of a student's work, when designers define and build a TEL environment, they produce an effort to model these objects in order to save them, to retrieve them, to edit them. Very often this modelling process constitutes the backbone of the development of the TEL environment. Experimental activity traces (interaction with the learner, feedback from the TEL environment, feedback from diagnosis shown to the student, etc.) are different since explaining, recording or retrieving these traces is often not essential for the functioning of the TEL environment, and editing these traces does not seem legitimate at all. But if we want to work on those traces a modelling work is also required in order to explain, retrieve, save and study them.

Why are we interested in studying these traces? In general, the experimentations are conducted to gain a better understanding of all kind of things concerned with TEL learning situations, such as learners' or teachers' behaviours, contents to be taught, or anything about the TEL environment itself. Therefore, this design work belongs to another world than the world of the TEL environment design and is concerned by experimentations with or about the TEL environment; despite there can be some common parts. In the present case, we focus on experimental activity traces looking for interactions between the user and the software; we consider the case where the user is a learner or a teacher, the software is a TEL environment, and the global context is a pedagogical situation where everything may change with time since learning is an evolutionary process. Although each one may think of a specific TEL environment and of a specific pedagogical situation, we aim to capture the fundamental elements that characterize such traces without being too restrictive.

3.1 Traces Usage

The way the traces will be used after being collected is highly important. The processes which are foreseen for the collection and processing of traces commonly have an influence on the way traces have to be concretely modelled and recorded. Following uses are to be expected:

• The TEL environment asks for elements from the traces in order to perform immediate diagnosis and then feedback, or personalization;

• The researcher asks for elements from the traces in order to explore the knowledge domain, the TEL environment, the way the learners do learn or the teachers do assess or give feedback;

• The end user (student, teacher, institution …) get value from the recording of the history from a replay system or global statistical report.

Our use cases belong mainly to the second type, but also include research of the first usage as shown in the next section.

3.2 From traces to data: lifecycle

The data lifecycle (figure 2) is described with three main parts: data production, processing and communicating. The cycle can also be divided into seven phases since the data production step can split in two phases: preparation and collection; the data processing phase can split into 4 phases: validation, enrichment, analysis and summarization. Archiving (not showed in the figure) is transversal to the whole process that runs from production to synthesis. All phases are shown in a sequential order, from the phase of experiment preparation to the phase of results synthesis. But in most cases it is an iterative process and at any phase the experimenter may have to reconsider a previous phase. However in an ideally well designed experiment there should not be any step backward from the data processing to the preparation and collection phases. In this paper we focus on the preparation, collection and archiving phases.

In the preparation phase, an experimental protocol is designed to answer a (set of) research question(s). It defines the experimental factors and the variables to be collected. It provides their structure and format, the context and means of data collection. It also states all the data processing. It includes a test stage meant for the validation of the experimental design. At each phase of the data lifecycle, the experimental design must be amended to report about the conditions of the field experiment when the process happens to differ from the original experimental design. These additions include the report of errors and of bad field conditions.

The collection phase is performed according to the experimental design though under the field conditions. Two ways for collecting the data are considered: through the capture of TEL logs [1]; or without TEL logs, consistently with the experimental design or because of bad field recording conditions. Other types of data are also commonly collected in situ: video and audio records, photographs, screenshots, paper and electronic documents, artefacts… Some other types of data are produced a-posteriori. For example, numeric time-coded annotations are produced from in situ data following an annotation grid. Transcriptions of verbalizations following a transcription grid are also a very common type of a-posteriori data in the context of TEL studies. TEL logs may be directly captured in the platform format. All other types of data have to be transferred and stored in appropriate format. The data that are collected in situ are the raw data and must be stored and preserved in their original form. Raw data are irreplaceable and unique since they are the only remains of the learning situation that have been observed. The data produced a-posteriori must be stored along with the description of their production and control process.

The archiving phase occurs at any stage of the data lifecycle and it is meant to memorize the experimental part of the research process and all its products: research questions, experimental design, raw data, validated and enriched data, results, summarization of results … Archiving guarantees the reproducibility of the data and the results. It also allows to reuse and to share the data and the processes. The conditions and processes that lead to any data and results do not only contain the information that allows the replay of the processes. It also carries the meaning of data and results. Therefore this latter information must be explicit and it has to be reported and stored too.

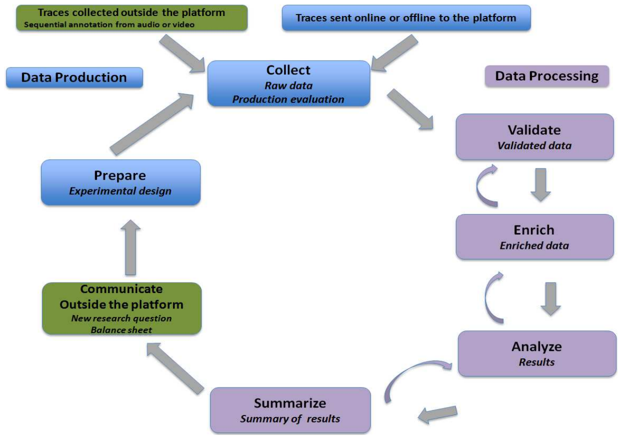

Figure 2. Data lifecycle.

3.3 Interaction traces

3.3.1 Case study

We present here briefly some TEL environments and experimental activity traces from the MeTAH team.

• Aplusix [5] is about the learning of arithmetic and beginning of algebra in secondary school. The TEL environment is based on a microworld for algebra with semantic or syntactic feedbacks and expert system commands available, different modes also exist (exercise machine, software companion). Numerous and large experimentations have been conducted in ordinary classrooms during more than 5 years. The traces were saved in local computer (with ad hoc format) they described basically the students' actions and the system feedback.

• Copex-chimie is about the learning of experimental design for chemical experiments at college and university level. The TEL environment is based on a tutor which gives help and feedback to the students with a global diagnosis of the situation. Experiments have been conducted in ordinary classrooms. The traces were archived in a server. They are organised in a SQL data base which describes basically the interaction between the system and the student as well as the evaluation of the student behaviour in some interactions.

• EDBA [6] is about the learning of algorithmic at college and university level. The TEL environment is based on a microworld for algorithmic linked with a large bank of exercises. Semantic feedbacks are available, with statistical and collaborative guidance. Experiments have been conducted in ordinary classrooms. The traces were saved online on a server in a SQL database and directly on the platform described here, see Table 1.

• Formid Suivi [7] is a tool dedicated to the teachers which allows the teacher to follow in real time the students' activities while working on a simulator. Formid Suivi uses the data coming from the interaction between the student and the simulators. These data are specified by a scenario which defines the variables the system has to trace. The TEL system offers the teacher several ways to follow the students: a set of students, one student, one problem solved by the student. Furthermore, Formid-Suivi traces the teachers' activities, for instance the teacher' level of observation and the type of students' information that the teacher looks for. The student data are saved on a server in a database while the teacher traces are saved in a local file (with ad hoc format).

• Elec+ [2] is an intelligent learning environment built in learning management system. It associates three kinds of resources [8]: the microworld TPElec[3], a simple text editor where the students propose hypotheses and physical laws and MCQ tests. The traces produced were analysed by DiagElec in order to give a knowledge diagnosis. The traces come from several sources with several schemas and formats (TPElec schema describes the circuit, the test editor is html form and MCQ are IMS-QTI standard). The system associates each interaction trace with the corresponding context data (user, problem, step ...). These traces are stored in a SQL database on a server.

• TELEOS[4] is about the learning of surgery (professional teaching of the gesture) at hospital university level. The TEL environment [9] is based on a haptic simulator, a gesture analysis system, an eye tracker and it delivers a cognitive feedback and global hints for the next activity (which exercise, lecture or clinical case). Experiments have been conducted in laboratory context. The traces come from the simulator, the haptic device and the eye tracker. They are sent to a server and stored twice first as raw data and secondly as enriched data since the eye tracker data are transformed to be more semantic. For example the enriched data informs that the user saw the vertebra when she pushed the pin. The traces are stored on a server in a SQL database.

The panorama presented above shows clearly the diversity of domains, TEL environments, student's level, mode of experimentation encountered in the field and stresses the importance of a global design and platform to model and capture data from all experimental studies conducted with TEL environments.

3.3.2 Trace and data in TEL

Activity traces exist in other domains; the most common example is "log files", web server traces of activity that are presented in the form of a sequence of lines or records, each representing a similar request/result for a web page, using the same format (figure 1):

- Origin of the request
- Date and time of the request
- Page requested
- Protocol used
- Kind of result (ok, page not found, …)
- Size of the result

[2] https:// http://testbeda0.imag.fr
[3] https://TpElec.imag.fr
[4] http://TELEOS.imag.fr

```
80.191.60.84 - - [18/Jul/2007:04:34:59 +0800] "GET /forum/archiver/tid-2135.html HTTP/1.1" 200 1682
127.0.0.1 - - [18/Jul/2007:04:35:01 +0800] "GET /whm-server-status HTTP/1.0" 200 21102
80.191.60.84 - - [18/Jul/2007:04:35:11 +0800] "GET /ss-xs/archiver/ HTTP/1.1" 404 -
80.191.60.84 - - [18/Jul/2007:04:36:38 +0800] "GET /forum/archiver/tid-781.html HTTP/1.1" 200 1870
```

Figure 1. Example of web server log lines (from apache server).

For TEL environments the overall structure of activity traces can take a similar form: a sequence of timed lines with a finite, constant, number of fields. Each line represents a significant event for the situation, related to some interaction or use of the TEL environment. This event can be either an action or a state. An action can be a software interaction initiated by the user, the activity of a conversational agent, an automatic feedback from the TEL system, ... From a general point of view, it can be any event that, from the user's or the researcher's point of view, changes the state of the situation. But it can also be the result of these actions, and then the trace is a collection of timed successive states of the TEL environment. There is a duality between actions and states. The recording of the overall state of the TEL environment in every timed line can be quite expensive. The recording of the actions is often much more economical. However, when a part of the global state is necessary, it may be associated with the recording of the action, and some specific action (or specific parameter associated with any action) can be defined for this purpose. Hence, we choose and promote as central in our log model the notion of action.

TEL environments are strongly concerned by the pedagogical situation and by the users (learner and teacher). It can be demanded that the trace integrates information about the situation and the users to each record temporally located, but it may cost a lot of space to archive it.

The pedagogical situation can be set at the TEL environment initialization or when the TEL environment or the learner performs the selection of a specific situation. In the latter case, the pedagogic situation appears as the result of an action and it can be recorded as such. However it can be useful to keep some parts or all parts of the situation characteristics in every timed line. The choice to keep the information in each record can be made on the basis of cost consideration. From a global perspective, the recording of this particular information is not strictly necessary at each moment; it is the kind of information that can be reconstituted at the global level, after a full reading of the records, with a certain cost (time) for the execution of the retrieving procedure.

The information about the user (learner or teacher) has not the same status since its place in each record is necessary: even with a complete knowledge of situated actions along the timeline, it is not possible to assign an action to an individual user; at a given moment, many users may perform similar actions on the same activity during an experiment. This leads us to introduce the learner or the teacher as a first order element in our model of the trace.

Then our model of activity traces for TEL is a sequence of timed lines, each representing an action using a unique format build out of core elements:

- Date and time of the action
- User information
- Action information
- Context (pedagogical and other) information

The context information has been introduced to offer the researcher a free space to include all kind of required context information, for instance about the learning situation or about the state of the TEL environment. This model is the basis for what follows; it was discussed at length to be finally accepted by the entire team which has several systems and several experimental research frameworks (see previous section). It is simple enough to be accessible to experimenters with little computer or database skills and it is flexible enough to cope with most TEL environments and experiments.

This model focuses on the user (learner or teacher), raising this category as a first-class object (such as time and action) in an activity trace of TEL environments. This position distinguishes traces of TEL environment from traces without TEL perspective. The educational situation does not appear at the same level as learner or teacher, partly due to common efficiency issues in database usage. However, being aware of the educational situation importance as said previously, our model set that the educational situation can be taken as the result of an action, or can be included in the context information associated with an action.

4. UnderTracks platform

4.1 Data modelling

4.1.1 Describe the experiment

First of all, the experiment has to be described: who is doing the experiment, with which TEL environment, when, where, in which domain, with whom, etc. These are the standard metadata of any experiment.

Some more information should be provided in order to cope with the open aspect of the platform for data issued from experiments with TEL environments: are these data public or not? Who can access the traces? Which part of the traces can be seen?

The experiment can be of various natures: domain centred, TEL environment centred, user centred; strictly delimited in time and on a narrow research question or without well definite start and end and aiming at a large a-posteriori analysis of usage.

4.1.2 Describe the data Log, user, context and action description

Our model chosen in the previous section needs to be put into practice concretely. The work of implementation must meet several challenges: how to cope with each TEL environments and keep enough simple and effective, how to keep openness and freeness and give the ability to add specific elements for each TEL environment, how not to fall in a solution that would be too general and would redo existing things, as phpMySql (a general platform to collect and manage data) while keeping our specificity, the domain of TEL.

It was chosen to implement a warehouse, available on the web, where each experiment would be associated with some general information about owner, date, location, ... and with a simple

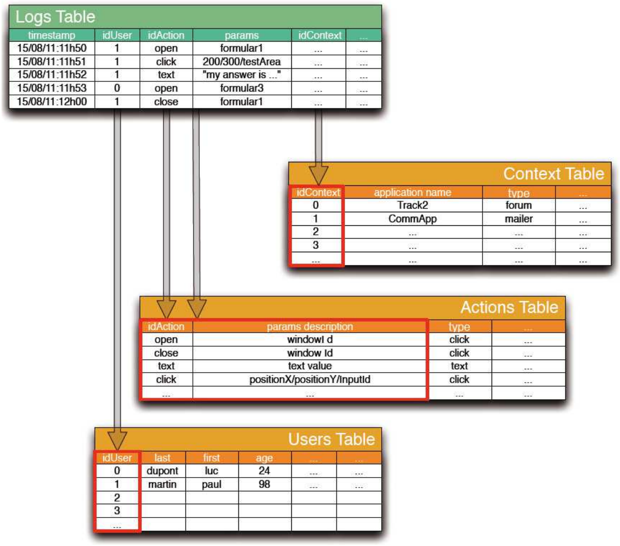

Figure 4. Structure of the database to collect the traces

database having four tables with the following structure (see Figure 4):

• A "log" table with a temporal field, a field identifying the user, a field identifying the action, a field identifying the context. In this minimal set a finite number of free fields can be added for additional dynamic parameters specific to each TEL or experiment, or for a particular purpose. This table is the main table of the device.

• A "user" table with a field identifying the user (primary key of the table, on which join can be done with the user field of the table "log"). With this minimal field can be stored free additional fields specific to each ILE to describe the user (name, class ...)

• An "action" table with a field identifying the action (primary key of the table, on which joint can be done with the action field of the table "log"). With this minimal field can be stored free additional fields specific to each ILE to describe the action (action type, format of parameters, settings ...)

• A "context" table with a field identifying the context (primary key of the table, on which joint can be done with the context field of the table "log"). With this minimal field can be stored additional static fields specific to each ILE to describe the context (pedagogical situation, current step in a scenario, knowledge component concerned ...)

Dynamic information, those which varies at each action, should be recorded in the log table. Static information, those which could be associated with a constant user, action, context, should be recorded in the user, action or context table. The distinction between dynamic and static is introduced to improve the cost of place needed for the recording and relates to the common database usage (redundant information should not be recorded each time in the log table). When information appears, the experimenter should wonder to what this information refers to, action, user or context and store it in the right table.

Also, in each table we can choose the type and the role of the different variables. For instance, when in the preparation phase an experimental design is created with some independent variables or some experimental factors, it is possible to declare, in the platform, if the variables are dependant or independent. This information could be used during the analysis phase.

4.2 Data collection

The collect of the data can be online, dynamic, during the experiment itself, or offline, after the experimental phase. The required software and functionalities are not the same.

For online collect, during the experiment, the TEL environment and the open platform must collaborate. A javascript API have been made available for the open platform so that the TEL environment could send data to the log table dynamically during the experiment via http protocol. A java API and a C++ API should be available in a near future. We are thinking about similar API for the other tables and for other types of requests (select, update) but the need for such access to the other tables is not yet clear in our context. Other types of requests introduce difficulties concerning security and privacy. Other tables are more or less static and can be accessed and modified offline.

Offline data could be uploaded to the platform in every table, from csv files (xls or xml file will be available in near future). Data can also be consulted freely or accessed via restricted password mechanism according to the public/private declaration made by the experimenter about these data.

timestamp	action	user	params
2011-10-26 19:36:27	IHM	2	lancementCommunAuChargement([object Event])
2011-10-26 19:37:20	IHM	2	montreEnBasAgranditLeHautSiNecessaire(idDivOutils)
2011-10-26 19:38:03	Test	2	4241::47340::206::gris::1::4::1
2011-10-26 19:38:15	IHM	2	montreTraces()

Table 1 : Log table for EDBA

4.3 Examples and first evaluation

Here we can give some results from our first uses with real systems.

Example 1. Table log was the only one used by EDBA (Tab. 1). The experiment is focused on the global aspect of the TEL environment (use of the different menu of the TEL environment) and on user's track (exercises attempted, success on test). An additional field has been used in the log table to describe the parameters dynamically selected for each action or result of tests. As there is no more information given in the action table associated to each action or result, the analysis of that additional field has to be done contextually (with respect to the action) by a program aware of every action or result which may occur in the log.

timestamp	iduser	action	type_action	params
12/01/10 18:58:24	733	1	connexion	acces tuteur illimite
12/01/10 18:59:04	694	3	consult_cs	/
12/01/10 19:07:24	733	5	ajout_produit	E124 /
12/01/10 19:07:24	733	8	ajout_action	5/fiole jaugée/E124/

Table 2 : Log table for Copex-Chime

timestamp	user	xp	source	action	params
1335780431571	U06	1942	eyetracker	Action_EyeTracker	350.46666666666664;1005.7333333333333;13.829574591635295;32.04718743075 9415;2523
1335780431811	U06	1942	eyetracker	Action_EyeTracker	476.10714285714283;1002.5;26.45970433535293;40.046099073697675;809
1335780431991	U06	1942	eyetracker	Action_EyeTracker	498.0;764.2857142857143;7.680681127135212;21.275644789864486;180
1335780432800	U06	1942	eyetracker	Action_EyeTracker	2;650.6;14.002384795697367;33.680855096033405;119
1335780433015	U06	1942	simulator	Repere_Cutane	157.38294;-700.0;314.25;157.38294;0.0;314.25;156.79286899072954;-241.32050799999996;384.4791463423255;156.79286899072954;120.660254;384.4791463423255;535.101996;498.37931;314.25;157.38294;120.6602….

Table 3: Log table for TELEOS

Example 2. Copex-Chimie experimentation (Tab 2) uses 3 tables: log, action and user with additional field for a better description of the type of the action (the action lead to a global category) and for parameters dynamically selected for each action. The action table gives the format of each parameter with respect to the action recorded in the log table. The information collected by Copex is semantically rich, associated with chemistry.

Example 3. Teleos experience has the log table (see Tab.3) with additional fields which inform about the source (eye tracker, simulator, haptic) and numerical parameters. The format of these parameters was described in the action table. For example, for the action "Action_EyeTracker" the parameters are X; Y; MeanRadius; MaxRadius; Duration. The raw data collected by Teleos are in part semantically poor (quite only numeric) but very numerous (eye tracks traces, haptic traces). The data on the "xp" field identify (key joint) the information of the context table. The context table describes the characteristic of the problem (kind of vertebra, devices used –haptic or not-, learning variables ...).

These three examples show different forms of use of the open data platform for different TEL environments. These constitute three proofs of our concept. In each case, the global model for the data has been met by the three environments to collect and store the traces of these research environments.

5. Discussion

The main goal for the platform is to share data as well as analysis processes. In order to be flexible, this first step (modelling and capturing traces) has been simplified with few constraints: specification of the logs based on the basic definition of traces: "trace as a sequence of observed elements". If more information is needed for envisaged treatments it is possible to describe the user (user table), give a description of the action (actions table) and describe the learning context (context table).

The proofs of concept built show that it is possible to collect different TEL data coming from different systems, different learning paradigms and also from different experimentations. Indeed it is possible to create several experimentations with the same TEL system and describe a data structure tailored to each experiment.

Our hypothesis is that the association of the data and the tools for treatment and analysis carry the sense of the process. Despite the fact that some process tools can be more adapted to a kind of data, this relationship has to be supported by the treatment and analysis processes and not by the data collection phase.

In order to help this matching, one perspective is to define some ontology of the TEL traces and of the process tools used to analyse the data. This ontology can assist the association between the data and the process tools for treatment and analysis. It could for instance support the scientific analysis of results if it carries semantic information about both the data and the process tools and check the coherence. However the use of the ontology should not be mandatory for the researcher who collects data and build a process for an analysis.

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