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Semi-automatic assembly of learning resources

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ABSTRACT

Technology Enhanced Learning is a research field that has matured considerably over the last decade. Many technical solutions to support design, authoring and use of learning activities and resources have been developed. The first datasets that reflect the tracking of actual use of these tools in real-life settings are beginning to become available. In this article, we present an exploratory study that relies on these datasets to support semi-automatic assembly of learning activities and resources for specific contexts. Starting from learning designs and other online sources that describe well designed learning experiences as they were used in practice, we derive sequencing patterns that capture re-occurring patterns of activities. A semi-automatic assembly framework uses these patterns to support teachers in the design and authoring of course activities. We present a case study that integrates recommendation support for sequencing activities as well as associated resources in the LAMS learning activity environment. Results indicate that the perceived usefulness is high: both teachers with expertise in the use of learning design tools as well as teachers with no background knowledge in the area indicate that the recommendations helped them in the authoring process. In addition, they feel more confident using learning design tools when support is provided that is driven by best practice knowledge.

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1. Introduction

Many existing course documents merge the representation of content and the instructional approach (Bush & Mott, 2009). Such hardwired pedagogy restricts the options for both reusability and adaptation of learning sequences. Typically, teachers create their lesson plans and content from scratch or reuse parts of existing course documents by ad-hoc and time-consuming copy-and-paste actions. In addition, adaptation to individual learning or teaching styles, background, experiences, interests or preferences is generally not possible, unless learning content is specifically designed for personalization purposes (Vercoustre & McLean, 2005).

In this article, we present a semi-automatic content assembly approach for generating learning sequences tailored to different pedagogical approaches. The overall goal is to enable the selection and assembly of relevant learning activities and resources in pedagogically sound learning sequences. In a first phase, we focused on providing assembly support to teachers, as, with the current state of technological support, at least some degree of quality control by the teacher is required when automating the reuse of existing resources. The assembly process is researched from two perspectives:

- First, we research the extent to which existing learning designs and lesson plans can be used to extract relevant sequencing patterns. These patterns are used by a content assembly framework to select and sequence learning activities and resources based on existing designs. The overall objective of this reverse engineering approach is to generate rich sequencing patterns that can be reused in new settings.
- Second, we investigate how we can support end-users with assembling and sequencing learning activities and resources. A first approach generates an overall template according to the available time, medium (online or face to face learning) and preferred teaching

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method of the teacher. In a second phase, this template is instantiated with tool and resource suggestions. A second approach recommends one activity at a time, based on the current sequence of activities that the teacher is editing. This approach matches the current sequence to available sequencing patterns that were used in a similar context and suggests a list of possible next activities. A case study has been conducted that compares and contrasts the usability and usefulness of the two approaches to support semi-automatic assembly. For this case study, recommendation support was implemented and integrated into LAMS (Learning Activity Management System) (Dalziel, 2003, pp. 7–10) – an open source learning design environment.

The study reported in this article is exploratory. A data-driven approach is elaborated that draws on concepts and frameworks that have been used and validated extensively over the last decade. In particular, we build on pioneering work in this area by Conole and Fill (Conole, 2004; Conole & Fill, 2005), as well as research on learning design tools (Griffiths, Blat, Garcia, Vogten, & Kwong, 2005), adaptive educational hypermedia (Brusilovsky & Millán, 2007) and recommendation techniques for learning (Manouselis, Drachsler, Vuorikari, Hummel, & Koper, 2010). By bringing together these efforts and datasets that have been captured from tools that rely on these frameworks, we evaluate whether best practice knowledge extracted from these sources can support teachers with the design and authoring of their course activities.

In a learning design study reported in (Derntl, Neumann, Griffiths, & Oberhuemer, 2011), 36 higher education teachers from all over Europe were asked what steps they usually take when they design a course. The top three most nominated steps were (the number in parentheses refers to the number of teachers who reported this step):

1. Design/select materials/content for learning and teaching (31);
2. Define content-oriented structure of the course (24);
3. Needs analysis and outcome definition (22).

These findings underline the relevance and necessity of supporting teachers (a) during the process of activity design and (b) in the selection of relevant resources for learning and teaching activities. The article is organized as follows: first, we present related work that positions this work within existing research that has been conducted in this area. Then, we present our semi-automatic assembly framework that supports the assembly and sequencing of learning activities and resources. A case study that integrates the approach in LAMS is presented in Section 4. Evaluation results are discussed in Section 5.

2. Background

2.1. Adaptive educational hypermedia

Research on adaptive educational hypermedia (AEH) has focused to a great extent on support for adaptive content selection and adaptive navigation through learning resources according to the needs of the user (Brusilovsky & Millán, 2007). Among others, pioneering work in this area was driven by De Bra (2002), Brusilovsky and Millan (2007), Henze and Nejdl (2000), and Specht (2000). In recent examples of AEH systems, multiple models are used to support adaptation (Jovanović, Gasević, Torniai, Bateman, & Hatalae, 2009). Table 1 presents an overview of models that are used. Note that this table only lists a limited number of adaptive systems and the models that they use to exemplify the approach. A comprehensive survey and discussion of various methods and techniques is presented in Knutov, De Bra, and Pechenizkiy (2009).

Many systems maintain a *domain model* to enable adaptation based on the concepts of the knowledge domain (Aroyo et al., 2006). Some systems also distinguish a *content model* from a domain model that defines the content types of learning resources, such as definitions, examples, illustrations, etc. Our earlier work on the definition of learning content at different levels of granularity (ALOCOM) (Verbert & Duval, 2008) relates to such models. *Instructional models* capture the semantics of the pedagogical strategy. Such models describe the logic behind the selection and delivery of learning resources, often based on pedagogical theories (Dagger, Wade, & Conlan, 2005). *Context models* describe the setting in which the system is deployed. Many systems rely on a pragmatic approach that defines a list of contextual variables (i.e. medium, timing, available tools, device, etc.) that can be used to support adaptation based on the current needs of the user (Aroyo et al., 2006). *Learner models* describe characteristics of learners, including their knowledge levels, tasks and goals. A recent survey of learner characteristics and how they are modeled is presented in Brusilovsky and Millán (2007). *Teacher models* have been researched to support adaptation toward teacher preferences. Dagger et al. (2005) for instance use a teacher model to scope course content toward a group of learners or the curriculum the teacher is using. Finally, *adaption models* specify the particular adaptation semantics (Aroyo et al., 2006). AHAM (De Bra, Houben, & Wu, 1999) for instance uses Condition-Action rules that use information captured in the various models in specific rules to trigger adaptation.

Research on adaptive educational hypermedia systems has often followed a top-down approach, greatly depending on expert knowledge and involvement in order to identify and model different variables (Manouselis et al., 2010). In open learning settings that automate reuse of existing resources available on the web, less expert-demanding approaches need to be explored. In the next section, we describe research on recommendation technologies for learning that have been deployed for such purposes.

Table 1
Overview of models employed by educational adaptive systems.

	Domain model	Content model	Instructional model	Context model	Learner model	Teacher model	Adaptation model
ACE (Specht, 2000)	✓		✓		✓		✓
ADAPT (Garzotto & Cristea, 2004)	✓		✓	✓	✓		✓
AHAM (De Bra et al., 1999)	✓		✓		✓		✓
Aroyo et al. (2006)	✓	✓	✓	✓	✓		✓
Conlan et al. (2002, pp. 100–111)		✓	✓		✓		✓
Dagger et al. (2005)	✓		✓		✓	✓	✓
GRAPPLE (De Bra, Pechenizkiy, van der Sluijs, & Smits, 2008)	✓		✓	✓	✓		✓

2.2. Recommender systems for learning

Recommendation techniques can be broadly classified into the following categories: *collaborative filtering* recognizes commonalities between users or between items on the basis of explicit (ratings, tags, etc.) or implicit (actions like reading, downloading, etc.) relevance indicators and generates recommendations based on preferences of other users (Herlocker, Konstan, Terveen, & Riedl, 2004). *Content-based filtering* matches descriptions of resources to descriptions of users (Pazzani & Billsus, 2007). Such techniques base their predictions on information about individual users and resources, and ignore contributions from other users. *Hybrids* combine recommendation techniques, to gain better performance with fewer drawbacks (Burke, 2007). A discussion of the advantages and drawbacks of the various techniques for learning applications has been presented in Drachsler, Hummel, and Koper (2008).

A recent survey of TEL recommenders that rely on these techniques has been presented by Manouselis et al. (2011). Most systems suggest *learning resources*, *learning activities* or *peer learners* to users. Some adaptive educational hypermedia systems rely on recommendation techniques to suggest open corpus (i.e. web) resources. Examples are CoFIND (Boyne, Dron, & Mitchell, 2002), Knowledge Sea II (Brusilovsky, Farzan, & Ahn, 2005) and work of Romero, Ventura, Delgado, and De Bra, (2007). CoFIND (Boyne et al., 2002; Dron, Siviter, Boyne, & Mitchell, 2000) for instance uses a collaborative filtering technique that uses explicit feedback of learners. Metadata, defined by the authors as qualities, are added to resources by users to share opinions with others. Examples of qualities defined by the authors are “detailed” and “simple to understand”. Resources are also classified into one or more topics. Through a combination of metrics, CoFIND then arranges the presentation of topics and resources dynamically.

2.3. Sequencing learning activities and resources

In addition to research on adaptation and recommendation of resources, several researchers have worked on the design and development of solutions to sequence activities and associated resources. As indicated by Bailey, Zalfan, Davis, Fill, and Conole (2006), there has been a shift in the technology enhanced learning area from describing and reusing learning resources to describing the “whole learning experience” so that it can be reused by others. Efforts in this area include the development of the Educational Modeling Language (EML) (Koper & Manderveld, 2004) for building structured learning units, that was the basis for the IMS Learning Design 1.0 specification (IMS Learning Design, 2003).

A learning design is often defined as “a conceptual model for the description of teaching and learning processes” (Koper & Tattersall, 2005). Knight, Gasevic, and Richards (2006) indicate that “an important part of this definition is that pedagogy is conceptually abstracted from context and content, so that excellent pedagogical models can be shared and reused across instructional contexts and subject domains.” Several learning design tools are available to author or play learning designs. The properties of these tools, including their conformance to learning technology standards and specifications and their license of use, have been analyzed by a number of authors in several surveys (Griffiths et al., 2005).

An extensive overview of research in the area of learning design has been presented in Koper (2006). Of particular interest for this work is the reuse of existing learning designs as a means to support the assembly of learning activities and resources in pedagogically sound learning sequences. Pioneering work on the use of patterns to support the development of designs has been researched in Boyle (2010) and Leo et al. (2006). The general idea is to provide teachers or designers with patterns as a basis to facilitate the authoring of a design. The distinction is sometimes made between a *bottom-up* approach where existing designs are analyzed to detect re-occurring sequences of elements and a *top-down* approach where patterns are developed by experts based on their interpretation of teaching practice (Brouns et al., 2005). Although the latter approach has been employed in many projects (Leo et al., 2006), the first approach has to our knowledge only been described at a conceptual level.

In order to support reuse of these patterns by teachers, Bailey et al. (2006) argue that it is essential to provide a set of taxonomies that teachers can understand and use. Taxonomies are defined for task types, task techniques, task interactions, role types, assessment techniques, assessment types, environment types, learning and teaching approach type, outcome type, tool types and resource types. These taxonomies have been used by several teachers in the DialogPlus project for describing their designs (Conole & Fill, 2005). An example design is illustrated in Fig. 1, which arranges a presenting activity with an associated slide deck and an answering activity with multiple choice questions in a sequence. The extraction of the flow of activities and resources and tools associated with these activities is researched in this article as a basis to provide assembly support for teachers.

2.4. Discussion

In this article, we build on many existing research efforts that were presented in this section. The objective is to automate reuse and sequencing of learning activities and associated resources by relying on concepts and frameworks that have been used and validated extensively over the last decade. Whereas much advancement has been made by the AEH and recommendation communities to adapt content or suggest a single resource, to our knowledge little research has been done to suggest a sequence of learning activities and associated resources. As learning is a process that needs a sequence of material, the extraction of sequence patterns and the exploitation of these patterns to support sequence recommendation is a highly relevant research topic. The closest attempt to describe such sequences comes from the learning design community. Several efforts in this area have focused on describing the learning experience as a whole instead of a single resource. Nevertheless, also in this area, little research has been done to automate the extraction of sequencing patterns from designs that were used in practice. Existing work has focused on a top-down approach that relies on expert knowledge to describe a learning sequence. In this article, we present an exploratory study that uses designs as they were used in practice to automatically extract such information. These sequencing patterns are used in combination with existing recommendation techniques and AEH models as a basis to automate sequence recommendations. By bringing together ideas and efforts in these areas and implementing these in a concrete scenario, we evaluate whether support for semi-automatic sequence recommendation can help teachers with authoring learning designs. To our knowledge, this study is the first attempt to automate reuse of learning designs with a bottom-up approach that relies on data derived from use in practice of learning design tools.

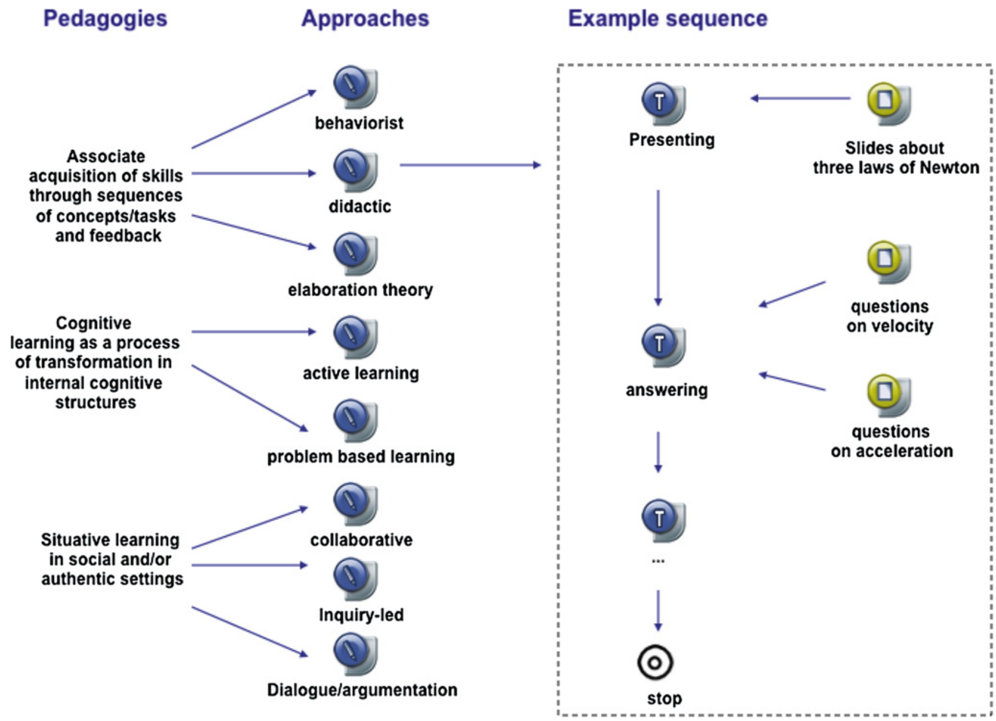

Fig. 1. Example sequence, based on work of (Conole & Fill, 2005).

3. Semi-automatic assembly framework

3.1. Introduction

Semi-automatic content assembly includes the selection and sequencing of learning activities and resources. A sample scenario is illustrated in Fig. 2. The teacher selects one or more concepts for the learning sequence from the domain model – indicating the topic of the activity sequence. The teacher also selects her preferred teaching method, such as inquiry-based, collaborative or active learning. She can then select an activity that is suggested (i.e. commonly used first activities that have been used in practice for the method she selected) or a template that is generated. In the first case, the assembly engine will generate a next activity suggestion based on the activity she selected. In the later case, a full sequence of activities is generated by extracting re-occurring patterns of sequences from designs that were tagged with the same method. In a next step, the design is instantiated with resource recommendations, such as questions for assessment activities and exercises for practicing activities. To support this process, we distinguish three research lines:

1. *Extraction of sequencing patterns from existing learning designs* (see Section 3.2). The objective of this reverse engineering approach is to generate rich sequencing patterns from learning designs available in design repositories and other online sources, such as lesson plans and curricula. In this study, we focus specifically on these data sources as a means to support bottom-up research on the generation of sequencing patterns. Alternative approaches could be the extraction of sequencing patterns from resource aggregations defined by specifications such as IMS Content Packaging (2007) or extraction of sequencing patterns from usage data in learning object repositories (Ternier et al., 2009). We presented an exploratory study of recommendation based on such datasets in Verbert et al. (2011).
2. *Sequence recommendation* (see Section 3.3). Two recommendation approaches were elaborated: a first approach takes into account the current activities that the teacher has already sequenced in a design and recommends a next activity by matching this sequence to existing sequencing patterns. A second recommendation algorithm takes into account different contextual variables, such as available time and preferred teaching method, to generate a full template. An alternative approach could give a user suggestions for improving a sequence she created manually – i.e. by contrasting her sequence to known sequences. However, the approach would require to have knowledge about what a good sequence is in order to suggest improvements. As we do not have the means yet to assess the quality of the sequence, the approach has not been researched in this article.
3. *Resource recommender* (see Section 3.4). In a next step, resource suggestions are generated for individual activities. Multiple recommendation techniques are used, depending on the activity type.

The research objectives and outcomes are detailed in the next sections. A case study that assesses the usefulness and usability of the approach when integrated into the LAMS (Dalziel, 2003, pp. 7–10) learning environment is presented in Section 4.

3.2. Extraction of sequencing patterns from existing learning designs

3.2.1. Data repositories

To enable extraction of sequencing patterns, learning designs can be collected from open learning design repositories, through a crawling process. In our experiment, we did so for the following repositories:

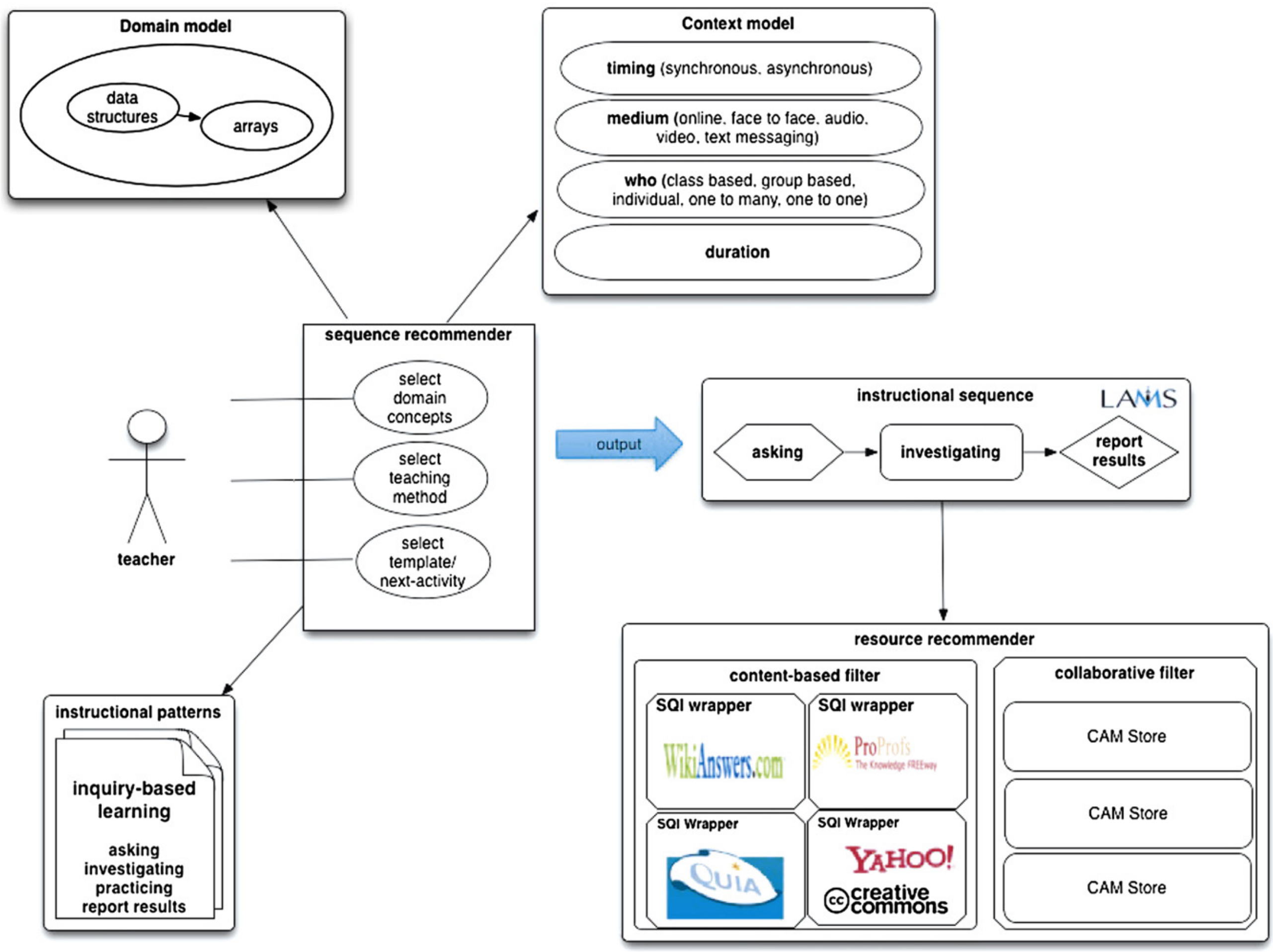

Fig. 2. Semi-automatic assembly framework.

- The JISC/NSF funded *DialogPlus* (Conole & Fill, 2005) project provides access to learning designs that are described according to the taxonomies of Conole and Fill (2005). At the time of writing, 258 complete learning designs are available that aggregate 1,894 activities. These designs include a description of the teaching and learning methods, a description of learning activities (e.g. activity type, activity tools, activity title, length, resources) and learning outcomes.
- IMS Learning Design (2003) (IMS LD) instances were crawled from the Open ICOPER Content Space (Totschnig et al., 2010) and a joint repository of the Learning Networks for Learning Design (LN4LD) (Hummel et al., 2005) and the Understanding New Frameworks of Learning Design (UNFOLD) (Griffiths & Blat, 2005) projects. At the time of writing, these repositories store 154 learning designs.
- The LAMS repository (Dalziel, 2003, pp. 7–10) provides access to 413 designs. These designs are compliant to the LAMS format, and include a title and description of the resources and tools that are used.

3.2.2. Implementation

Sequencing information was extracted from the data sources described above. This extraction process was different for each source. Learning designs of the DialogPlus project are described in HTML files. We extracted information about the teaching and learning method of the design and information about the types, techniques, length, tools and resources of learning activities that are aggregated in the design. The teaching and learning method is specified in 210 of the 258 learning designs and include 45 associative designs, 127 cognitive designs and 38 situative designs. These designs aggregate 1,894 learning activities, including 461 activities that employ a discussing technique, 235 practicing, 344 presenting and 130 brainstorming activities. In addition, we preserve the information about the sequence of each activity in each design, thereby building the sequencing relations of each activity. An overview of the number of learning designs and learning activities according to Conole and Fill (2005) is presented in Table 2.

LAMS designs aggregate activities that have a tool description and title. In a first phase, we mapped tool types to tool concepts that are defined by Conole and Fill (2005). In addition, a simple Naives Bayes classifier was trained and used to identify the task technique based on activity titles.

A similar approach was employed to classify activities that are aggregated in IMS LD instances. IMS LD instances contain a description of the learning or teaching method, a sequence of activities and environments (i.e. learning resources or services such as forums and chat tools) that are used. The IMS LD specification prescribes that the title of the design should reflect the kind of didactic scenario. However, accuracy results of different automatic classification from these descriptions were low (<50%). Therefore, we only used a few LD instances from the

Table 2
Number of learning designs and activities described according to Conole & Fill taxonomies.

Learning and teaching method	DialogPlus	IMS LD	Task technique	DialogPlus	IMS LD	LAMS
Associative	6		Answering	74	35	306
Behaviorist	4		Asking	60	19	14
Didactic	24		Brainstorming	130	11	15
Elaboration theory	3		Debating	28	3	3
Instructional system design	6		Demonstrating	110	4	7
Intelligent tutoring systems	1		Discussing	461	25	14
Training needs analysis	1		Experimenting	54	1	13
Cognitive	23		Game playing	14	0	15
Active learning	52		Investigating	79	32	62
Cognitive apprenticeship	7		Practicing	235	49	24
Constructivist based design	13		Presenting	344	11	3
Inquiry based	12		Reflecting	96	22	38
Goal-based scenarios	4		Role play	14	2	10
Problem-based	15	3	Snowballing	2	0	0
Reflective practitioner	1		Voting	6	4	80
Situative	3		Studying	187	34	10
Action research	0					
Activity theory	3					
Apprenticeship	1	1				
Collaborative learning	19	1				
Dialogue/argumentation	3					
Experiential learning	4					
Project-based learning	4	1				
Reciprocal teaching	0					
Vicarious learning	1					

ICOPER project that were created by experts as templates for some of the methods, as indicated in Table 2. The automatic classification of IMS LD instances according to concepts defined by Conole and Fill (2005) constitutes a further line of research that we do not elaborate upon here.

3.2.3. Result

The result of this research is a repository that contains a description of the structure of 825 learning designs that aggregate various learning activities. The activities are classified according to task techniques and task types of Conole and Fill (2005). Sequencing relations between these activities indicate the order of activities within a design. These sequencing relations are useful to suggest a next learning activity when a user is creating a learning design. For instance, when a user is creating an inquiry based learning design that already sequences an investigating and studying activity, a sequence recommender can suggest a next activity (e.g. discussing) based on existing designs that feature these activities. In addition, re-occurring sequencing patterns can be used to generate full templates. The approach is detailed in the next section.

3.3. Sequence recommender

We elaborated two sequencing recommendation techniques, namely activity and template based recommendation techniques. An *activity based* technique takes into account the current activities that the teacher has already sequenced in a design and recommends a next activity by matching this sequence to existing sequencing patterns. Selection of the first activity is based on commonly used first activities of designs tagged with the same teaching method, as described in Section 3.1. A *template based* recommendation technique suggests a full sequence of activities.

3.3.1. Implementation

To support the first approach, we implemented a sliding window algorithm for:

1. determining the next activities that can follow the observed set of activities;
2. predicting the likelihood of each of these activities.

The recursive algorithm takes as input the current sequence of activities and matches this sequence to existing learning design patterns, as illustrated in Fig. 3. In this figure, the current sequence of activities is C-B-B. To suggest a next activity, the system tries to match the current sequence with the A-B-C-B-B-D activity sequence pattern. In the third comparison step, a match is found, and the system would then

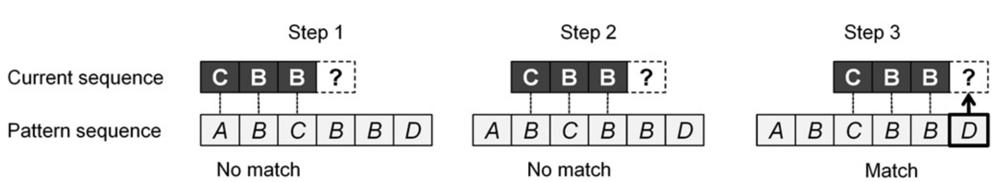

Fig. 3. Finding a matching pattern using the "sliding window" technique (adapted from Verpoorten, Luyten, & Coninx, (2007)).

add the next activity D from the pattern as a candidate next activity. If no matches are found, the window size is decreased stepwise—i.e. the first activity is removed from the input sequence—to increase the probability of finding matching (sub)sequences in existing patterns.

The template based approach uses a clustering algorithm based on editing distance to detect re-occurring patterns. Editing distance indicates how many changes have to be made to convert a sequence into another sequence - i.e. the number of insertions and deletions. For example, to convert C-B-B to B-B-C, the C at the beginning needs to be deleted and a C at the end needs to be added, so the distance is 2. The shorter this distance, the more similar the sequences. The algorithm identifies clusters of similar sequences for each teaching method. Then, the duration is used as the primary selection criterium for patterns (i.e. shorter sequences are recommended for lessons with a short duration whereas longer sequences are used when more time is available). The approach is rather simple and worked for the implemented case study because the data we collected are still limited. More advanced techniques could take into account better estimations about the typical length of activities as they were used in practice. Although such information can be specified in the data format that was used in the DialogPlus project, time information is in many cases not available in the sequences.

3.3.2. Result

The result of this step is an instantiated design that can be launched in a learning design authoring environment for further editing and fine-tuning, as illustrated in Fig. 2. Two interfaces are available for supporting authoring of learning designs. A first interface presents the user with a full template of activities that she can refine. A second approach suggests a next activity based on the current sequence of activities that she has sequenced. The user interfaces to support this process in LAMS are detailed in Section 4.

3.4. Resource recommendation

In a next step, resources are suggested for individual activities. A hybrid recommendation approach is used to suggest relevant resources depending on the activity type. The current implementation supports retrieval of questions and exercises and resource suggestions for assimilative activities. For other activities, such as discussing, debating or voting, resource recommendations are less straightforward. Generating such recommendations constitutes a further line of research.

3.4.1. Implementation

Retrieval of questions and exercises is based on the Simple Query Interface (SQI) for query transport (Simon et al., 2005) and the PLQL query language (Ternier et al., 2008) as query interchange format. A content-based recommender maps domain concepts to PLQL queries and federates the queries to SQI-enabled repositories in the GLOBE alliance of educational repositories (Ternier et al., 2009). Moreover, to enable retrieval of relevant content resources on the Web, several SQI wrappers were built on top of community driven websites that host large amounts of content, such as WikiAnswers.com, ProProfs.com and Wikipedia. For the case study presented in this article, these wrappers were built on top of repositories that store resources related to C programming, including indiabix.com and ProProfs.com. These wrappers typically exploit the structure of pages to identify relevant content fragments, such as individual questions and answers of multiple choice questions within HTML pages. An evaluation of the relevancy of these resources is presented in Verbert, Wiley, and Duval (2009).

In addition, we implemented support for retrieval of documents that students used in previous editions of the course. A monitoring mechanism was deployed in a face-to-face, second year engineering course with 220 students over an 8 week period. A virtual machine was used to track interactions of students with tools and resources. Interaction data are stored in a CAM (Contextualized Attention Metadata) database (Wolpers, Najjar, Verbert, & Duval, 2007). Resources that students visited during their activities are processed and the set with highest similarity to the course topic selected by the teacher are recommended. A combination of lexical analysis and information retrieval techniques is used to analyze and select the most relevant resources that the students visited. The approach has been validated with an empirical study in an undergraduate engineering course with more than one hundred students and is detailed in Romero Zaldívar, Crespo García, Burgos, Delgado Kloos, and Pardo (2011).

3.4.2. Result

The result of this step is an implementation of resource recommenders that suggest web resources and resources available in open learning object repositories during the authoring process. Note that these recommendation techniques were implemented to support evaluation of the particular case study presented in this article. More elaborate descriptions of the various techniques and evaluation results, specifically for these resource recommendation techniques, are presented in Romero Zaldívar et al. (2011); Verbert et al. (2009).

4. Case study

4.1. Introduction

In this case study, we assess the usefulness and usability of semi-automatic content assembly. The study was conducted with 20 teachers in October 2011. Each session involved one participant, who performed three tasks during a 1 h session. Details about the study subjects are presented in Section 4.3. For this case study, we integrated assembly support in LAMS (Dalziel, 2003, pp. 7–10). LAMS is a web-based learning design system that integrates different environments for authoring, running and monitoring learning designs and is released as open source software. The authoring environment of LAMS enables authors to sequence different types of learning activities with a drag and drop interface, as illustrated in Fig. 4. The author drags and drops activities, such as discussion activities, web polls, students posting material, and structured debates, into a flow chart. In the next step, learning resources can be added to the learning activities.

We extended the LAMS authoring environment to automate, at least partially, this process. In a first step, the plug-in presents the author with an interface to design a sequence of activities with activity recommendations or a full template, as illustrated by Fig. 5. Our plug-in also presents resource suggestions for individual activities to the author. As an example, Fig. 6 presents our extension of the multiple choice tool. Available multiple choice and free text questions are automatically provided in the content suggestions area. These suggestions are retrieved on-the-fly from learning object repositories and various online Web sources, such as WikiAnswers.com and ProProfs.com – see Section 3.4.

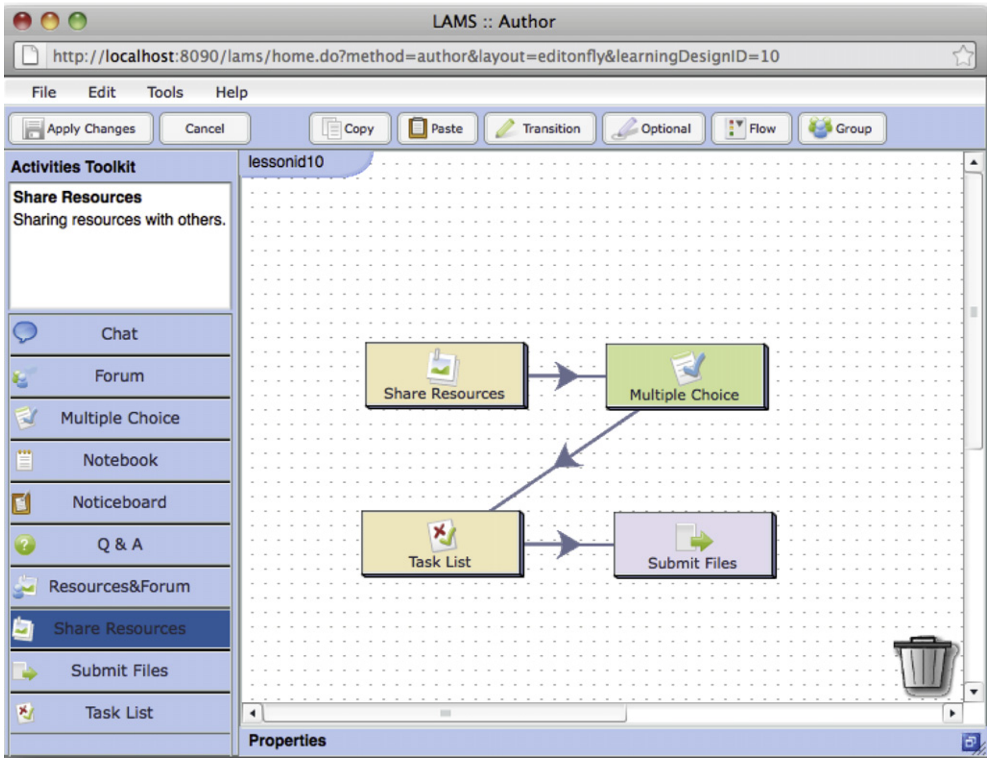

Fig. 4. Authoring a learning design in LAMS.

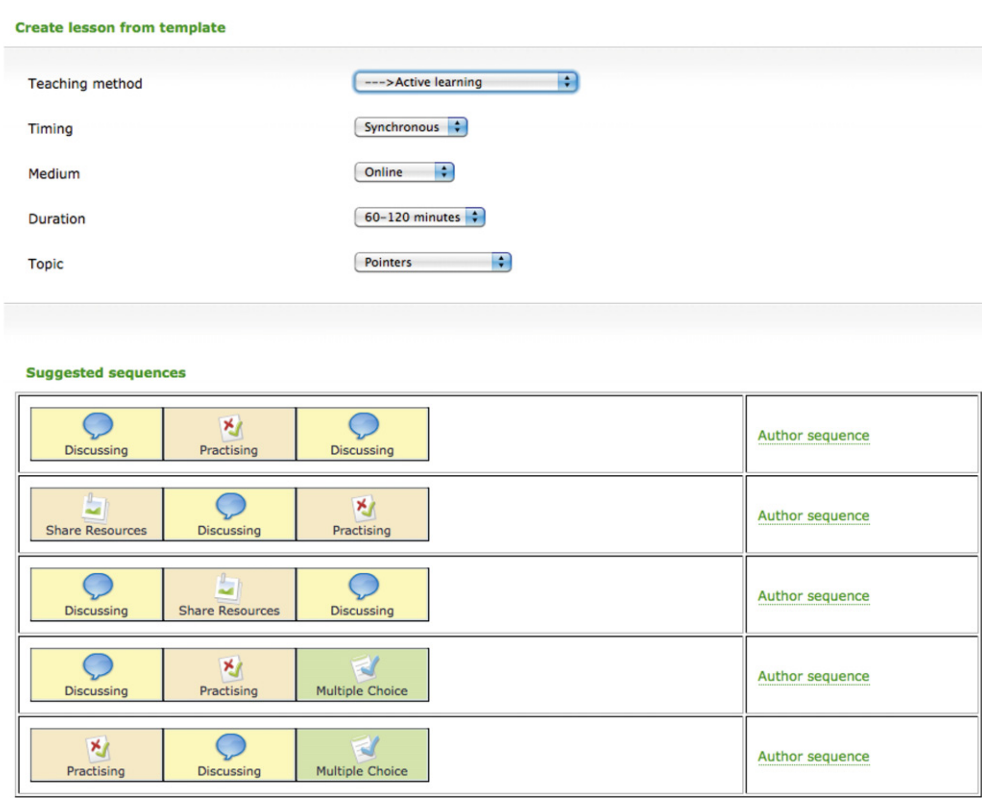

Fig. 5. Template interface.

4.2. Objectives

The overall objective of this evaluation experiment is to assess to which extent the provision of a template or next activity recommendations during the authoring process helps teachers in accomplishing their design tasks. Data were collected to identify indicators on perceived usefulness of the two approaches (suggesting a full template or next activities during authoring) and to compare potential benefits and drawbacks. Additional objectives were to identify usability issues and to collect feedback to improve the assembly process. In the remainder of this article, we refer to the *template environment* when describing experimental results with the template recommender and *activity environment* when describing evaluation results with the environment that incorporates support for generating next activity recommendations based on the current sequence of activities.

4.3. Demographics

Twenty teachers from 3 different universities participated in the evaluation study. We selected participants with different backgrounds and knowledge on learning design concepts and tools in order to enable a comparative evaluation study. Participants are professors and teaching assistants in Computer Science. Four participants have more than 10 year of teaching experience, 7 participants have between 5 and 10 years of teaching experience and 9 participants have relatively little teaching experience (<5 years). Seven participants have extensive experience with learning design environments. Nine participants are TEL researchers, but have no expertise in research on learning design tools. Four participants have little or no knowledge about TEL.

4.4. Tasks

After a short introduction of the tool and the different environments we created, each participant was asked to create three lessons in LAMS to enable a comparative study between the template, activity and default authoring environment of LAMS. The task scenarios were the following:

1. a face to face lesson on memory management in C programming,
2. an online lesson on pointers that follows an active learning method with students participating synchronously,
3. an online lesson on C data types that follows an inquiry-based learning method with students participating asynchronously.

The tasks were elaborated with different recommendation support. Participants were asked to created one of the tasks with the traditional authoring environment in LAMS without sequencing recommendation support, a second task with the template environment and a third task with the activity environment that incorporates next activity recommendation support. The order of the tasks was mixed: some participants elaborated the first task with the authoring environment, whereas others used the template or activity environment first. The tasks were selected to provide a similar degree of complexity.

4.5. Data collection

Camtasia Studio[1] was used to record participant interactions, capturing the screen and voice. The think aloud protocol (Nielsen, Clemmensen, & Yssing, 2002) was used during the completion of the different tasks. The participants were also asked to complete a questionnaire after the tasks. The questionnaire was adopted from the ICOPER project (Derntl, Neumann-Heyer, Griffiths, & Oberhuemer, 2012) where the usefulness and usability of a different learning design environment was evaluated and a usability evaluation of the AriadneFinder (Najjar, Klerkx, Vuorikari, & Duval, 2005). The purpose of this questionnaire was to collect additional qualitative feedback about the perceived usefulness of the different recommendation approaches, including main difficulties, advantages and potential drawbacks.

4.6. Measurements

The following characteristics were measured during the experiment:

- Template environment: we measured the number of changes that participants made to the templates that were suggested to them (i.e. the number of activities they added or removed or for which they changed the order in the sequence). The objective was to gain insight into the quality of the recommended templates by measuring the number of changes that were needed according to the participant.
- Activity environment: we measured the number of recommended activities that were selected by participants as well as the number of times that the participant did not follow the recommendation and selected another activity. The objective was to gain insight into the quality of automated activity recommendations.
- Time on task: we measured the time that participants needed to complete the tasks. The objective was to compare the time needed to complete a design with the different environments – i.e. the template, activity and default authoring environment of LAMS.
- Satisfaction was assessed through a questionnaire filled in by each participant after finishing the tasks. Questionnaire questions intended to measure the overall satisfaction on the usage of the different environments. The questionnaire was adopted from the ICOPER project (Derntl, Neumann-Heyer, et al., 2012). The objective was to collect additional qualitative feedback from participants about the quality of the recommendations as well as perceived usefulness, main difficulties and drawbacks.
- Ease of use: a questionnaire was used to collect feedback on the ease of use of LAMS and our integrated recommendation support. The questionnaire was adopted from a usability evaluation of the AriadneFinder (Najjar et al., 2005).

[1] http://www.techsmith.com/camtasia.html

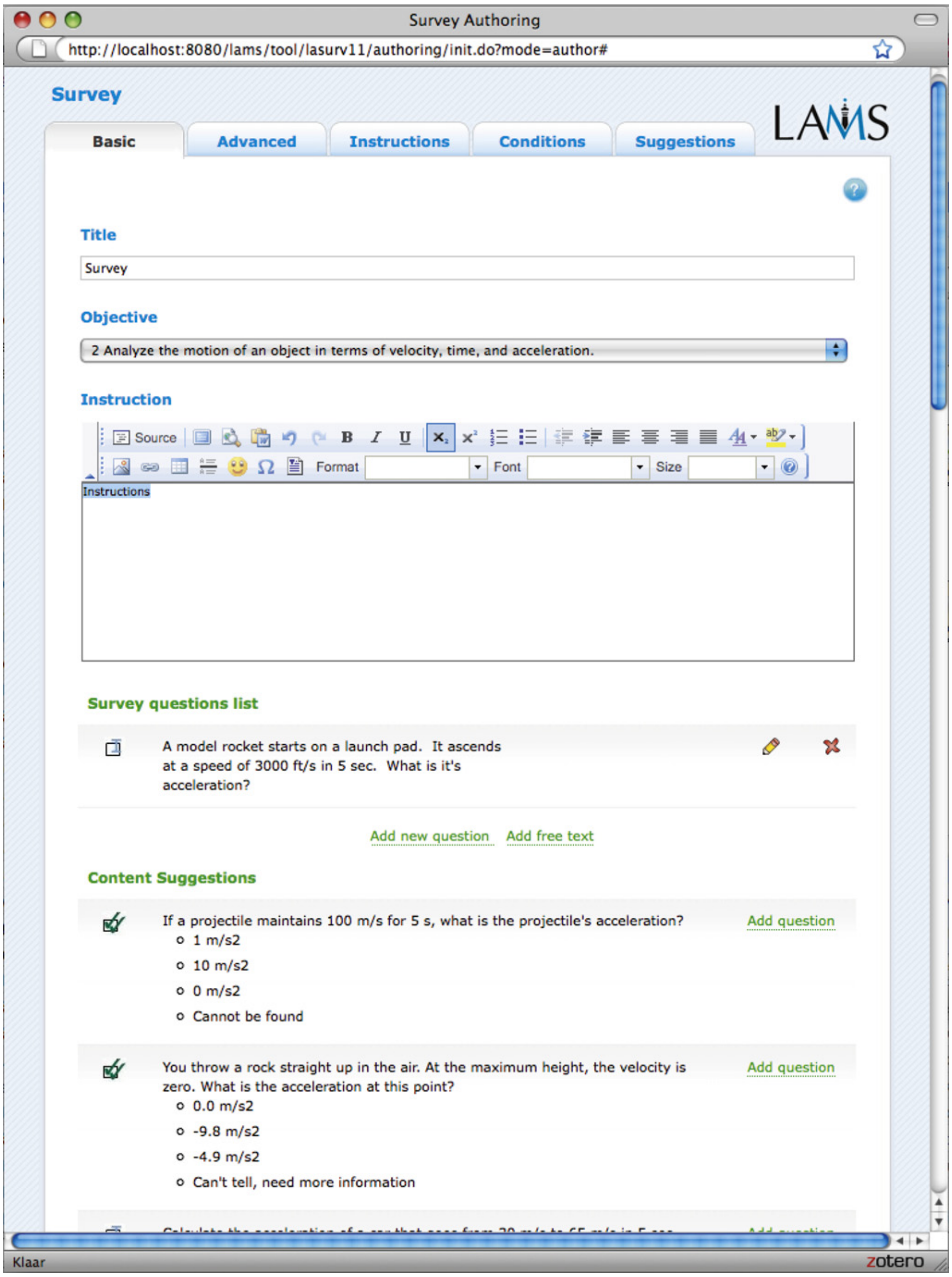

Fig. 6. Learning resource recommendations in LAMS.

4.7. Results

4.7.1. Template environment

Fig. 7 presents the number of activities in the sequences that were created with the template environment. Teachers selected suggested templates that sequence between 2 and 6 activities. Eleven teachers authored the instantiated templates without adding additional activities. This process constitutes selecting suitable resources from the resource suggestions or adding new resources. Six teachers added one additional activity to the suggested sequence and two teachers added two additional activities. These activities were added to the end of the sequence or inserted in between the existing activities. Remarkably, none of the teachers removed any activity from the suggested sequence.

4.7.2. Activity environment

Fig. 8 presents the learning sequences and the number of activities in these sequences that were created with the activity environment. Teachers were given suggestions for activities, but were free to select any other activity in case they did not find the suggestions relevant. The bottom part of Fig. 8 represents the number of recommendations that the teachers followed and the middle part shows the number of activities they added manually. Whereas eight teachers were satisfied with all given recommendations, most teachers did not follow the recommendation during the entire design process. Eight teachers added one activity manually, two teachers added two activities and one

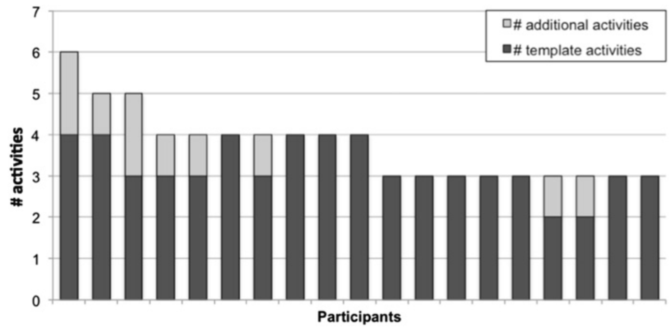

Fig. 7. Number of activities in sequences created with the template environment by the participants (ordered by descending magnitude).

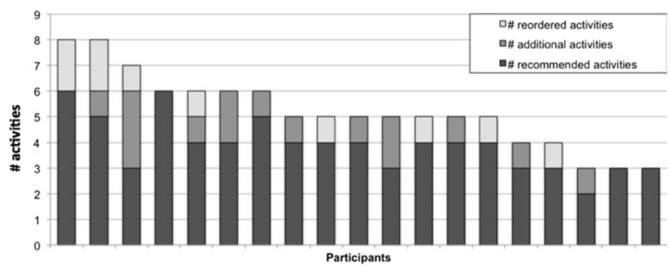

Fig. 8. Number of activities in sequences created with the activity environment by the participants (ordered by descending magnitude).

teacher added three activities. Also changes in the order of activities were made after the initial design. Eight teachers changed the order of one or two activities in the sequence.

4.7.3. Default authoring environment

Fig. 9 presents the learning sequences and the number of activities in these sequences that were created with the default authoring environment. Teachers were given no suggestions for activities in this environment and were free to select activities and tools to support these activities in LAMS. We include these data to enable a comparison of time needed to construct a full sequence of activities with the default authoring, template and activity environments.

4.7.4. Timing of tasks

As illustrated in Fig. 10, the average time to complete the design tasks was 468 s in the default authoring environment, 518 s in the activity environment, and 290 s in the template environment. A one-way within-subjects analysis of variance (ANOVA) showed that there is a significant difference between the time the participants took to complete the tasks in each environment ($F = 10.46$, $p = 0.000$). A pairwise paired t-test confirmed that when participants used the template environment, they completed the task significantly faster than when performing the task using the default authoring environment ($t = 3.67$, df = 18, $p = 0.002$) or when the activity environment was used ($t = 3.76$, df = 18, $p = .001$). There is no significant difference between the completion time in the activity environment and the default authoring environment.

A comparison of the number of activities shows that there is also a significant difference in the number of activities sequenced in each environment ($F = 13.95$, $p = 0.000$). There are fewer activities in sequences built with the template environment (mean = 3.7) compared to the default authoring environment (mean = 4.6; t = 3.92, $p = .001$) and activity environment (mean = 4.7; $t = 5.86$, $p = .000$). Again, there is no significant difference between the default authoring environment and the activity environment.

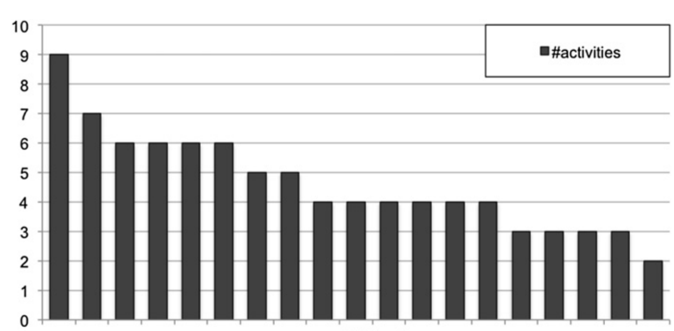

Fig. 9. Number of activities in sequences created with the default authoring environment by the participants (ordered by descending magnitude).

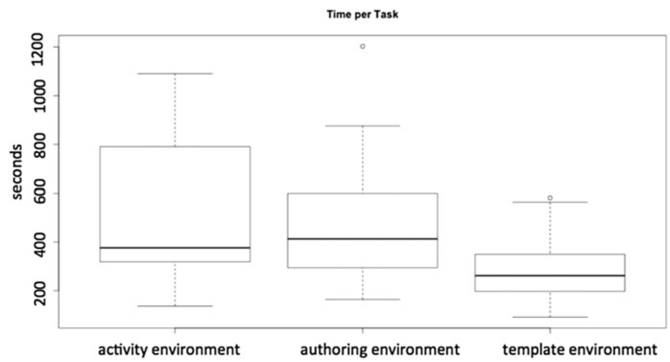

Fig. 10. Time on tasks.

To obtain a better indication of the time needed to add an activity in each of the three environments, the total time was divided by the number of activities in the final sequence. After removing the length bias, a similar result is still obtained. There is a significant difference between the time per activity in the different environments ($F = 3.62$, $p = 0.034$). A pairwise analysis corroborate that the template environment with a mean of 81.0 s per activity is significantly faster than the default authoring environment (mean = 115.1; $t = 2.23$, $p = .039$) and the activity environment (mean = 118.4; $t = 2.188$, $p = .042$). The time per activity in these two last environments is statistically similar.

No significant time difference was found between groups with different teaching experience (one-way ANOVA). Also, previous experience with learning design tools did not affect the time taken to complete a task in the experiment.

These results suggest that the template environment was the most time-efficient alternative partly because the resulting sequences contained fewer activities and partly because the time per activity was also lower. This result is confirmed by Figs. 7 and 8 that show that in the template environment eleven participants—more than half of the sample—accepted the template "as is" without adding or changing any activity to the templates' suggested activities. On the other hand, in the activity environment, only three participants accepted all recommended activities and did not add or reorder any additional activities.

4.7.5. Satisfaction

Additional qualitative data about the perceived usefulness were collected through a questionnaire that participants filled out after completing the three tasks. The main objective was to collect additional information about potential benefits and drawbacks as perceived by teachers and to identify difficulties and collect feedback to improve the process.

Twelve teachers preferred using the template environment, seven the activity environment and one teacher preferred using the default authoring environment of LAMS. Many teachers remarked that both template and activity environments would help them with authoring a sequence of learning activities. They appreciate the support through best practice examples and often felt more confident when recommendation support was offered. Some teachers also indicated that the approach would help them save time during authoring. Several teachers preferred the template environment over the activity environment because they felt it was easier to use and they liked the fact that a full sequence was suggested that they could then later on modify. Some of these teachers remarked that although the activity environment provided them with suggestions, still more guidance is needed. They indicated that activity suggestions in the activity environment could also be an obstacle when no clear design plan is given. In addition, they indicated that explanations why certain recommendations are made would be helpful.

Other teachers found the template environment too restrictive and preferred the activity environment. They indicated that little liberty is given initially and that they felt they were too constrained after choosing a template. In addition, teachers indicated that more variations in the suggested templates were needed. They appreciated mostly that they received support during the authoring process, while still maintaining complete freedom to choose the activities they would like to use.

Several teachers remarked that combined template and next activity recommendation support would be interesting to explore, as such an approach could for instance resolve some of the issues of the activity environment (i.e. giving teachers a clear sequence of activities to start with).

We analyzed in more detail the preferences of teachers and potential correlations to their background (i.e. expertise in learning design tools, technology enhanced learning in general or no knowledge related to the field of research). Whereas we expected that experienced users would prefer the next activity approach and less experienced users the template approach, no significant difference was found in their preferences. Therefore, no general conclusions can be drawn from the experimental setup on which kind of support to offer to teachers. We discuss these findings further in Section 5.

4.7.6. Ease of use

Fig. 11 presents the responses of participants to seven questions (V1…V7) concerning the ease of use of LAMS and our integrated recommendation support. The questionnaire was adopted from a usability evaluation of the AriadneFinder (Najjar et al., 2005). A Likert scale with seven points (ranging from 1-poor to 7-good) was used to measure the response of participants on the overall use of the environment.

The mode for the level of ease of use was 6 (V1), meaning that the participants found the environment easy to use. Most participants were also satisfied with the speed (V2) and level of information organization (V3), although default pop-up windows in LAMS were found disturbing by some participants. There were some issues with the use of terminology (V4). As we automatically suggest tools for different activity types (e.g. a task list tool for a practicing activity), some participants were confused because of inconsistent use of terminology. Providing support and explanations of tool suggestions based on selected activity types could potentially resolve this issue. An alternative solution is to directly suggest a tool to a teacher instead of an activity type.

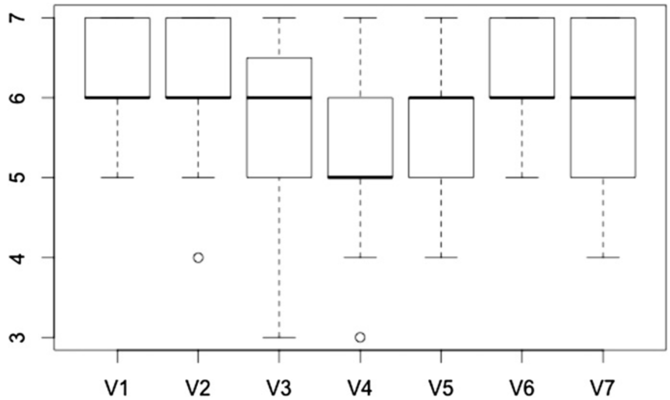

Fig. 11. Usability questionnaire.

Navigation was perceived as moderate (V5 – mode 6), potentially also because of too many pop-up windows in LAMS. Our extensions to insert learning resources could be used in a straightforward manner (V6 – mode 6). Finally, result lists were found easy to read (V7 – mode 6) by most participants.

5. Discussion and conclusion

5.1. Limitations of the study

Before discussing the findings and their impact on future work related to semi-automatic assembly of learning activities and resources, some words on limitations inherent in the study design are necessary. In order to manage the available time of participants, the task scenario was kept moderate in terms of number and complexity of activities. Also, the demonstration of LAMS at the beginning of the session was targeted at enabling participants to solve the given task using the authoring environment. Most of the actions required in the task were demonstrated.

Another factor of potentially positive bias in this study could be that most participants had a high technology affinity in teaching. Although the tasks carried out were not technological, a technical background may have helped participants in understanding some details of the learning design environment more easily than teachers or instructional designers who have no technical background.

In addition, we performed the evaluation experiment with three predefined tasks – each with a different teaching or learning method (i.e. inquiry-based, didactic and active learning). These methods were selected based on the availability of data in our learning design repository. For many other teaching methods, the current data and extracted patterns are too limited to support the automatic generation of templates or useful next activity recommendations.

It is also sometimes argued that teachers are not the primary target group of learning design tools. Prominent learning design specifications like IMS Learning Design (2003) and related research (e.g. Koper & Olivier, 2004) do typically not mention teachers as designers nor as end-users of the tools. In higher education and training institutions which distribute the design and delivery of courses over different roles, the teachers are typically not involved in the design of the courses; this is for instance the case in highly standardized open and distance education providers. However, in most "traditional" higher education institutions, the individual teacher has to take the key role during both design and delivery of courses (Derntl, Neumann-Heyer, et al., 2012; Hoogveld, Paas, Jochems, & van Merrienboer, 2002). While this justifies the recruitment of teachers for our study, the sequencing and resource recommenders presented in this article might support professional learning and course designers as well or even better. We reported results of a previous study with instructional designers in (Verbert et al., 2009).

5.2. Discussion

The discussion of the measurements must reflect the setup of the case study. The task scenario required only a moderate effort by the participants of the study, thereby simplifying the amount of time and complexity for the participants. In addition, the developed learning activity sequences were not used in any course. Hence, we cannot make any statements about the meaningfulness of the developed sequences and their impact on the course. We therefore focus on the use of the indicators we collected to identify future lines of research.

In general, the results of the case study presented in this article indicate that teachers value the (semi-)automated support for sequencing learning activities in university course learning scenarios. This was found to be independent of the background or familiarity with learning design tools of the study participant. Most teachers prefer the template based approach as a means to semi-automatically assemble learning activities. They indicate that having a skeleton of activities to start from gives them more confidence and could also help them save time during the authoring process. The time-saving aspect was actually confirmed by an analysis of time spent on the task. The analysis showed that the template based approach took statistically significant less time than tasks completed in the activity environment and the authoring environment, respectively.

At the same time, teachers felt that using templates restricts their design options. Although the templates could be edited, many teachers made only small additions and changes in the sequence. Significantly more changes were made to activity sequences that were built with the activity based approach. While some teachers prefer activity recommendations as they provide more freedom in assembling the learning sequences as opposed to a full template, other teachers were clearly struggling with the approach. Time measurements also indicate that the approach requires substantially more effort to deal with the recommendations in meaningful ways. One obstacle was the lack of explanation why a certain recommendation was made. A potential solution would be to show the full design on which a recommendation is based. Such an approach would also give teachers an indication of a further design plan in which their current sequence fits, while still maintaining full freedom to select activities. The use of information visualization techniques (Shneiderman & Bederson, 2003) has a significant potential to provide teachers with such an insight into the recommendation process.

Ease of use of our LAMS extension was generally good, but default pop-up windows in LAMS were disturbing for some participants. More importantly, there are issues with the use of terminology. Recommending activities to users and automatically suggesting relevant tools for these activities should be supported with clear, for instance also visual, explanations. More generally, the use of terminology that is used for creating learning designs is often not clear to teachers. Such issues have also been identified in (Derntl, Neumann, & Oberhuemer 2011; Griffiths & Blat, 2005). In these studies, participants did often not understand the meaning of a teaching method and other technical learning design terms. Addressing problems with terminology when supporting teachers that author learning designs therefore constitutes a further line or research.

The exploratory study presented in this article was driven by datasets that we crawled from open learning design repositories. Whereas the data were sufficient to support the task scenarios that we selected (i.e. three predefined tasks with an inquiry-based, didactic and active learning method), for many other methods the data that we collected were insufficient to generate recommendations. In addition, our approach builds on clearly defined taxonomies of task types, techniques, tool types and teaching methods to automate recommendation. While the data of the DialogPlus project are a highly valuable source of information for our approach (i.e. all elements in the available designs are clearly described along the various attributes of the framework of Conole and Fill (2005)), automating the extraction of such information from IMS LD instances is a challenging task. Particularly the identification of teaching or learning method from the title of the designs was not successful by any automatic classification approach that we tried (accuracy $< 50\%$). An interesting future line of research would be to investigate to which extent the current IMS LD specification can be used to support bottom-up extraction of design patterns from available LD instances. Such research would be valuable to identify limitations to automate reuse of LD instances in different settings and potentially also to help steer further research in the development of learning design tools. In addition, although the specification has been in use since 2003, the number of available designs in open learning design repositories is still limited. Research in this area would benefit from an increased number of learning designs as they have been used in practice to support other teachers with best practice knowledge and possible automated recommendation support based on this knowledge.

5.3. Conclusion

In this article, we have presented an exploratory study to identify whether the automation of learning activity sequencing is meaningfully applicable for university teachers. A bottom-up approach has been researched that automatically extracts sequencing patterns from available learning designs. In addition, we tested the implemented software in a case study with 19 university teachers, which typically results in a reasonably tight confidence interval (Nielsen, 2006). While this is a rather small group of participants in our study, it provides a good indication if the use of templates eases the uptake and re-use of learning designs. This result is backed up by findings from other domains, e.g. software development (Riehle & Zllighoven, 1996), where patterns provide a simple way to bootstrap and accelerate software development.

The contribution of the article is three-fold: first, we have demonstrated that existing designs can be used in a meaningful way to support the authoring process of learning activity sequences. Although the approach could only be evaluated for teaching methods for which we had sufficient data, results illustrate that the perceived usefulness is high. Both teachers with expertise in the use of learning design tools as well as teachers with no background knowledge in the area indicate that the recommendations helped them in the authoring process. In addition, they feel more confident using learning design tools when support is provided that is driven by best practice knowledge. Second, we compared two approaches to support sequence recommendation. A first approach presents teachers with a full template, whereas a second approach suggests a next activity based on the current sequence the teacher is editing. Results suggest that the template environment was the most time-efficient alternative partly because the resulting sequences contained fewer activities and partly because the time per activity was also lower. Results from a satisfaction questionnaire indicate that most teachers prefer the template approach over the next activity recommendation approach but, at the same time, ask for more flexibility. Such flexibility can be supported with the activity based approach, but the current implementation without explanations why certain recommendations are made was not perceived well by many teachers.

Third, we have outlined further areas of research. Whereas results of this study indicate that perceived usefulness is high, many open issues remain that need to be tackled in order for the approach to work in real-life settings. A first issue is related to the availability of data. Although specifications and tools to edit learning designs have been available for several years, the availability of learning designs compliant to these specifications is still limited. A larger uptake is needed to collect learning designs as they have been used in real-life settings to evaluate recommendation support for a wide variety of teaching methods. Finally, it would be beneficial for research to extend the case study with a larger group of university teachers. Even further, the teachers should be asked to use their developed sequences in the classroom and see how they work. Based on the findings there, further conclusions can be drawn on the effectiveness of the semi-automatic assembly framework and its impact on teaching and learning. Acknowledgments This work is supported by the STELLAR Network of Excellence (grant agreement no. 231913). Katrien Verbert is a Postdoctoral Fellow of the Research Foundation - Flanders (FWO). The work of Martin Wolpers has received funding from the EC Seventh Framework Programme (FP7/2007-2013) under grant agreement no 231396 (ROLE). The contribution of Xavier Ochoa was supported by VLIR through the RIP Project ZEIN2010RIP09. The contribution of Abelardo Pardo was partially supported by the eMadrid Network (S2009/TIC-1650) and the EEE project (TIN2011-28308-C03-01).

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