Abstraction of Learning Management Systems Instructional Design Semantics: a Meta-Modeling approach applied to the Moodle case-study

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Abstract. Nowadays Learning Management Systems (LMS) are not restricted to distant uses. Nevertheless, the pedagogical expressiveness of designed courses is strongly dependent on the teacher's knowledge and expertise about the targeted platform. The funded GraphiT project aims to help teachers in focusing on the specification of pedagogically sound and technically executable learning designs. To this end, we propose to support teachers by providing an LMS-specific Visual Instructional Design Language (VIDL). This paper proposes a specific LMS- centered approach for raising the pedagogical expressiveness of its implicit learning design semantics. We discussed, in accordance to the activity theory, how the LMS low-level parameterizations could be abstracted in order to build higher- level building blocks. Based on the Moodle application, we present and illustrate our approach by formalising the abstract syntax of a Moodle-dedicated VIDL.

Keywords: Instructional Design, Visual Instructional Design Language, Learning Management System, Modeling and Meta-modeling

1 Introduction

Nowadays, *Learning Management Systems* (LMS) are widely spread in academic institutions. They are not restricted to online and distant courses but are also useful during or in addition to face-to-face learning sessions [11]. Nevertheless, the results of a study we conducted with 203 teachers, put forward their heavy form-oriented human-interfaces and tools/services-oriented course design lead to reduce their uses. In order to set up complex learning activities, teachers must develop high-level skills on how to use the existing LMS: how and when managing and sequencing the available features and tools for pedagogical purposes. Such skills can be acquired through specific teacher education programs, often focusing on the features and technical aspects of the platform, but few courses deal with how to design pedagogically sound learning situations on the LMS

(specific learning design). Because of the multiple educational theories [16] and approaches, as well as the lack of tools and processes dedicated to existing LMSs, teachers develop *ad hoc* and individual learning design techniques.

In such context, it seems relevant to help teachers in focusing on pedagogical aspects and their instructional design setting-up for the specific LMS they have at their disposal. Whereas improving their know and know-how about the platforms features, a focus on the instructional design possibilities and how they can rely on the platform features should encourage individual and collective understanding about the pedagogical uses of the targeted LMS.

We on purpose propose an LMS-centered designing approach in opposition to the usual platform-independent approaches [3, 13]. The GraphiT project (funded by the French Research Agency) is based on this approach. Its main objective is to investigate Model Driven Engineering (MDE) and Domain Specific Modeling (DSM) techniques to help specifying LMS-centered graphical instructional design languages and development of dedicated editors. This paper focuses on the main challenge: raising the pedagogical expressiveness of the LMS learning design semantics by using meta-modeling techniques.

To this end, we detail in Section 2 our research context, including the presentation of the GraphiT project from a MDE and DSM perspective. The section 3 is dedicated to the presentation of our abstraction approach. We analyse users' activities on an online course according to the activity theory. We also detail the designers requirements and needs collected during interviews. We also formalise, as a metamodel, the concrete Moodle application of our approach. We explain and illustrate the 4-levels architecture we propose in Section 4 and illustrate it by a simple but representative example in Section 5. We also illustrate, in Section 5, some concrete mapping examples we tooled by using some specific DSM tools. The final conclusion sketches the next steps we are tackling to drive the elaboration of the graphical instructional design language from this abstract syntax.

2 Research Context

2.1 LMS and instructional design

LMSs development is usually based upon an educative theory rationale, or some specific pedagogical approach. For example Moodle claims a socio-constructivist pedagogy philosophy [9]. Most spread LMSs generally follow such an orientation because of the various production and communication tools provided. LMSs are the activity-centered evolution of former learning-objects-centered TEL-systems. Indeed, current LMSs provide designers with some numerous functionalities that can be used to rrealisevarious learning activities and are not restricted to give resources access to individuals.

Nevertheless, activity-centered standards like the *de facto* IMS-LD fail to integrate existing LMSs. Experiments on extending Moodle to import IMS-LD learning scenarios proved that adapting existing LMSs requires some complex

and heavy re-engineering (in particular integrating a dedicated runtime-engine) in order to overcome the limits of the platform features and semantics [7]. Educational Modeling Languages [5] fail to provide a support for operationalizing EML-conformed learning scenarios into existing LMSs. For now widely spread LMSs like Moodle still do not propose an IMS-LD compliance but a SCORM one if administrators decide to enable such import abilities to the LMS instances available to teachers-designers.

Moodle proposes its own format for importing questions into quizzes. Our idea is to generalise it to the whole instructional design aspects. Similarly to the SCORM compliance about Learning Objects, the rationale of the GraphiT project is based on the idea that LMSs should make explicit their learning design format in order to ease the import/export of learning scenarios.

2.2 Overview of the GraphiT Project From an MDE and DSM Perspective

The project main goal is to study the possibilities and limits about the pedagogical expressiveness of operationalizable languages. The project methodology consists in exploring how *Model Driven Engineering* and more particularly *Domain Specific Modeling* techniques and tools can be relevant and useful to achieve this goal.

Similar research works follow different approaches. For example the *Glue! architecture*, including the *Glue!PS* editor [3], and the CADMOS editor [13] are LMS-independent solutions offering an LMS deployment feature towards the most spread and used Moodle platform [15].They both achieve the deployment by generating a Moodle course backup with all the information, mapping their own data model concepts to Moodle data model concepts; this backup is then imported and deployed within a Moodle course using the Moodle restoration process. Such approaches result in semantics adaptations and semantics losses during their internal mappings because of the gap between the instructional design language and the specific learning design capabilities and features of the targeted LMS. Other works [1] shows that transformation models techniques from the MDE theories and tools can be useful to translate a designer-centered and LMS-independent learning scenario to a specific LMS one. Nevertheless, they also highlighted the complex transformation model to specify, the LMS metamodel to capture, the semantics losses during translation, and the requirement of an LMS- dedicated tool for embedding the scenarios into the LMS.

Our approach is different: we propose an LMS-dependent architecture that only focuses on one existing LMS in order to provide an instructional design language that will be specified and tooled according to the future mappings to realise. Our idea is to conduct the platform abstraction in accordance with the formalisation of future learning scenarios. We do not aim at extending the LMS semantics with new add-ons/plugins enriching it with more pedagogical-oriented features. Our objective is to support learning scenarios specification in conformance with the LMS semantics (its abilities as well as its limits). We also do not

aim at only providing a notation layer on top of the LMS metamodel. By extending the LMS metamodel we also extend the abstract syntax of the instructional design language and then losing the LMS-compliance format. We plan to restore it by DSM techniques (weaving and transformation models) we are currently experimenting. We aim at guarantying that learning scenarios could be fully operationalized into the LMS without semantics losses. Obviously, our approach can take advantage of this LMS-dependance but it has also the inconvenience to be restricted to one LMS and one of its versions.

A global architecture of our solution is illustrated in Figure 1. The LMS instructional design semantics has first to be identified and formalized as a domain metamodel. This metamodel drives the elaboration of an XSD schema that will be used as a format reference for the API to develop. This API will be used through an import facility available to teachers-designers in their LMS courses. It will take in charge the XML-based scenario parsing and the LMS's databases filling-up. The LMS metamodel will also act as a basis for the elaboration of the visual instructional design language. According to DSM techniques and tools (like the EMF/GMF ones for example), this language will be composed of an abstract syntax from which the graphical, tooling and mapping models will be derived. The editor will also be developed using the code-generation feature of DSM tools.

The produced scenarios have to be compliant with the initial LMS metamodel to be deployed by the API. We propose then to run two models transformations. The first one will consist of various, fine-grained transformations during design-time: it will show some LMS mappings to teachers-designers in order to help and guide them in the design process. They are endogenous transformations because source and target models will be both conformed to the instructional design metamodel. The second transformation, unique and large, will be used as an export feature (after design-time). This exogenous transformation will produce a scenario/model conformed to the LMS-metamodel.

Past works have focused on the LMS meta-model formalization [2]. We are currently focusing on the abstract syntax of the instructional design language.

2.3 Focus on the Instructional Design Abstract Syntax from a Metamodeling Perspective

The main challenge of this project is to abstract enough the LMS instructional design semantics to provide teachers with some pedagogically-sound higher design blocks. The LMS expressiveness and limits have to be overcome in order to offer teachers some instructional design mechanisms closer to their practices and needs about specifying and sequencing learning activities. Concretely, the issue is about how specifying the metamodel of the instructional design language (MM-ID) in close relation to the LMS one (MM-LMS).

To this end, we already led some experiments [14] about three different approaches: 1/ MM-ID and MM-LMS are two different metamodels without any structural relations, 2/ MM-ID and MM-LMS are the same, the ID-language is

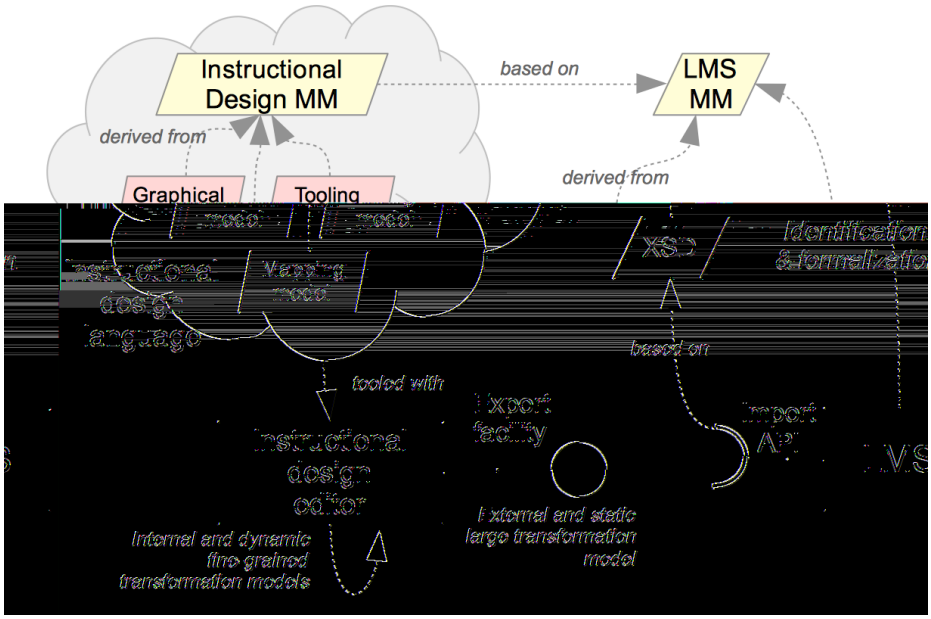

Fig. 1. Global overview of the GraphiT architecture

only built upon the graphical concrete syntax, 3/ MM-ID is an extension of MM-LMS. The first approach corresponds to the usual way to specify an instructional design language with its main advantage (expressiveness) but also inconvenience (difficulty to operationalize). The second one reveals the limits of the concrete syntax expressiveness when only defined by derivation of the abstract syntax. Finally, the third approach is intermediate on all criteria: best expressiveness / LMS compliance ratio. However, it requires a strong metamodeling expertise to reduce the developing cost while restoring the LMS compliance. This approach also highlights the importance to drive the expressiveness (and semantics) extension of the initial metamodel with the binding capacity. This paper focuses on our further results and propositions about this issue.

2.4 Analyzing LMS uses from an Activity Theory perspective

According to the activity theory [6], the activity is the minimally meaningful unit of study to consider. We can then analyze the activity of learners/tutors from the activity theory perspective. By analogy we analysed the minimal actions one can attempt to realise when accessing an LMS course. We exemplify this analysis through specific Moodle cases.

The *subject* refers to an individual (learner/tutor) or a group of individuals who are enrolled and involved in the course. The Moodle group concept is out of our scope because of our generic design approach (a scenario should

be run several times for different enrolled students). The *object* refers to material/concepts, like resources, to be transformed into *outcomes* according to the course objectives. The *instrument* can also be any Moodle tools (Moodle refers to them as activities) used to help the transformation process. The *community* is a group of learners/tutors who share the same general object. In Moodle, role refers to a collection of permissions defined for the whole system. Although they can be managed by the LMS administrators they are only useful for pedagogical purposes when learners have to participate in the design of the course themselves. Otherwise the grouping concept allows restricting specific activities and resources to specific groups of learners. It is then pedagogically interesting to declare them as communities when designing a learning scenario. Their uses also correspond to the *rules*, governing behaviors of community members within activities, as well as the *division of labor*, that is the distribution of tasks and powers between the members of the community. This division of labor relies on several Moodle concepts for sequencing (section, elements indentations (horizontal position within the section), restrict accesses, achievement conditions) and showing (visible/non-visible, restrict access information display) of courses elements.

This analysis highlights the idea that LMSs support the setting-up of activities according to the different components of the activity theory. It could be useful to help and guide teachers to think more about the design of their courses in terms of more abstract pedagogically-oriented activities instead of focusing on the technical-oriented setting-up of activities. To this end, it is relevant to consider the LMS instructional design metamodel as a basis from which an higher abstraction level could be raised.

2.5 A Practical Overview of Teachers' Requirements

Before tackling the LMS metamodel extension we first had to collect LMS-specific pedagogical needs and practices. We then conducted several theoretical, from literature sources [8], and practical studies with surveys and iterative interviews of 203 teachers and pedagogical engineers. These interviews covered a large variety of LMS use contexts: online learning, local learning within universities, full distant courses as well as blended learning. Although the GraphiT project deals with different LMSs for guarantying the reproducibility of its results, we on purpose propose to focus on the Moodle platform which is the most popular open-source Learning Management System. The analysis of these different sources aimed at collecting pedagogical practices or needs, and requirements about the languages and editors to specify and develop.

Most regrettable point highlighted is that practitioners do not really have complex practices to capture, because of the heterogeneity of their Moodle expertises and pedagogical backgrounds. Nevertheless they have in common to think about Moodle tools according to their basic pedagogical uses. Indeed, they all point the heavy parameterizations of tools and resources and the need for having an abstract view of what are the pedagogical uses in order to help and guide them in selecting and configuring the right implementation activities.

From advanced studies with pedagogical engineers we listed some specific requirements for language/editor to develop. First, they mentioned the need for the graphical authoring-tool to allow designers to select pedagogical blocks on top of the LMS semantics as well as with Moodle building blocks to compose with. In their mind, the editor will not have to strictly follow a top-down process from abstracted specification elements to implementation one expressed in terms of Moodle; abstractions from Moodle and its own concepts should be mixed up together according to practitioners' expertise about instructional design (speci cation and implementation concepts mix). Secondly, they are interesting in the idea that mappings from pedagogical design blocks to Moodle concepts can be showed to practitioners (default mapping) and adapted if required (mapping adaptation). This design approach could help practitioners in the appropriation of the pedagogical constructs and guide them in designing more abstract learning scenario while mastering the translations into LMS elements.

Another design point highlighted (declarative non-visible information) is about the possibility to design and declare within the learning scenario some information that do not required to be mapped into LMS concepts or just mentioned as non-visible labels (for students/tutors) for the teacher him-self: information about the face-to-face sessions mixed up with the LMS-centered ones, about pedagogical strategies or pedagogical objectives, about activities to realize on the LMS at a specific runtime moment according to concrete data (enrolled students, dates, etc.). Finally, another design need was to help teachers in sequencing the course in more advanced structures (choices, sequences with elements showed one-by-one according to their progress (advanced activity structures). Indeed, these can be done manually but it requires to parameterize many low-levels and technical-oriented properties (achievements, restricted access conditions...) that they would appreciate not to have to set up by themselves.

3 Formalization by Metamodeling

According to these practitioners' needs we propose to drive the abstraction of LMSs semantics by raising the LMS uses supporting learners/tutors activities. The following sections present these abstractions in relation with their formalizations for the Moodle LMS (Figure 2). We used the Ecore metamodel format because it will be handled by the EMF and GMF metamodeling tools [10] in order to drive the specification of the instructional design language and the development of its dedicated graphical tool. The metamodel from Figure 2 can be considered as the general abstract syntax of the instructional design language to be developed.

3.1 Fine-grained Pedagogical Activities as First Abstraction

The first LMS-abstract building block we propose is the pedagogical activity. We define this activity as an *abstraction of parameterizations one can realise when*

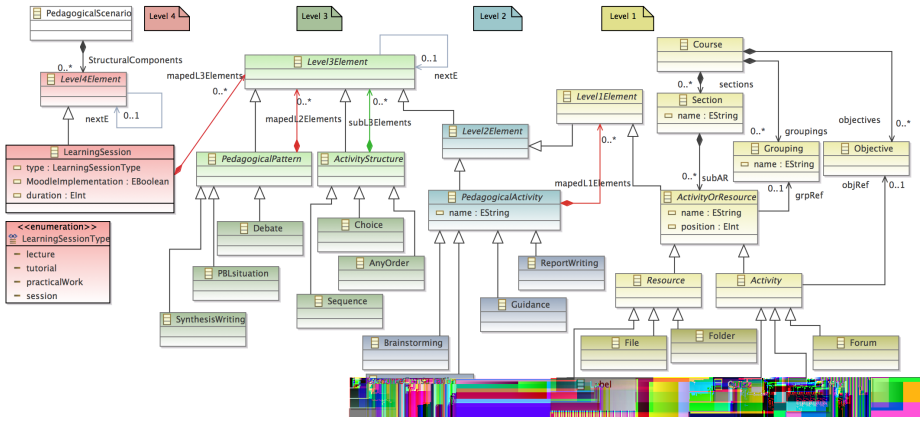

Fig. 2. The 4-levels abstract syntax of an instructional design language on top of the Moodle metamodel

using a LMS tool or resource for a specific pedagogical usage. From a single tool, for example a forum, one can design several pedagogical uses, depending on its configuration: to provide news to students, to set up group work, to propose a peer reviewing activity, etc.

Because several LMS functionalities can be used for the same pedagogical purpose, we have to find the discriminatory criteria that can guide to identify the right tool and default configuration (as well as the relations to objectives, resources, groupings, etc. that are involved in the right setting-up of the pedagogical activities).

To be used appropriately, this first abstract block requires a name, a description, and specific properties (the former discriminants), set at design-time by practitioners, that will drive the default mapping. For example an exchange activity, involving student communication, could either rely on a forum or a chat, depending on a synchronous property. The mappings will not be limited to the parameterization of a tool. For example, it will also impact some other elements in relation with the tool/resource: grades, objectives, groupings, restriction access and achievements rules, etc.

3.2 Large-grained Pedagogical Activities as Second Abstraction

The second LMS-abstract building blocks are of two kinds. We propose to adapt and integrate some pedagogical patterns and templates from literature [4, 12] for examples as high-level blocks to use and combine for building learning sessions involving instructional strategies: inquiry, problem solving, role-playing, exploration, etc. Although practitioners from our studies do not use to compose with them, we aim at integrating them to encourage some pedagogical reflections and to guide designers towards new ways to realise their didactic and pedagogical objectives. This kind of pedagogical patterns will also have a description of

their context, problem and solution uses. They will rely on a mix of structural activities, low-levels blocks (pedagogical activities) and LMS elements.

In order to ease and assist the practitioners when assembling and setting-

order to visually indicate their collective relationships. This *position* property will be used by the dynamical mappings, in order to position the corresponding elements in accordance to the source element position in the global learning scenario. The relations with a red composition indicate that the content will not be showed in the future concrete syntax (notation) as nested elements but will be shown in another sub-diagram where the parent container will play the role of the root canvas. Differently, the green composition indicates that content will be showed as nested elements of the parent container in the same diagram. Finally, the *nextE* reflexive relation allows, by inheritance, to provide a previous/next information to sequence the various elements within their dynamic pedagogical context (the ordering concerns the child elements sharing a same *Level Element* parent). The future authoring-tool will directly propose to practitioners the *level-4 elements* in the tool palette. Indeed, these elements are necessary to map to Moodle sections in order to sequentially structure the course skeleton. Sessions that do not rely on Moodle features can also be described if designers need an overall view of a global module/course larger than the ones involving the use of an LMS. Other *level-4 elements* will then open an empty sub-diagram when double-clicked. It can then be used to arrange *levels 3-to-1 elements* from the new palette. Indeed, practitioners can then choose the method (top-bottom, bottom-up), the description level (specification versus implementation) and the elements to select, combine and adapt. Except activity structures, other *levels 3-to-2 elements* can be opened up as another sub-diagram containing the default mapping to *levels 2-1 elements*. Every mapping can be adapted and modified by deleting/adding new elements (according to those accepted under the parent element) or modifying the elements properties.

The leaf meta-classes from figure 2 (dark elements) sketches some examples of future elements. They are on purpose not showing their attributes (for ease of reading). However each of them owns specific properties in accordance with the different in-progress formal specifications we are studying about the Moodle instructional design semantics, pedagogical activities and patterns, and activity structures.

The current abstract syntax proposition still has to be improved in order to allow the declaration of didactic objectives to the various *Level 4-to-1 elements*. Such objective will be mapped into Moodle *Objectives*, attached to the root *Course* and referenced by the direct or indirect corresponding *Level 1 elements*. Similarly, roles or groups have to be included in order to allow the division of labour in the learning scenario. Mappings to the Moodle concepts of *Group* and *Grouping* will be studied.

4 Illustration

4.1 A learning scenario example

We on purpose propose to illustrate our proposal by formalising a very simple but representative learning scenario for the Moodle LMS. We propose at first a brief textual description, then the equivalent specification as a model conformed

to the dedicated metamodel we proposed in section 3 (Figure 3 is a screendhot of the EMF-tree-based model editor, annotated to highlight the elements' level).

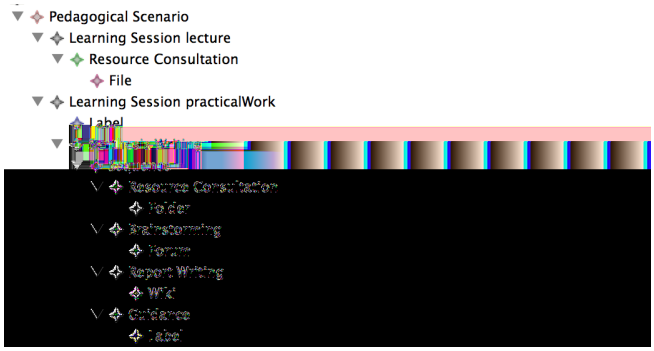

Fig. 3. Example of learning scenario composed of elements from the 4 levels.

The learning scenario is composed of two learning sessions. The first one is a *lecture* session for which the teacher only want to propose learners with a *Resource consultation* corresponding to his face-to-face course material. This pedagogical activity has the *quantity* property set to "one" and the location one set to "local". These properties will lead the dynamic mapping process to propose the *File* Moodle element.

The second learning session is a *practical work* that the teacher wants to realise in face-to-face within a computerized classroom. He would like to use the Moodle platform for supporting a pedagogical pattern "*Synthesis writing*". This pattern is automatically composed of a *sequence* activity structure embedding 4 sub-components. The first one is another *Resource consultation*. This time, the properties set to "many" (quantity) and "local" (location) by the teacher will lead the transformation process to add a *Folder* tool. The second sub-element is a *Brainstorming* pedagogical activity. Its *orientation* property set to "discussion" leads to propose a Forum tool. Similarly the third one is another pedagogical activity *Report writing* leading to a *Wiki* tool because of the *collaborative* property set to "true". Finally the fourth sub-component is a *Guidance* activity that aims at reminding the teacher to evaluate the synthesis in the wiki. Thanks to a *public* property set to "tutor" it leads the mapping process to set the corresponding *Label* to be invisible (*visible*="false") to students (it will be only visible to the teacher).

The teacher can change at any time the activities properties, leading to other mapping adaptations. He can also manually delete the mapping elements, re-arrange their order, or add some other elements. Figure 3 shows a global overview of the learning scenario elements including all the automatic mappings according to the various properties and values (not depicted within the figure).

4.2 An internal mapping example

According to our Model Driven approach, we can use model transformations to achieve such mappings. The transformations will be run on demand at design-time, to add mapped elements to the model and populate the sub-diagrams. Such transformations are complex (proportionally to the mapping complexity) and numerous, thus costly to write. We on purpose propose to use model weaving

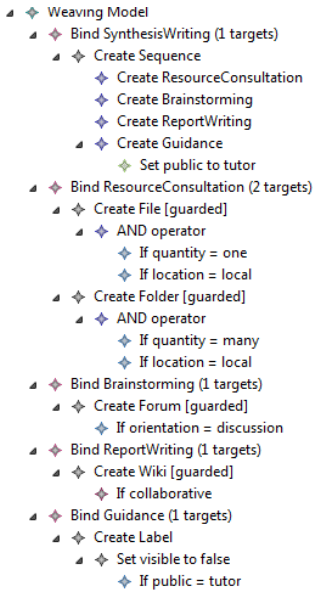

Fig. 4. Example weaving model specifying mappings from Figure 3

to capture the mapping semantics in dedicated weaving models and automatically generate models transformations. From a practical point a view, thanks to representative specifications from the teaching community, an engineer will model the mappings in a weaving model, using a tree based editor. He can then run a generic *High Order Transformation* (HOT) that will generate the concrete "mapping transformations". These final transformations can then be integrated within the graphical editor to be run at design-time.

The weaving models can be expressed using a weaving language, based on a generic weaving metamodel we designed. This weaving metamodel defines the "syntax" of the mapping/weaving model. Each mapping (or binding) has one *source* element and one or several *targets* (chosen from the extended instructional design metamodel). Targets can have conditions on whether they have to be instantiated or not, attributes can be set to specific values (also with conditions)... Figure 4 is a weaving model, displaying the mapping strategy from the example in section 4.1.

We used languages and tools from the Epsilon project to build a software framework fulfilling our model weaving requirements. Weaving models are edited through ModeLink, a three pane editor displaying the source and target metamodels in side panels (which are the same in our use case). The final "mapping" transformations are expressed using Epsilon Object Language (EOL), and are generated through a Model-to-text transformation using EGL language. This last transformation replaces the HOT traditionally used in model weaving environments.

5 Conclusions

This paper proposes a specific LMS-centered approach for raising the pedagogical expressiveness of its implicit learning design semantics. We discussed how the LMS low-level parameterizations could be abstracted in order to build higher-level building blocks. Based on the Moodle application, we present and illustrate our approach by formalising the abstract syntax of a Moodle-dedicated instructional design language following a specific 4-levels architecture. Such abstraction of LMS semantics may be a promising approach to develop a new generation of LMS-centered learning design languages, enabling teachers to develop pedagogically sound and technically executable learning designs.

The complete version of our metamodel proposition will drive the definition of the concrete syntax model (graphical notation), the palette and the mappings models in order to develop and tool the authoring-tool. Because of our former experiences about the EMF/GMF frameworks, we will also have to pay attention to the abstract syntax adjustments required in order to realise some specific visual representations.

We are also currently experimenting different frameworks about weaving and transforming models (more broadly about models composition). Indeed, the different default mappings during the design-time require a contextualised transformation model to perform. We are studying some weaving tools that will allow us to specify the mappings and automatically generate transformation rules (at design-time). First results have been illustrated within this article.

Also, in our approach the 4-levels extended metamodel will not allow to serialize future learning scenarios in conformance with the LMS format (source metamodel): a global transformation is required to restore this conformance. This transformation will be available as an export feature from our authoring-tool.

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