DIAM: Towards a Model for Describing Appropriation Processes Through the Evolution of Digital Artifacts

Amaury Belin, Yannick Prié
Université de Lyon, CNRS Université Lyon 1, LIRIS, UMR5205, F-69622
{amaury.belin,yannick.prie}@liris.cnrs.fr

ABSTRACT
Appropriation of technology is a process by which users complete the work of designers by making interactive systems functional within the frame of their situated activities. While existing theories and studies about appropriation are oriented toward the psychological or organizational dimension of this process, we propose a model to describe it through evolutions of digital artifacts and information structures. We also present a case study demonstrating how this model helps to identify particular user operations, and related digital transformations, as a part of the appropriation process. These findings open perspectives to bridge scattered theoretical approaches of appropriation around a low-level, artifact-oriented, and objective way of describing appropriation. Our model could also improve the way appropriation is taken into account in design, by bringing more focus on technical aspects of interactive systems.

Author Keywords
Appropriation of technology, design-for-appropriation, information structures.

ACM Classification Keywords
H5.2 Information interfaces and presentation (e.g., HCI): Theory and methods.

General Terms
Design, Theory, Human Factors.

INTRODUCTION
Appropriation is the global process by which people continuously integrate artifacts into their practices. Appropriation of interactive systems involves a variety of sub-processes, such as customization of tools or repurposing and reconfiguration of practices [4,16]. The appropriation process is clearly revealed when users develop workarounds to adapt a tool to their practices, or when they develop usages that were not anticipated by designers. This is all the more true for activities carried in open environments, where rapid evolutions of their practices lead users to spend as much time appropriating or re-appropriating artifacts (constructive dimension of the activity) as being directly “oriented toward the production of results” (productive dimension of the activity) [13].

It is through appropriation processes that a user completes the work of designers by making interactive systems functional within the scope of their situated activity [1]. Appropriability is an important characteristic of an interactive system, and should be thoroughly considered in design. Several studies, guidelines, models and methodologies have been developed in this regard. This body of work builds on various scientific fields, covering multiple dimensions of human activity, from sociology [1] and ethnmethodology [4] to psychology [16] and organization science [2]. Such a variety of origins reveals the complexity and richness of the notion of appropriation, and underlines the situated nature of this process; users considering various dimensions (technical, organizational, social, etc.) in order to integrate artifacts in their own particular practices [4]. These works often focus on only one theoretical dimension of appropriation, and are mostly based on case studies. Therefore, findings about the design of interactive systems are either limited by the specificities of the observed situations (difficulty to provide general and powerful statements about appropriability) or by remaining too abstract or distant from technical concerns (use in design is not straightforward). To sum up, an important gap appears between over-descriptive and theoretically scattered works on the one hand, and pragmatic designers’ needs of concepts clearly related to the system they have to design on the other hand [1,3,4,9,15].

In this paper we propose a step towards bridging this gap by bringing light to the ways digital artifacts, and related information structures, evolve as they are appropriated. For that purpose, we propose a theoretical model articulated around the notion of digital instruments, defined as a stabilized functional unit composed of customized artifacts and utilization schemes developed by a user. We show how the appropriation process could be seen as a dynamic co-construction of these two components. We propose the notion of circulations of digital structures to describe typical co-evolutions of information structures and tool customization that are observable on the artifact side, and
we show how these circulations can participate in a higher-lever appropriation process.

So as to challenge the value of our proposal, we conducted a case study of the appropriation of a software application in the context of knowledge work. Results show that data related to the evolution of artifacts allow the identification of particular moments in the activity, where customization of tools, modification in information structures, and new patterns of actions provide precise evidences of the appropriation process. These findings open perspectives for what could be called “appropriation-centered” design or evaluation.

The first section of this article is devoted to the notion of appropriation of digital artifacts and the related issues for design. The second section deals with our research objectives towards a theoretical model to map evolutions of digital structures to an appropriation process. The third and fourth sections detail our theoretical model and present a case study. The last section discusses our proposal in the context of design.

APPROPRIATION AND DESIGN

Appropriating Technology

In CSCW and HCI fields, several studies report unanticipated uses of technology, workarounds and modifications set up by user in order to make technological artifacts work in particular situations, as well as extensions of the functions initially envisioned by the designers. A generally accepted definition of appropriation is given by Dourish [4]: “Appropriation is the way in which technologies are adopted, adapted and incorporated into working practice. This might involve customisation in the traditional sense (that is, the explicit reconfiguration of the technology in order to suit local needs), but it might also simply involve making use of the technology for purposes beyond those for which it was originally designed, or to serve new ends.”

From this definition, we see that a part of the appropriation process is oriented towards the technological artifacts being appropriated. That is evident when a user adapts and customizes the artifact to meet their particular needs and constraints. But this part of appropriation can also pertain to assigning new functions to the artifact, as the user also develops associations between the artifact and a set of goals that it could help to reach [5,16]. In Instrumental Thoery [13], the part of the process of appropriation that is oriented towards the enrichment of artifacts is called instrumentalization.

Another part of the appropriation process is oriented towards the user and their practices. Making use of an artifact can constrain and lead to a re-organization of tasks, workflows or working spaces [4,12]. As they are making an artifact functional in their activities, a user also develops skills in handling the artifact, and schemes that guide their perception of a situation and organize their actions in order to reach a goal [10,13]. This sub-process of appropriation, oriented towards the user and their schemes of utilization, is called instrumentation in Instrumental Theory [13].

Appropriation processes also rely on the social and the organizational dimensions of activity. Many CSCW studies deal with how collaborative and organizational settings contribute to the appropriation of technology, such as the sharing of good practices [4], sometimes mediated by artifacts. The Adaptative Structuration Theory explains how the appropriation of artifacts could mediate the sharing of social practices, as artifacts integrate implicit social structures that are enacted by users as they use them [2,11].

Appropriation of Digital Information Structures

Studies about appropriation of technology often report workarounds developed by users to overstep differences between their conceptualizations of the information and its actual representation through digital structures. The nature of digital artifacts as a support to hold and manipulate information (e.g. use of formal language) comes with particular potentials and limits that constrain usages.

For instance, hierarchical structures are popular in information management systems, but several problems have been identified related to their usages, such as: heavy cognitive activity to decide how to classify elements and to maintain coherent structures [8]; difficulty to make hierarchical structures evolve; impossibility to put an element in different places, and impossibility to develop different views of the same set of elements for different tasks [4]. Other information structures, such as collections or free spatial arrangements, have been proposed in order to overcome these limitations but they also bring their own issues (see [8]).

Indeed, Marshall and Shipman [17] point out issues inherent to digital structures manipulation, such as the effort of formalization that they involve, leading users to prematurely execute certain tasks like “breaking information into chunks” or “characterizing content with a name or keywords”, before they have a clear idea of how they will use this information.

Another important problem is that, from the user point of view, the same information is often represented within different applications, and then within different digital structures. This adds complexity and leads users to develop procedures to manage and maintain coherence between these structures, all the while mapping them with the needs encountered amongst their different tasks [4,9].

These different findings reveal a gap between how users understand and handle their information, and how interactive systems hold and operationalize it. In order to bridge this gap, users develop specific procedures and new understandings of their information. This constitutes a part
of the appropriation process that we believe is specifically related to the digital nature of interactive systems.

Designing Digital Artifacts for Appropriation

By now it should be clear that appropriation is a topic that challenges design. As it is difficult to predict the uses that people will develop with a system, designers tend to focus on facilitating creative uses in order to make it more appropriation [15]. This leads to the topic of design-for-appropriation, for which studies and theoretical works provide guidelines.

Some of these guidelines focus on the functionalities or characteristics that a system should integrate in order to facilitate its appropriability. Salovaara [16] recommends artifacts to support the user in “finding mappings from the functionalities of the artifact to a large number of goals” by making it “ubiquitously available” and facilitating perception of the operations than can be carried with it. This last point echoes Dix’s recommendations [3] on making artifact’s functioning visible to the user, or on facilitating plugability with other artifacts. Concerning digital structures embedded within artifacts, it is recommended to leave possibilities for users to freely associate their own meaning to elements (e.g. possibility to attribute colors to folders and files in MacOS) [3], and to allow the same information to be considered through different structures [4] which can evolve over time [17].

Other recommendations concern usage sharing, which plays an important role for appropriation in workplace settings. It should be encouraged by making usages, and thus interaction with the artifact, more visible to other users [16], for instance by letting end-users contribute to documentation related to the artifact. Reification of customization parameters in a shareable form is also envisioned as a powerful solution in this perspective [3].

By listing some of these guidelines, we can see that despite their potential values, they do not provide explicit guidance about how they could be integrated into systems, taking into account technical and interactional concerns. This issue is clearly recognized, even by the authors who provide these guidelines [9,15]. An explanation given by Dourish [4] is that knowledge concerning appropriation has mainly been built on social investigations, which focus on evolution of working practices through organizational and collaborative dimensions, disregarding the precise role played by technology.

Finally, some works also provide methodological perspectives to take into account appropriation in a design process. Technology Probes [7], or RAID Framework [6] are for instance oriented towards a design practice in which the work of designers continues in collaboration with users, as they start to appropriate the technology.

TOWARDS A MODEL TO MAP APPROPRIATION WITH EVOLUTIONS OF DIGITAL ARTIFACTS

Our bibliographical study reveals a scattered set of studies and theories that shed multiple lights on appropriation of technology, exploring various dimensions of such a phenomenon. Studies focusing on appropriation of information structures report more precise findings about how digital artifacts are appropriated in particular. A first requirement of our model is to articulate these theories and findings, and to provide a broader conceptualization of the appropriation process of digital artifacts.

We think that particular evolutions of digital artifacts and information structures participate in the process of appropriation. A second essential requirement of our model is to allow for the identification and description of these evolutions. Ultimately, we should be able to associate these evolutions with high-level descriptions of the appropriation process that is recognized in existing theories. Meeting this requirement involves making relations between phenomena belonging to different time-scales and of different nature.

DIAM: DIGITAL INSTRUMENT APPROPRIATION MODEL

Here we consider the rich theoretical heritage left by constructivist theories, like Piagetian’s Genetic Epistemology and Activity Theory [10,14], and develop a model to understand appropriation processes in activity mediated by digital artifacts. Our work is especially inspired by Instrumental Theory [13,14], which had been developed by Rabardel in the lights of both aforementioned theories. This theory describes how users build instruments, i.e. how they adapt artifacts and develop related knowledge and skills to establish an effective functional unit “in the service of their goal oriented activity” (process of instrumental genesis) [5].

We believe that the notion of instrumental genesis is particularly relevant to understand appropriation, and we extend this notion by taking into account digital artifact specificities. We introduce the concept of digital instrument that we define as a functional unit composed of the various computer tools that users have configured in a particular way, the information structures they have set up across these tools and the knowledge and skills they have developed to articulate these elements in a coherent and sustainable way. As these components are inter-related, we explore the way they co-evolve, as users try to make (or to keep) their instruments effective in a dynamic environment. We particularly focus on evolutions of information structures as being the consequence (or the causes) of more global instrumental developments. By doing so we show how small changes, that are observable on the artifact side, can participate in a more global appropriation process.

Constructivist Approach to Human Mediated Activity

By exploring the development of instrumented human activity, Activity Theory provides a rich framework that helps to consider how the use of an artifact can, over time,
modify the organization of activity, as well as user skills and perception (when the function of a tool is internalized as a new psychological function). Activity Theory is our general framework. It is especially helpful to articulate different dimensions (cognitive, social, and developmental in particular) of the activity through different time-scales and levels of activity, from the slow development of a user skill to the operations they carry out in a specific situation. Activity Theory also brings the idea of functional organs [10]. Defined as a construction by the user that combines both psychological (internal) and material (external) resources, these organs form functional wholes that are highly integrated in activity, while “remaining liable to adjustment” [13]. Instrumental Theory deepen this notion by introducing the concept of instrument.

Another important inspiration for Instrumental Theory is the notion of scheme introduced in Piagetian genetic epistemology [12]. A scheme can be understood as a stabilized generalization of a useful behavior. In a specific situation, directed by a goal, a subject will mobilize a scheme to associate a functional meaning to the different elements of their environment and organize their activity in order to reach their goals (assimilation of the situation to the scheme). If a scheme provides incorrect results in some situations, the subject will make it evolve and eventually develop a new scheme over time (accommodation of the scheme to a new class of situation). Different studies and theoretical developments built on Piaget’s work deal with the development of schemes, including a phase where subjects take a reflexive posture toward their actions and consciously take part in the construction or evolution of their schemes (see [14]).

Instrumental Theory [13,14] deals with the process where a subject integrates an artifact in their practice, making it a mean to their activity, i.e. an instrument. This instrument genesis is thought of as two interdependent processes. The instrumentalization process is oriented towards the artifact, and consists in its enrichment, by customization or association of functional significations. The instrumentation process is oriented towards the subject, it pertains to the development of utilization schemes that are skills and knowledge specifically developed to make a functional use of the artifact. An instrument is then defined as a stabilized and “mixed functional unit (…) made of an artifact component” (a part of one or more artifacts), “and a scheme component” (the utilization schemes developed by the user). Utilization schemes can be oriented towards the artifact, and are, for example, related to the way to operate it (usage schemes), or towards the activity, dealing with the way a goal is reachable with the help of the artifact (instrumented action schemes). Kaptelinin [10], who studied functional organs, makes a very similar classification. In particular, he identifies operational competencies (oriented toward artifact), and task related competencies (related toward activity) as parts of functional organs.

A situation where a user can mobilize an instrument whose function is convenient to reach the targeted goal is a situation of instrumented action. But in particular situations, such an instrument does not exist, or artifacts related to an appropriate instrument are not available, and the user has to improvise a way to manage the situation. As similar situations are encountered, a user can develop an efficient way to mediate their actions with artifacts, and will progressively abstract a functional unit, i.e. creating an instrument. This user can also find a way: to employ an existing instrument so they can reach new goals (extension of the class of reachable goals with the instrument); or to replace missing artifacts by adapting an available one (extension of the class of artifact related to the instrument).

Modeling Digital Instruments and their Evolution
We think that the conceptualization provided by instrumental theory is relevant to describe appropriation of technology within an individual scope. We now introduce the DIAM model that extends this conceptualization to account for appropriation of digital artifacts.

As this model is complex, we present in a first part the different concepts underlying digital instruments at a given moment of a user activity. In a second part, we focus on how these components evolve over time, leading to evolution of the instrument, i.e. appropriation.

Components of Digital Instruments
We define a computing-artifact as a piece of software that provides users with different renderings and input mechanisms over data. As an example, we can consider a classical calendar application on a desktop computer as a computing-artifact, since it is a piece of software that displays events (data) and lets users manage them.

We propose the concept of digital instrument as an extension of the concept of instrument developed by Rabardel [13,14]. A digital instrument is a constructed and stabilized composition of one or more customized computing-artifacts on the one hand (artifact component), and different utilization schemes constructed by a user on the other hand (scheme component). As an example, Bernard, a user of the calendar computing-artifact, knows how to create an event in his calendar, or how to navigate efficiently in order to find out if he is available on a certain date. Bernard has therefore developed utilization schemes and created an instrument from the artifact.

When an instrument is used, data exist at different levels. At each of these levels data is organized within structures, defined as “the elements of an entity or the position of such elements in their relationships to each other” [17]. The organization of one structure can be related to certain constraints or logics, that we generalize as schema, defined as a “set of element types, and the conditions under which they can hold properties, values, and relationships to each other” within the structure.
If we consider the calendar application, the data (user’s events) exists at a storage level where it is encoded (storage schema) in a file on the hard drive. A computing-artifact loads this data at a computing level, which is designed and organized to compute this data efficiently (computing schema), considering the commands that the artifact should offer to the users. At the interaction level, the computing-artifact presents data to the users through an interface as an interaction structure (see Figure 1). Designers, taking into account the activity of end-users, shape a representation of user’s events and available commands to manipulate them. To do so, they use a set of graphical user interface elements, formats, metaphors, etc. that can be abstracted as an interaction schema.

At the appropriation level, we consider the way by which a user, in a specific situation, understands and manipulates the information rendered by the application. In the case of a situation of instrumented action, the user assimilates the different elements of the screen according an appropriation schema. Such a schema helps the user to articulate the digital representation of information with his understanding of the situation, especially with the situated action schemes that guide his actions and operations towards the achievement of the task at hand.

![Figure 1. Calendar graphical interface](image)

Like interaction schema, appropriation schema is a conceptualization of the elements presented in the interface, but developed by the user who associates his own significations to these elements. For instance, by examining figure 1, we can see that Bernard uses uppercase characters on events titles to note that these events are important, and a question mark to note that they are uncertain. These properties exist at the appropriation level and make sense according to the appropriation schema developed by the user within the calendar instrument. However, at the computing level, these properties are not formally taken into account, they are not defined in the computing schema of the application and therefore cannot be processed, to filter the data for instance. In this case, the user takes advantage of rewriting possibilities offered by the artifact to overload the interaction structures with a notation corresponding to his appropriation schema.

We extend the original notion of instrument by considering the artifact component through storage, computing, and interaction levels, with particular schemas that organize data at each of these levels. We also introduce appropriation schema as a new type of utilization scheme being part of a digital instrument. Appropriation schemas are particular because, even if they remain “mental representations” that cannot be objectively observed, they play a role in the organization of information structures on the digital side, and can be indirectly addressed by these structures.

**Evolutions of a Digital Instrument**

**Tensions, Circulations and Instrumental Instability**

In this section, we consider the evolutions of the different components we defined for an instrument (Figure 2). These components are data structures and schemas (for each of the levels we introduced), utilization schemes and appropriation schemas. Mismatches between two of these elements can induce a tension in a user activity. As an example, when Bernard is in the process of reorganizing his schedule, he could experience difficulties, as he won’t be able to filter his events to show only the important ones. As we explained, the “important” property doesn’t exist at the interface and computing levels, and the difference between appropriation and interaction/computing schemas leads to a tension in this situation.

A tension can lead to a circulation, defined as the subsequent conjoint evolutions of two instrument components. For example modifying a schema will lead to modifying a structure in order to make it compliant with the new version of the instrument. Figure 2 presents the different possible circulations for an instrument.

An instrument is a coherent construct made of stabilized and inter-dependent components. Changes in the activity of the user (like apparition of new goals), or update of the computing artifact, could lead to changes of one component, making the instrument unstable and potentially non-functional. The user has to transform the components of his digital instrument to make it functional and stable again. In our model, we explain this process as certain types of circulations between the components we identified.

**Circulations Related to the Productive Dimension of Activity**

Tensions and circulations between structures are related to the productive dimension of activity, i.e. directly oriented towards the product of the activity (see Figure 2). The user and the computer artifact can solve these types of tensions and operate these types of circulations without questioning the stability of the instrument. For instance, when Bernard finds out that he has a new meeting, he will use his calendar instrument and consider this new meeting through an appropriation structure, i.e. an ideal representation of the state of the interface with the new meeting, and make the actual state of the interface match with it (circulation from the appropriation structure to the interaction structure). These kinds of circulations do not relate to appropriation.
Circulations Related to Constructive Dimension of Activity

The other types of circulations relate to the constructive dimension of activity (see Figure 2), i.e. oriented towards the production of resources to better support the activity. The circulations and tensions in this dimension involve either evolutions of utilization schemes or evolutions of the computing-artifact schemas.

In our example, a user (Bernard) encounters difficulties as the capital letter notation he used to describe important events cannot be computed to provide functions like filtering. In some situations, the lack of visibility over important appointments (see Figure 1) already led Bernard to re-organize his schedule in a non-optimal way. He then tries to figure out a new way to use his calendar in order to make the instrument functional in this kind of situation. In the calendar application, Bernard has organized his events through four categories (see Figure 1), each event being associated with a unique category. This organization is part of the appropriation schema that Bernard has developed, but also of the interaction schema as the interface relies on these different categories. In order to face the problematic situations encountered thus far, Bernard decides to abandon the “capital letter” notation, and to create a new category called “important” where he will duplicate every important events (development of new schemes to systematize these operations). By doing so, Bernard will be able to get a clear view of only the important events (by displaying only events belonging to the new “important” category) and hopefully handle this kind of situation better. We see that in order to make his instrument functional in this type of situation, Bernard has modified the organization of his personal information (appropriation and interaction schema), and also developed new schemes in order to maintain this organization effective. However, a tension still remains between appropriation and computational levels, as an important event for Bernard (appropriation level) is represented as two events, scattered in two categories, in the interaction and computing structures.

We see through this example how the structures of personal data, user representation (appropriation schema), and utilization schemes co-evolve, caused by the difficulties and failures encountered with the instrument, and driven by a chain of subsequent circulations.

Table 1. The representation of digital structures and their different circulations for a digital artifact and a digital instrument.

<table>
<thead>
<tr>
<th>Circulation operated by</th>
<th>Productive dimension</th>
<th>Constructive dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>The user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The designer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The computing-artifact</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Schematic representation of digital instrument and circulations of digital structures. Arrows represent typical circulations between two types of elements.

In our example, as we mentioned before, Bernard encounters difficulties as the capital letter notation he used to describe important events cannot be computed to provide functions like filtering. In some situations, the lack of visibility over important appointments (see figure 1) already led Bernard to re-organize his schedule in a non-optimal way. He then tries to figure out a new way to use his calendar in order to make the instrument functional in this kind of situation. In the calendar application, Bernard has organized his events through four categories (see Figure 1), each event being associated with a unique category. This organization is part of the appropriation schema that Bernard has developed, but also of the interaction schema as the interface relies on these different categories. In order to face the problematic situations encountered thus far, Bernard decides to abandon the “capital letter” notation, and to create a new category called “important” where he will duplicate every important events (development of new schemes to systematize these operations). By doing so, Bernard will be able to get a clear view of only the important events (by displaying only events belonging to the new “important” category) and hopefully handle this kind of situation better. We see that in order to make his instrument functional in this type of situation, Bernard has modified the organization of his personal information (appropriation and interaction schema), and also developed new schemes in order to maintain this organization effective. However, a tension still remains between appropriation and computational levels, as an important event for Bernard (appropriation level) is represented as two events, scattered in two categories, in the interaction and computing structures.

We see through this example how the structures of personal data, user representation (appropriation schema), and utilization schemes co-evolve, caused by the difficulties and failures encountered with the instrument, and driven by a chain of subsequent circulations.

Circulations and Evolution of Instruments

We identified several types of tension and circulation types that can participate in evolutions of a digital instrument (see Figure 2). Tensions can exist between utilization schemes and appropriation schema when a user’s conceptualization is not suitable to carry out particular operations over data. Such tension can potentially lead to the modification of one of these components. As we saw in our example, tensions and circulations could also exist between appropriation and interaction schemas. Finally tensions and circulations can occur between schemas and structures (at the appropriation or interaction level) when the evolution of a structure questions a schema, or when a schema is modified and the structures need to be updated to comply with it.

Designers can also modify an artifact, which could lead to other types of circulations (dotted arrows in Figure 2). Indeed, an application update can lead to transformations of computing and interaction schemas. Effects of such transformations have to be appropriated by the user, leading to circulations from interaction and computing schemas to appropriation schema and utilization schemes.

An instrument is a “mixed functional unit” made of different interdependent components. In order to keep an instrument functional in one’s dynamic activity, a user will make these components evolve in a coherent way, which could lead, as we see in our example, to a chain of circulations by which the instrument progressively evolves. The user operates these circulations by carrying out certain actions. For example, when Bernard restructure his calendar by creating a new category and reorganizing his events, he carries out actions participating in the circulation from appropriation schema to interaction schema and to interaction structures. Our model states that these actions, and subsequent data structure evolutions, are manifestations of the appropriation process.

USER STUDY

We decided to study appropriation through observation of real-life usage, as we wanted to take into account the inherently situated dimension of said process. Our goal was to evaluate to what extent our theoretical model allows a description of real appropriation processes. We approached this process from both:
1. A user perspective by conducting interviews with subjects in order to identify developments of utilization schemes, and constitutions of appropriation schema;

2. A digital perspective by capturing users interaction traces in order to observe evolutions of information structures and manifestation of utilization schemes in the form of pattern of interaction.

Our main expectation was to see articulations between phenomena observed at these two levels, and to explain these articulations with the concept of circulation that is central in our model. For instance, we wanted to observe an evolution in the organization of data as a consequence of a new utilization scheme reported by the user.

Context
For 3 weeks, we followed the work of 7 cinema students, who tried to use a digital tool to annotate video material (Lignes de Temps\(^1\), see Figure. 3) in order to carry out movie analysis. Such context is particularly relevant, as students have never used this kind of tool before; therefore they had to appropriate it in their practices. Essentially, Ligne de Temps allows users to associate annotations to temporal segments of a movie. Each annotation has an editable title, description, tags and color, and is represented in a timeline called “a cutting”. Users can freely create cuttings and organize annotations through them. Once a set of annotations is created, the software offers several ways to explore annotated movies (e.g. play a sequence of the movie segments annotated with a certain value), or to customize the visualization of annotations in the timeline (e.g. by moving cuttings, or coloring annotations depending of their association with a tag).

We gave a 20 minutes presentation of Lignes de Temps to the students and demonstrate its potential value for movie analysis. Students showed interest in the presentation as they had never used digital tool to work on movies before and were responsive to the potential of this solution. Two groups of 3 and 4 students were formed to work on two different movies. Each group was asked to give a presentation to the class, with the help of the software, on a certain topic decided by the professor. They had 3 weeks to prepare this presentation. They didn’t receive any specific indications on how to use the software or on how to organize group work. Each student had the software installed on his or her computer. Students could exchange their files to work collaboratively within each group.

Methodology
In order to study the appropriation process, we conducted two semi-structured interviews with the students, one at the beginning of the work, before they started to use the tool, and one later. We also attended two group-work sessions where students were working together with the tool.

During the first series of interviews, subjects were interviewed in pairs. We focused on usual movie analysis practices of the students, their perception of the tool and the way they intended to use it. We tried to understand their expectation by asking them about problems they came across in their current practices. We also tried to identify new goals and tasks anticipated by the students.

The last series of interviews were individual. We asked students about the unfolding of their work, the difficulties they encountered and how they overcame them. We tried to understand the structure of their activities by identifying goals they initially tried to reach, the development of new goals, and how they mapped these goals with functions of the tool. We also tried to see if they developed typical actions or operations.

We also automatically collected user interaction traces. Basic user actions like “create an annotation”, “play the movie”, “save the project” were collected thanks to a version of Lignes de temps we had modified. Regular screen captures of the interface were also captured.

Results

First Series of Interviews
Even though they shared some abstract principles, each student had their own way of analyzing a movie. Some developed particular note-taking practices, others drew timeline-like representations of the movie, etc. In comparison with their current practices, their main expectations about this software were related to efficiency in the production of richer and more precise descriptions of the movie, and better organization of their ideas.

Explanations on how they intended to use the tool were vague, and generally appeared inspired by what they had seen during the presentation in their class. All students understood that they would have to describe the movie with annotations; two of them specifically mentioned the tagging functionality in order to carry out this description. Three students reported their intention to combine visualizations

---

\(^1\) http://www.iri.centrepompidou.fr/outils/lignes-de-temps-2
of different “groups” of annotations to see if “links would emerge”. None of them knew how these tools could ultimately help them to complete a movie analysis.

We notice that students, when considering the tool, identified interesting properties to develop functions that could help them, without knowing exactly how they could relate these potential functions to existing goals in their activity, or to issues they identified in their current practice. We can see the upcoming appropriation process as the progressive development of utilization schemes and intermediary goals to articulate possible functions of the tool with needs in the activity. In that case, our model does not really address this early state of appropriation when users can “feel the potential benefits” of a tool.

Observation of Work Group Sessions
During group work sessions, we observed students’ discussions about the tools, their project and its organization. In these discussions, students mobilized concepts presented in the software to organize information, such as cuttings or tags. These concepts appeared well-understood and facilitated discussion and task assignments amongst group members. For instance, an idea of research was referred to as the cutting they had created in order to explore this idea, and assigned to a member of the group. Here, we can see how students integrated the cutting generic structures embedded with the tool (interaction and computing schema), to develop an appropriation schema in which this concept is associated with a descriptive dimension of the movie to explore (as expected by the designer of the tool). But as the need to organize division of work emerged, the appropriation schema was enhanced and each cutting was therefore understood as being associated with a collaborator. We have here a clear example of the development of an appropriation schema that participates to the evolution of the instrument, which is enriched by a collaborative function.

Later, before their final presentation, a group of students integrated all their personal cuttings in the same file. In order to facilitate organization of this file, they prefixed the title of each cutting with the name of its author. We notice that the part of appropriation schema, developed by the students to handle collaborative dimension of their work, was reified in the interface. We can observe a circulation from appropriation schema to interaction structure, where students take advantage of rewriting possibilities of the tool to organize the interface according to a property of their appropriation schema (as this property is not taken into account by interaction or computing schema).

Others occurrences of circulations from appropriation schema to interaction structures were observed. For instance one group decided to annotate the movie collaboratively and defined a shared vocabulary of tags at the beginning of their work. During the activity, differences appeared between individual utilizations of this vocabulary, limiting analyses based on these tags. Therefore, some students had to correct several of their annotations to match the shared version. We see here how the tags vocabulary acts as an appropriation schema. Students knew they had to comply with this schema to make sure that later analyzing operations would be possible. It is interesting to see that, in accordance with our model, they naturally perceived appropriation schema as a necessary component to make the instrument functional. Based on the same observation, we observe that some users reconsidered their own appropriation schema (to match the shared version), which leads to a circulation, as tagging structure has to be updated in the tool. Consequently, these users had to perform numerous modifications on their digital material (reorganization of digital structures).

Attending these group sessions was instructive. Students’ discussions revealed parts of their appropriation schemas and their construction. We noticed that these schemas were built from concepts existing in the application on the one hand, and from constraints and needs related to the activity on the other hand. We also found examples of how users materialized their appropriation schema in the interface.

Second Series of Interviews
At the end of their works with Lignes de Temps, we interviewed each subject about their experience. Most of them had decided to use tagging functionalities to describe the cuts of the movie. This was apparently motivated by the demonstration of the tool they had in class, where tags were used to create an abstract visualization of the movie. With the idea of producing such visualizations for their work, they assimilated the utilization scheme that was demonstrated. From the beginning, this drove them to the use of tags as a main generic information structure to describe movie segments precisely. Here we see how a user can integrate a prior existing scheme, and how this scheme influences the establishment of particular interaction and appropriation schemas.

After using the tagging functionality for a part of her work, a student decided to use color to characterize annotations, because from her point of view, “annotating with tags involved putting a word on something that you’re sometime not really sure about”. We can observe how the choice of a generic structure (tags) led to an interaction schema that is not convenient for the user and her utilization schemes. This tension led the student to consider another information structure (colors), with the objective of developing more convenient utilization schemes. Here, our model helps to describe how a user is rethinking their instrument.

Students also reported that parts of their work were dedicated to repetitive actions (e.g. tagging each cut of the movie). One student explained that progressively, after a phase where she had to “get used” to the tool, discovering its little “subtleties”, she developed a “mechanism” to tag the cuts of the movie (development of usage schemes).
Later, as she started to tag the movie according to another theme, she had to change this “mechanism”. Indeed, as Lignes de Temps recompresses the video, the quality was not good enough to observe some important details. Therefore she had to check these details by using another video player, before tagging each segment of the movie. In this case, we can see an extension of the class of situation where an instrument is functional, involving an enrichment of an utilization scheme. We notice here that the instrument is then based on two applications.

Subjects were all interested in using the software again. However, they couldn’t say exactly how they would use it in the future. Even if they developed some skills with the software (such as manipulating annotation and using tags) and could sense the potential of the tool, they did not develop a clear idea about how it could generally help them in their movie analysis project. This shows that the instrument they started to develop with this software was not stable yet; it still had to evolve to reach higher-level goals involved by user activity.

Traces of Interactions
We collected interactions traces of 4 students. We noticed that 3 students spent between 8 and 12 hours actively using the application, while another one spent more that 25 hours. For each hour, between 1000 and 2000 interaction events were collected, alongside 400 screenshots of the application window. Processing, visualizing, and analyzing interactions traces was challenging given the large amount of data we had collected, and we overcame several engineering issues related to interactions traces by developing our own tools.

Timeline visualizations of user actions (e.g. in Figure 4), synchronized with screenshot sequences, helped us to distinguish certain tasks completed by the users. Displaying specific actions dedicated to these tasks allowed us to identify phases in students’ work (e.g. a user spends 20 minutes to tag a particular sequence), and helped to complete our understanding of their global activity.

We noticed that students spent most of their time in the creation of annotations and associating them to segments of the movie, and to tags. Users had different ways to complete these tasks. For instance, some created all the annotations first and associated them with tags later, others attributed tags to each annotation just after its creation. These different strategies resulted in different utilization schemes, that we were sometime able to observe as patterns of interactions. For example, figure 4 shows what we consider to be the manifestation of a scheme that a subject developed to tag annotations. We can see that the user is repeating the same sequence of actions: selection of the annotation, playing corresponding movie segment, and tagging. We notice that one occurrence of this scheme is interrupted as the user decides to save their work. We also observed what appears to be evolutions or variations of a scheme. For instance, after a while, a user who had a scheme similar to the one shown in figure 4, stopped to systematically play the part of the movie corresponding to the annotation, and just looked at the first image.

We also tried to analyze evolutions of data structures over time. Each user used between 2 and 5 cuttings to organize their annotations. During their individual work, they did not reorganize their cuttings, and we could not find an evidence of schema evolutions based on these type of structure. Users created numerous annotations. They barely used the title, description or color properties associated with these structures, whereas they spent time to define related movie segments and tags. We observed different moments where users proceeded to evolutions of their tag vocabulary. They generally seemed to reconsider this vocabulary as they were tagging an annotation that challenged it. Subsequently, they browsed and updated some of the annotations they had already treated, with the objective of complying with the new version of the vocabulary. According to our model, these actions, corresponding to a moment of reorganization in tag data structure, are a manifestation of an evolution of the appropriation schema and of a circulation towards the interaction structure.

DISCUSSION

Bridging Different Theories about Appropriation
A first requirement for the DIAM model was to bridge different theories and findings about appropriation. Our case studies shows that it was convenient to describe and understand the articulations between several phenomena usually associated with appropriation, such as tool customization, development of specific skills, workarounds, and digital structure evolutions.

Further theoretical work would be necessary to consider social and collaborative dimensions of appropriation. Our model could be extended to cover theses dimensions. Instrumental Theory states that utilization schemes are not necessarily constructed by the subject, and can exist as a prior form and be socially shared [14]. Considering utilization schemes and appropriation schemas as social construction is certainly an interesting orientation. Our case study has for instance shown that appropriation schemas could be the objects of negotiations between users. In that case, we could consider a phenomenon of circulation between the individual appropriation schemas of different
users. In turn, some processes identified in Adaptive Structuration Theory (which considers appropriation under its organizational dimension), like enactment of structure [11] could be considered as a circulation from interaction structures to appropriation schema and utilization scheme.

**Mapping Different Levels of Description**
The second requirement for our model was to map the evolutions of digital artifacts and structures with high-level descriptions of the appropriation process. The study shows that our model, and the notion of circulation in particular, were useful to identify and understand moments of the activity where students were reconsidering their practices and making information structures evolve in the tool. This intermediary level of description allows us to relate high-level appropriation processes to observable user actions and objective artifact evolutions.

**Methodology**
Our model articulates different levels of description of the appropriation process. In our case study, we collected both traces of interactions and interviews with the users to address both of these levels. Interaction traces were particularly interesting to study emergence and evolution of utilization schemes, however it was not as effective as we expected regarding the observation of circulations involving evolutions of data structures. Studies occurring over longer periods of time, as well as further methodological and engineering work, should help to take better advantage of this type of material.

Beyond the needs specifically related to our research goal, association of interviews and interaction traces proved to be complementary in order to understand users activity more precisely. This could open up interesting perspectives to better support HCI longitudinal study, and helps to explore phenomena (like appropriation) which occur over long periods of time in computer-mediated activity.

**CONCLUSION**
In this paper, we introduced DIAM, a theoretical model describing appropriation through the evolution of digital artifacts and structures. This model can support designers in precisely understanding how the components of an interactive system play a role in an appropriation process. Our work also opens up perspectives to bridge theories and findings which address the different dimensions of appropriation, by providing tools and methods to observe such a process through objective artifact evolutions.

**ACKNOWLEDGMENTS**
This research is funded by Cinecast Project (http://cinecast.fr), supported by French Ministry of Industry. We would like to thank the students of Lyon 2 University who participated in our study and their professor. We thank our co-workers P.A. Champin and A. Tabard for their support, and K. Longman and A. Westcott-Lacoursiere for their help with English.

**REFERENCES**
5. Folcher V. Appropriating artifacts as instruments: when design-for-use meets design-in-use. Interacting with Computers 15, 5 (2003), 647-663.