Investigating teachers' understanding of IMS Learning Design: Yes they can!*

Michael Derntl[1], Susanne Neumann[2], Dai Griffiths[3], and Petra Oberhuemer[2]

[1] University of Vienna, Faculty of Computer Science, Austria
michael.derntl@univie.ac.at
[2] University of Vienna, Center for Teaching and Learning, Austria
{susanne.neumann-heyer | petra.oberhuemer}@univie.ac.at
[3] University of Bolton, Institute for Educational Cybernetics, UK
dai.griffiths.1@gmail.com

Abstract. In order to understand whether conceptual obscurity is truly the reason for the slow uptake of IMS Learning Design (LD), we have initiated an investigation into teachers' understanding of IMS LD outside of technological environments. Using paper representations ("snippets") of IMS LD component and method elements at levels A and B, 21 higher education teachers from nine countries recreated a prescribed textual learning design. Results showed that the teachers achieved an average conformity of 78% with a prototypical expert solution after watching a 45-minute IMS LD introduction. Despite successfully using IMS LD's elements, teachers reported having difficulties understanding the concepts environment, property, role-part, and condition. We conclude that the specification per se does not present an insuperable obstacle for teachers, and that from a usability perspective the calls for a new or modified LD specification might be premature, since most obstacles can be overcome with appropriate abstractions in LD tools.

1 Introduction

The ICOPER project [1] is tasked with making recommendations for interoperability specifications for e-learning in Europe. In the area of learning activities a key specification is IMS Learning Design (LD) [2], as it is the only interoperability specification which supports the definition and orchestration of complex learning flows. However the adoption of the specification has been poor, and largely restricted to research projects and pilot implementations. It is therefore necessary to consider if this is due to shortcomings in the specification, to implementation issues, institutional aspects, or to other factors. This is a complex question which is discussed in greater breadth in [3], who identify four aspects to adoption of the specification, considered as a modeling language, interoperability specification, infrastructure and methodology. In this paper we focus on the first of these, and seek to separate it from the influence of the other factors.

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As a modeling language, IMS LD is intended to provide a means of defining a wide range of pedagogic strategies. Its performance in this regard has been evaluated by van Es and Koper [4], who conclude that it fulfills this requirement to a high degree. This is largely confirmed by practical experience, as few reports have been published of designs which it is not possible to represent in IMS LD. Some aspects which have been identified as being open to improvement include drawbacks in the definition of groups which are not specified in advance, and in the handling of document flows. However these are not impossible to achieve with IMS LD, but rather are tricky to implement, and it can also be argued that they are, in whole or in part, implementation issues. We therefore take as our point of departure the assumption that a lack of expressivity is not a significant barrier to the adoption of IMS LD.

However some critics—most notably [5]—have maintained that while the specification may be sufficiently expressive, it is too conceptually complex to be comprehensible and to be used in practice by authors who are not technical specialists. If true this critique would not of itself disqualify IMS LD as an effective specification, as it could still be a valuable means of transferring learning activities between systems. Nevertheless, the conceptual structure of the specification informs many of the authoring applications and runtime systems so far developed [6]. If the conceptual structure of the specification were indeed to be too complex for authors to understand then this would have implications for the way in which it can be used. Therefore we seek to answer the following questions:

1. Does the conceptual structure of IMS LD present a serious challenge for teachers to understand?
2. Which conceptual structures present the most significant challenges to teachers' understanding?

The challenge in answering these questions is to separate out the various potential causes of confusion and obscurity which could be experienced by authors. The specification is primarily intended for use by developers of authoring applications, rather than as a document which will be read and understood by authors. The *information model* [7], which contains the conceptual structure, is lengthy and formal, and this is still more true of the XML binding. Thus it is reasonable to investigate the way in which authors engage with the specification when mediated by an authoring application. However, the interfaces of authoring applications introduce usability issues which are hard to quantify. It is easy to compare two applications and conclude that one is more usable or effective than the other [8], but it is hard to assess the degree to which they transparently provide access to the conceptual structure of IMS LD. Moreover, the applications can take the modeling task out of the teachers hands, e.g. by providing templates [9] or by providing a new set of metaphors [10] and treating IMS LD simply as a file format. In this use authors may have little (or no) contact with the conceptual structure of IMS LD, and their effectiveness with the applications tells us little about the comprehensibility of IMS LD as a modeling language.

The original contribution of this paper is to directly evaluate the comprehensibility to teachers of IMS LD's conceptual structure through a evaluation activity which sidesteps the difficulties identified above. We are aware that the design of learning activities is often carried out by professional instructional designers or technical experts, but we choose to work with teachers as the most challenging case. Building on the information model of the specification we identified the key concepts which need to be assimilated in order to build a model, while missing out some of the associated detail (cf. Section 3.3). The elements of the conceptual structure of IMS LD were then represented in paper "snippets". These require the teacher to provide information which shows that they understand how the elements can be used in creating an IMS LD unit of learning.

The rest of this paper is structured as follows. In Section 2 the research design and methodology for collecting and analyzing data on teachers' use of IMS LD is set out. In Section 3, the results of quantitative and qualitative analyses are presented along with limitations and findings. Section 4 concludes the paper and discusses the findings in the light of current developments around IMS LD. Note that the core parts of this paper require solid knowledge of the IMS LD specification. IMS LD novices are kindly referred to an excellent general introduction openly available in [11], and to the full specification of the IMS LD information model in [7].

2 Research Design and Methodology

2.1 Data Collection and Participants

The data were collected in two workshops with an identical setup. One workshop was held in late 2009 in Kaunas, Lithuania ($N_K = 12$) and a second workshop was held in early 2010 in Vienna, Austria ($N_V = 9$), for a total of $N = 21$ participants. In Kaunas, all participants came from the Baltic States or Russia, while in Vienna the participants came from Austria, France, Sweden, Estonia, Germany, Slovakia, and the United Kingdom. Participants' background data were collected through a survey at the beginning of the workshops.

The average teaching experience is 9.9 years, so participants may generally be characterized as experienced teachers. The range of subject areas in which participants are teaching was quite diverse. However, most participants had a rather technical background: 16 of the 21 participants provided one or more subject areas with a technology focus, e.g. computer science, information (communication) technology, or engineering (see a word cloud of the provided teaching areas in Fig. 1). The vast majority (81%) of participants were teaching in the higher education sector, with a few occurrences of secondary, primary and other educational sectors (e.g. vocational training). Fig. 2 shows that only five of the 21 participants had previous experience with IMS LD authoring tools, with only two of them having seen an IMS LD unit of learning running in a player. That is, three out of four participants have never "done" anything with IMS LD.

2.2 Workshop Setup

Each workshop started with a demonstration of IMS LD. The objective of the demonstration was on the one hand to acquaint participants with IMS LD at

Fig. 1. Word cloud of participants' teaching backgrounds.

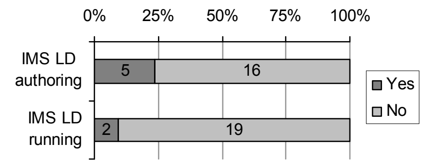

Fig. 2. Participants' previous experience with IMS LD.

levels A and B, and on the other hand to provide guidance for the following hands-on design task. The demonstration took the form of a 45-minute presentation with PowerPoint slides including (1) a brief general introduction to IMS LD, (2) a demonstration of IMS LD components and method elements based on a simple, one-role example that required the use of all IMS LD level A and B elements, and (3) guidelines for using the paper snippets in the design task.

After the demonstration, every participant had the task of transferring the learning scenario shown below in italics into representations of IMS LD elements without any assistance. The scenario was more complex than the example shown during the demonstration, so that participants would have to perform more than a simple transfer of identical concepts from the example to the task.

> *The following scenario is an online learning scenario. The instructor gives a presentation to learners via a presentation conferencing service about coal-burning power plants as well as their positive and negative side effects. After the presentation, learners can choose to do one of the two following activities:*
> 1. *set up controversial questions regarding coal-burning power plants (to be used during a later discussion round), or*
> 2. *collect credible sources on the World Wide Web regarding new developments in coal-burning power plants (to be used during a later discussion round).*
>
> *The outputs learners created in the previous activities will be used during the subsequent discussion activity: The learners engage together with the instructor in the discussion using the questions and materials. After the discussion, learners rate their own agreement with the statement "Coal-burning power plants have a future in Europe's energy production" (scale of 5, where 5 is the highest agreement). Learners, who rated themselves with a level of at least 3, will next do an activity involving the creation of a (digital) poster on one positive aspect of coal-burning power plants. Learners, who rated themselves at a level of 2 or lower, will next create a (digital) poster on one negative aspect of coal-burning power plants.*

Every participant received an envelope with paper snippets, each representing one instance of an IMS LD level A or B element (see Fig. 3). Each paper snippet is divided into boxes which represent information about the element. Participants were told that those boxes with a bold, all-capitals label must be filled out, whereas those boxes labeled with a plain text format are optional. The snippets with their information boxes were designed as an immediate, slightly simplified representation of the IMS LD elements as specified in the IMS LD Information Model [7]. For instance, plays were not considered in the method, only one type of property was offered to be used as needed, and there were no self-contained items for activity descriptions, learning objects, and service instructions.

Each element had its own unique color. In order to guide participants in placing connections between elements (e.g. link an environment to an activity), the reference box of the snippet was colored with the color that represents the target element (e.g. the "environments to display" box on the activity snippet is colored with the signature color of the environment snippet, since it should reference an environment's ID). Each act was represented as a letter-size sheet of paper. The assignment of a role-part to a particular act was achieved by sticking a role-part snippet onto the sheet representing the act with provided paper glue or tape. Participants had to number the acts consecutively. Conditions were also to be glued onto the act sheets to simplify the workshop setup, although we are aware that in IMS LD conditions are captured as part of the IMS LD method.

During the task, participants had several "cheat sheets" available. One cheat sheet showed the conversion to IMS LD elements for the sample learning scenario used in the IMS LD demonstration. Another sheet offered a tabular overview of IMS LD elements (snippets) including a description and a use example for each element. This information (snippet description and use example) was also printed on the back side of each snippet, e.g. the back side of the *role* snippet

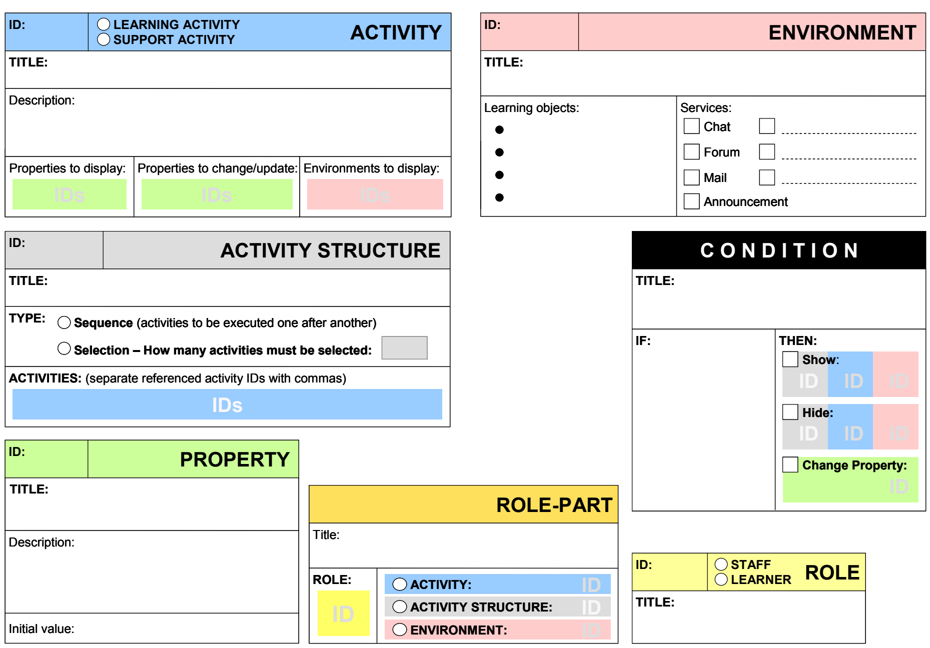

Fig. 3. Paper snippets representing the IMS LD components and method elements.

read, “A role expresses the function that a person carries out in a learning design. Example: Learners can take the roles of moderator, group member, or learner.”

Participants were not offered any help or guidance during the task other than personal answers to questions for clarification. They were thus asked to keep a task protocol by writing down any issue, problem or question they encountered during the task on a protocol sheet. They were also asked to indicate for each identified issue whether or not they were able to solve this issue on their own.

After the design task was completed participants were asked to fill out a survey, which aimed to collect information about what gave participants the most trouble in completing the task. The purpose of the post-task survey was to complement the task solutions with additional qualitative information about participants’ problems and perceptions of IMS LD.

2.3 Data Analysis

Two IMS LD experts created a prototype solution for the design task. This solution was decomposed into 81 solution parts by specifying a checklist of actions that needed to be performed to obtain the solution. For example, the checklist for the activity structure where material for the discussion is to be collected includes the action items: create activity structure, define type (selection of one activity), and link activities (two activities to choose from). The two experts independently analyzed all participants’ solutions and matched them with the prototype solution by assigning a correct/incorrect flag for each item on the checklist. For 21 solutions with 81 checklist items each, the experts had to make a total of 1,701 judgments each. The two experts independently agreed on 1,617 (95%) of these judgments. The interrater reliability as calculated using Cohen’s Kappa is very high ($\kappa = .87$, $p < .001$). The 84 judgments, on which the experts had disagreed, were reconciled and the decisions recorded in a protocol.

The resulting solution checklist data were analyzed using the layered model depicted in Fig. 4. The left-most layer comprises the IMS LD element instances required for completing the task solution. These element instances are connected with general actions to be performed with IMS LD elements at the IMS LD Action Layer. Essentially, each connection between these two layers refers to one item on the solution checklist. During the creation of this model, some actions that appeared on the original checklist were removed, added, or merged with the objectives of (1) improving focus on solution-relevant actions, and (2) simplifying the model. Of the 81 original checklist items, 60 “survived” this cleanup. Each action on the IMS LD Action Layer was assigned a level (A or B), and 18 of the 20 actions were connected with their corresponding IMS LD elements at the IMS LD Element Layer. While most of these connections are trivial, only the use of input to and output from activities were not linked to one specific element, since the linkage can—depending on the context of the action—relate to activities, environments and properties. The actions on the IMS LD Action Layer were also used to identify the performance of participants on IMS LD levels A and B. The elements on the IMS LD Element Layer were used to analyze the performance of participants in regard to the different IMS LD elements. Based on

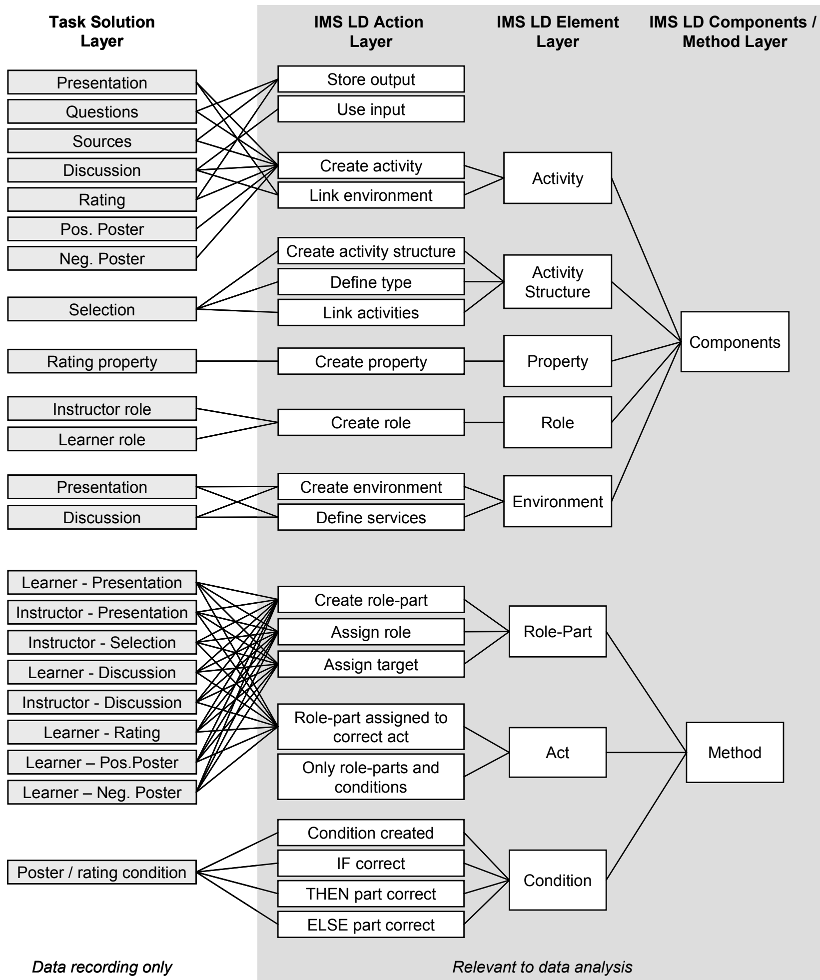

Fig. 4. Layers of data analysis and connections between the layers (solid lines).

these data, it is also possible to separately analyze the correct use of component elements and method elements. Finally, the actions at the IMS LD Action Layer were used to calculate the overall correctness of participants' solutions.

3 Results and Discussion

3.1 Quantitative Results

This section presents quantitative data analysis results and figures according to the layered data analysis structure presented in Fig. 4.

IMS LD Action Layer. The results of the IMS LD Action Layer (cp. Fig. 5) show that participants' solutions had a generally high conformity with the prototype solution created by IMS LD experts. Some actions in this layer depend on others. For instance, an environment can only be linked to an activity, if the activity was created first. These dependent actions (marked with an asterisk in Fig. 5) were only included in the analysis of a participant's solution if the participant had created the underlying element.

The percentage of conformity varies between 95% and 67%, whereby only 2 out of 20 actions realized less than 70% conformity. The actions "create [element]" rank on average among the highest actions that were successfully resolved. Participants were thus able to perform the most essential step of unit of learning authoring: They could recognize when an element needed to be created to represent a portion of the learning scenario, and for most of the elements they could adequately define this element with necessary parameters or descriptions. Role-parts were the element whose creation caused participants the most trouble. There may be several factors contributing to this. First, creating role-parts and gluing them onto the (correct) act sheets was presumably for most participants

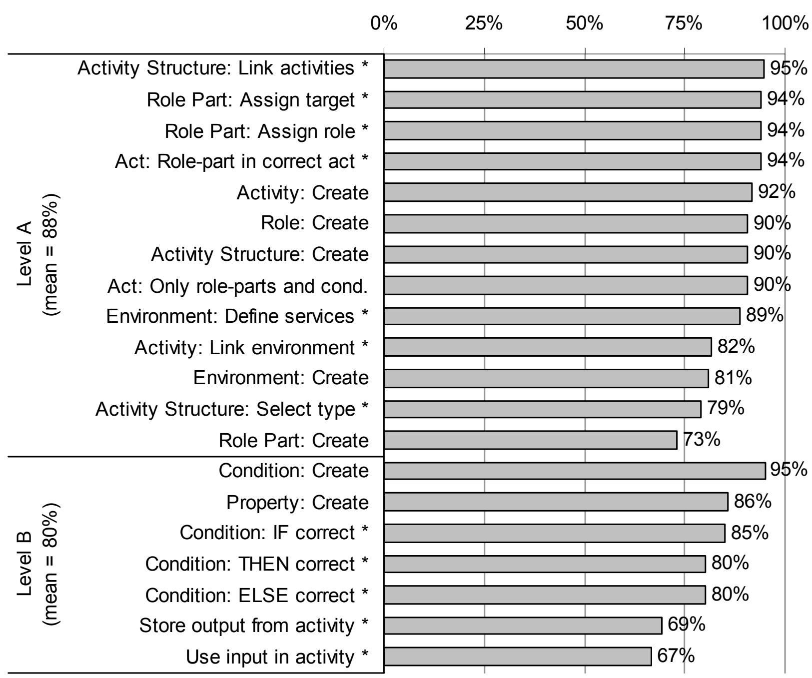

Fig. 5. Participants' solutions' conformity with the experts' prototype solution at the IMS LD Action Layer. Legend: The value 92% for "Activity: Create" means that on average each participant created 92% of the activities of the correct prototype solution. Dependent actions are marked with an asterisk (*); these actions could only be performed when the underlying element was created.

the final phase of authoring, and some of them may already have run into time constraints. Also, role-parts are complex elements since each role-part needs to be connected to one role and one target activity, activity structure, or environment. From a cognitive viewpoint, this is probably the most demanding element. However, once created, people were obviously easily able to assign a target and a role, and put the role-part into the correct act (94% average conformity each).

Fig. 5 shows that there are 8 percentage points difference between conformity scores of actions at level A (88% average conformity) and level B (80% average conformity). A significant share of this difference is accounted for by the level B actions related to activities, namely considering input to activities (67% average conformity) and output from activities (69% average conformity) using properties. In the task scenario this was the case, for instance, when students were to produce materials, and these materials were to be used during a subsequent discussion activity as demonstrated in the task description. Other than that, the use of level B elements added little to the task's complexity.

A separate view on the same data with focus just on IMS LD beginners (i.e. those 16 participants who have not had any previous experience with IMS LD authoring or playing) reveals little difference between beginners and the overall group. In fact, for most actions the results are almost identical (only $1-3$ percentage points difference). Actions where beginners perform worse by more than 5 percentage points are: selecting the correct type of activity structure (-8 percentage points), correct use of THEN and ELSE parts in conditions (-7 percentage points each), as well as creating environments and linking environments to activities (-6 percentage points each). The average difference of conformity between the overall group and the beginners is 3 percentage points. It seems safe to claim that beginners did not perform considerably worse on the IMS LD Action Layer, and, since this layer is the primary determinant of the scores on all subsequent layers, for IMS LD in general.

IMS LD Element Layer. Moving on to the IMS LD Element Layer, we averaged the conformity percentages of all actions at the IMS LD Action Layer that map to a particular element. This way, we obtained data on participants' success to use IMS LD elements. The data is represented in Fig. 6. All percentages are at a rather high level, with the most "difficult" elements being conditions and environments (85% average conformity each) and the "easiest" one being the act (92% average conformity). Since the difference between those two is only 7 percentage points, it seems valid to state that participants performed well with all level A and B elements.

IMS LD Components/Method Layer. IMS LD conceptually distinguishes elements belonging to the components part (i.e. activity, activity structure, environment, role, and property) or to the method part (i.e. role-part, condition, and act). While the component elements are frequently used concepts in several approaches to educational modeling and design, the method section is particular to IMS LD since it follows the metaphor of stage plays, where actors perform their role-parts in several consecutive acts. The average conformity scores for elements in the components and method sections are almost identical (87% and

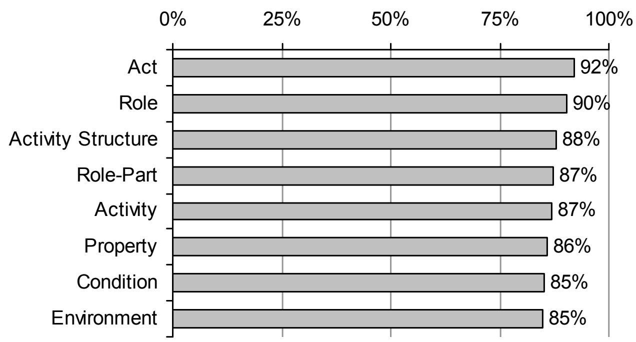

Fig. 6. Participants' performance on the IMS LD element layer.

88%, respectively), thus demonstrating that the stage-play metaphor of IMS LD does not pose any significant problems to its users.

Overall Quality of Solutions. The average overall conformity of participants' solutions with the IMS LD experts' prototype solution was computed using data from the IMS LD Action Layer for the following reasons: (1) The data on the IMS LD Element Layer was abstracted from the actions that had to be performed; and (2) using the checklist on the Task Solution Layer would assign more weight to those element types that occurred more frequently in the solution (e.g. since there were two environments and eight role-parts in the solution, the weight for creating role-parts would be four times as high as for creating environments). As an additional measure, all checklist data for dependent actions (i.e. actions that pre-require another action to be performed) were included in this calculation. This was considered necessary, since otherwise those participants who created an element but failed with the element's dependent actions could be "punished" more than participants who failed to create the element at all.

As a result, the average overall match of participants' solutions to the prototype solution based on correctly performed actions at the IMS LD Action Layer was 78.1% ($n = 21$; $s.d. = 20.2$ percentage points; $min. = 23.8\%$, $max. = 100\%$).

3.2 Qualitative Results

The IMS LD demonstration did not provide the entirety of information needed to perform the task. Some of the information was held back on purpose to see whether participants could figure out which IMS LD element should be used to perform specific actions. The two concepts that participants were not explicitly instructed about were (1) how to express that two roles perform a joint activity, and (2) how to reuse the output of an activity in a latter activity. Concerning this limitation, participants performed well in concluding which IMS LD elements it was correct to use to perform these actions. These two actions also represented the most difficult portion of the solution to complete successfully.

Role-Parts. As the quantitative results showed, participants were not as successful in creating role-parts correctly. This was especially true for activities, which were jointly performed by two roles. In the task, this was the case for the presentation activity (instructor presents while students listen during the presentation) and the discussion activity (the instructor and students discuss together). The anticipated way to express a scenario with two roles joining in an activity is to create two role-parts (one for each role) within the same act that both link to the same activity. Often, participants created just one of the role-parts. On average, participants were able to create 73% of the role-parts required for the task. Two role-parts which accounted for a large share of these difficulties were the instructor's role-part in the discussion activity (only 57% of the participants created this role-part) as well as the learners' role-part in the presentation activity (only 52% of the participants created this role-part). Obviously, participants were tempted to link only the "dominant" roles to these activities, i.e. the instructor with the presentation, and the learners with the discussion, respectively. Other role-parts that caused considerable trouble were the role-parts for the creation of a positive poster (57% created this role-part) and a negative poster (48% created this role-part). This was a complex part of the task, since participants had to use a condition to control the visibility of the poster-creation activities based on a property value set during a previous rating activity. While participants were highly successful in solving these challenges (86% created the property, 95% created the condition, and 85% referenced the property in the condition), they may have simply forgotten to create the needed role-parts for these activities. Another explanation could be that participants viewed the condition as being responsible for showing the activities, and therefore not deeming it necessary to create role-parts for the poster creation activities.

Activity Input and Output. One of the more difficult actions for participants was to store the product or output of an activity. In the task learning scenario, learners were supposed to collect credible sources on the web or set up controversial discussion questions. These items were then to be used during a later discussion activity. The difficulty for the participants was to decide how to store and reuse the learners' output. 16 of the 21 participants managed to create both output-generating activities. Of those, 12 participants stored the outputs of the pre-discussion activities. 67% of them used properties to store the output, while the rest used dedicated environments (e.g. for collecting the questions in a forum) to do so. 9 of them managed to link this property or environment as input to the discussion activity. Three additional participants linked an environment with outputs from preceding activities as input to the discussion activity; however, they did not link the environment to the output-generating activities. Either they forgot or failed to do this, or they considered it as redundant to link the environment to all involved activities. Although properties would be the correct way of expressing this solution in IMS LD, we regarded both ways as correct, since the technical constraints on properties and environments were not covered in detail in the introductory demonstration. In any case, the participants were obviously quite resourceful in finding a reasonable solution to this problem.

Conditional Activities. Participants further demonstrated problems when setting up the poster creation activities that were to be displayed or hidden automatically according to a condition. Most participants correctly set up the condition, which determines whether the learner will next see the activity for creating a pro-coal burning power plants poster or a con-coal burning power plants poster. Although the condition to control the display of one or the other activity was often set up correctly (80%), some participants additionally set up an activity structure of type selection referencing both poster activities. Seemingly, they did not trust that the condition will automatically arrange the display.

Referencing Elements. Uncertainty could also be recognized in regard to the link between activities and environments. Participants correctly linked environments to activities as the quantitative solution showed. However, the same environment was frequently linked twice: Participants referenced an environment in an activity on the activity snippet (correct action), but would then link the activity and again the environment to the role within the role-part (incorrect action). The same pattern, but not as frequent, appeared with activities and the activity structure: Participants would correctly set up the activity structure and reference the corresponding activities. However, when constructing the role-part, the participants would then link the activity structure, and link on the same role-part again the activities that were part of the activity structure. It appears that referenced elements caused uncertainty in their use and display.

Issues Protocol. In the protocol, participants recorded issues or problems they encountered while solving the workshop task. They were also to record whether they were able to solve the documented issue themselves. Fig. 7 shows the results of recorded issues, whereby issues were clustered in order to identify common themes in issue reporting. Clustering was performed whenever an item was mentioned more than once. Issue reports that only appeared once in all protocols, such as "not enough working space on the table" were omitted. Participants did not put down for every reported issue whether they were able to solve it or not. Therefore, for all non-marked issues we assume that these are unresolved issues.

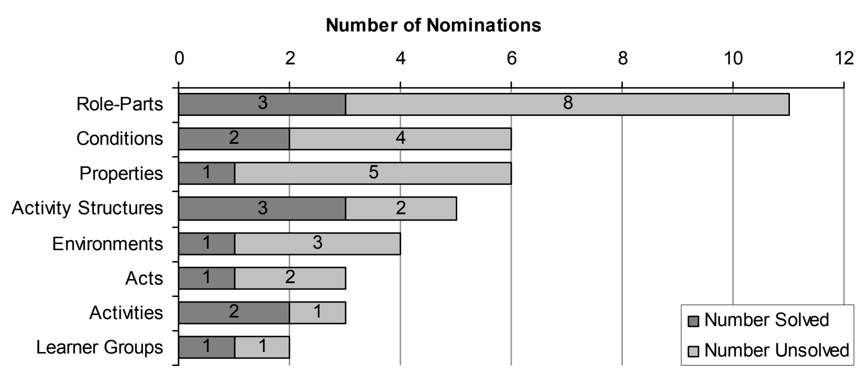

Fig. 7. Participants' reported issues and problems encountered while solving the task.

Role-parts received the greatest number of nominations. Participants had most trouble with the 1:1 matching of a role and either an activity, environment, or activity structure. The protocol entries show uncertainty regarding this matching, and most often they reported that they were unsure whether to link the activity and the environment over again.

The second most reported problem related to conditions. Most often, the reported issue was whether conditions should be used to show and hide activities which could be represented in a sequence. This is in fact true, since conditions could be used instead of acts to structure a learning sequence. Participants understood that it is possible to use both elements to structure sequences. Properties were reported as the third concept that caused a significant number of unsolved problems. Participants reported that they were unsure whether they understood the concept of property. Specifically, some pondered whether the property is the appropriate element to use when storing the output of activities. One participant asked whether a property can be specific to a person (addressing the concept of personal properties, which was not explained in the IMS LD demonstration). This issue was reportedly unsolved to the participant.

Three Greatest Perceived Troubles. Test participants clearly had good understanding of using the IMS LD elements after only a brief introduction. When asked to name three things about the task that gave them the most trouble, they reported that the concepts environment (7 nominations), property (5 nominations), and condition (4 nominations) caused the most trouble. Another aspect that proved difficult for participants was the differentiation between some IMS LD components. The three confusions that were nominated most often were distinguishing between activity structure and act, between activity and activity structure, and between activity and environment. The question participants asked was, "when do I use which element?" They also had trouble understanding how to represent learner groups within IMS LD's role concept. This is a typical IMS LD problem, which has been reported elsewhere especially for building collaborative learning scenarios, e.g. in [12].

3.3 Limitations of the Study

Some comments on limitations inherent in this study are appropriate before arriving at general findings. The task carried out by participants required the use of virtually all level A and B elements. In order to manage the available workshop time, the task was kept moderate in terms of number and complexity of activities and was situated in a purely online context. Another reason for the positive results of this study could be that most study participants had a high technology affinity regarding their teaching backgrounds. Although the tasks carried out were not technological and most of the concepts used in IMS LD are also not technological (e.g. environment, activity structure, act ...), a technical background may have helped participants in understanding some details (for example in understanding the nature of properties). However, since IMS LD is meant for technology-enhanced learning and teaching, the workshop participants may in fact be representative of a typical audience that implements e-learning.

Compared to the IMS LD information model, the paper snippets representing the IMS LD elements were simplified in terms of structure (e.g. only one instead of five types of properties) and information content (e.g. textual instead of hierarchical IF-statements in conditions, or omitting to represent learning objects as paper snippets). We believe that this is appropriate in seeking to understand comprehension of the structure underlying the specification.

Last but not least, the demonstration of IMS LD at the beginning of the workshop was targeted at enabling participants to solve the given task using the paper snippets. Most of the actions required in the task were demonstrated. Actions not required in the task (e.g. employing several plays in a learning design, or employing a monitor service) were not demonstrated and were also not represented as paper snippets.

3.4 Answers to the Main Study Questions

The results indicate that teachers are able to handle level A and B elements presented in the IMS LD specification to an extent that enables them to solve a moderately complex learning design task. The problem is thus not to be seen in the specification itself, but in the tools and processes of using IMS LD.

In the introduction to this paper, two main research questions were stated: "*Does the conceptual structure of IMS LD present a serious challenge for teachers to understand?*" Based on the results in the empirical analyses this question can be answered with "no". Participants performed well on the components and the method sections of their solutions, and they performed equally well on level A and level B. They achieved at least 79% conformity with the correct prototype solution for 17 out of 20 distinct actions required to solve the design task.

The three actions with less than 79% conformity are used to answer the second research question, i.e. "*Which conceptual structures present the most significant challenges to teachers' understanding?*" The conceptual structures in the IMS LD specification that presented the most significant challenges to teachers' understanding were (1) the action related to using role-parts to link roles with activities, activity structures and environments; and (2) the handling of the "document flow" between activities, which is related to the actions of defining output of and input to activities.

4 Conclusions and Recommendations

In this paper we have presented an empirical study into the use of IMS LD by teachers to collect evidence for either maintaining or rejecting the common conception that IMS LD is too conceptually complex to be understood and used by teachers. To remove the bias introduced by IMS LD editors and tools, we adopted a paper-based approach: Elements of the conceptual structure of IMS LD were directly projected onto paper snippets. The qualitative and quantitative data analyses indicated that teachers were mostly able to create high quality solutions to a given design task which required the use of virtually all level A and B elements. Thus, our principal conclusion is that teachers were able to understand the elements, the structure, and the modeling metaphor of IMS LD after a brief introductory demonstration. Since the conceptual structure of IMS LD does not present a serious challenge for teachers to understand, the barriers to adoption may lie elsewhere. Suggested candidates for investigation are the length of time needed to develop mature tooling for a complex specification, and the social, professional and organizational changes required of an institution that is to adopt a learning design approach.

Secondly, we identified a number of conceptual structures which present the most significant challenges to teachers' understanding. We recommend that software developers be particularly aware of these when designing authoring applications. The first of these challenges, i.e. the management of role-parts, is largely resolved by existing authoring platforms. For example, the ReCourse LD Editor [6] and the Graphical Learning Modeller [9] hide the definition of role-parts from the learning designer with no loss of expressivity. The other principal aspects regarding the storage and reuse of user output should be investigated in greater detail: There is a need to identify the best way to show learning designers the consequences of conditions (what is being shown and what is hidden) and the most effective way of representing environments and their linkage to activities.

Additionally we note that obstacles to understanding such as the challenges presented above led some to conclude that radical changes to the specification are required or that a new and simpler specification should be developed. This is the position adopted by [5]: "it is complicated to create a learning design specification meeting both usability and technical needs. IMS LD tried to do that and it's maybe not the right way to proceed." In response they suggest that two new specifications should be developed. One of these, Simple Learning Design 2.0, would be a technical interoperability specification, while the other would be "a real UML for learning design."

Without entering here into a discussion of the perceived need for two specifications, we note that this is a path fraught with pitfalls. As Duval points out, "...the decision to develop a new standard is often taken without proper due diligence. The enthusiasm and will to create something useful is of course positive, but channeling that energy in the development of a new standard is often misdirected" [13, p. 229]. Developing a new standard and delivering the functionality to end users in a way that is useful and usable may take many years [13]. The study presented in this paper may be seen from the perspective of the due diligence. The appropriate response to a critique of a specification from the user's point of view is to thoroughly test if there is a problem with the existing specification itself, or if innovative and creative use and implementation can meet the requirements set out by the critique. For example, in our case we have identified that some teachers do not find the relationship between environment and activity in IMS LD to be intuitive. Due diligence requires us to consider if this can be resolved at the level of implementation metaphors, rather than at the level of the specification. In this case it seems clear that a graphical interface, which enables authors to place activities within an environment, could be mapped onto the specification. The tool would represent this as an association between an activity and an environment. In any event, it seems clear that this problem, one of the most challenging experienced by our participants in working with environments, does not necessarily require a change in the specification.

Extrapolating this example to the wider context the implication is that the development of usable authoring interfaces for simple learning designs is clearly welcome. However, it should be made clear that the evidence to date indicates that these conceptual mappings and simplifications can be achieved with only minor proposed modifications to the specification (e.g. as reported in [10]), and that our results provide direct evidence that the underlying elements, structure, and metaphors of the IMS LD specification are not an insuperable barrier to its effective use.

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