Towards Pedagogy-Driven Learning Design: A Case Study of Problem-Based Learning Design

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Abstract. Existing learning design languages are pedagogy-neutral. They provide insufficient support to explicitly represent pedagogy-specific approaches such as problem-based learning (PBL). As the first step towards pedagogy-driven learning design, we developed a PBL design language and an associated authoring tool by adopting a domain-specific language (DSL) approach. The language and the tool provide means for teachers to think and represent their own PBL designs in vocabularies that the teacher daily uses to describe their PBL approaches. This paper presents a case study to investigate whether the language and the tool can facilitate the design of a PBL course plan. Although participants had minimal knowledge of PBL and were not skilled in process modeling, after a short training they were able to prepare their own PBL course plans using the PBL authoring tool. They reported that the vocabularies in the PBL design language were easy to understand. Some thought that the tool provides flexibility and others did not think so. Nevertheless, some found the process somewhat difficult to represent the narrative into a course plan. In addition, most participants found that the tool is user-friendly and easy to learn.

Keywords: Learning design, IMS-LD, DSL, PBL, PBL design language, case study.

1 Introduction

Nowadays new pedagogies such as problem-based learning and inquiry-based learning and innovative use of technologies such as internet and virtual collaborative environment seem to offer much promise in terms of providing new educational experiences for learners. However in reality practitioners are overwhelmed by the plethora of choices and may lack the necessary skills to make informed design decisions about how to use these theories and technologies [7]. Designing high quality, technology-supported learning experiences is a significant challenge for educators [23]. Recently

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learning design has emerged as a distinct field of research, which is concerned with the development of methods, tools, and resources for helping designers in their design process [4, 23]. Although learning design and instructional design are similar and both aim to maximize the benefit and impact of learning by using the right learning model and by designing the right conditions for learning, instructional design focuses more on designing learning content and assessment of outcomes for knowledge transmission from the perspectives of teachers. Whereas learning design focuses more on planning, structuring and sequencing learning activities and designing learning context and environment with technical support for knowledge construction from the perspectives of learners. Examples of such learning activities are: identifying and analyzing problems in a session, brainstorming learning issues using a digitalized whiteboard, gather information from internet with a search engine, proposing and discussing solutions in a discussion forum, and co-authoring a group report using wiki. In addition, the term of "learning design" also denotes the result or product of the design process, a computational description of a teaching-learning process that may happen in a lesson or a course. Learning design aims at providing a means to represent and communicate the designs of learning activities so that they can be shared among practitioners at design-time. Furthermore, the learning designs can serve as a means to orchestrate and scaffold teaching and learning practice at run-time [25].

Learning design was proposed by Rob Koper and his colleges at Open University of Netherlands [19, 20] when they developed an educational modelling language (EML) and initiated an international e-learning technical standard, called IMS-LD [17]. Since then many learning design languages and associated tools have been developed. Some learning design languages such as LDVS [1, 5], LDLite [28] and CompendiumLD [8] are intentionally developed for teachers to reflect on and exchange the pedagogic ideas and the rationale of the actual design through using semi-structured description as a tabular or a diagram. Such a learning design is to inspire teachers to implement them and hence improve practice [11]. Other learning design languages such as IMS-LD, LDL [24], MoCoLADe [15], and LAMS [9] emphasize more on the support of automation of teaching and learning processes through formally modelling a pedagogic strategy consisting of detailed activities with associated learning resources and services. This kind of learning design is mainly to enable machine to execute the process model and scaffold teaching and learning practice. No matter for teaching or for learning, these learning design languages are pedagogy-neutral and can be used to describe a wide range of pedagogical strategies. However, the practitioner has difficulties to represent complex learning activities using these languages like IMS-LD [14, 26, 27], because the vocabularies of these languages are pedagogy-irrelevant and technology-oriented terms such as "activity", "property", "learning object", and "data-type". They provide less or even no vocabularies and guidance to represent and implement specific pedagogic strategies such as problem-based learning and inquiry-based learning.

Some researchers have argued that it is almost impossible to develop a new generation of e-learning environments that are completely pedagogically neutral [22]. In comparison with a pedagogy-neutral learning design language like IMS-LD, a pedagogy-driven learning design language may be more useful and easy to use for practitioners. However, it is not realistic to define a high-level learning design language with a common set of vocabularies to explicitly describe various pedagogical approaches, because there are many different learning theories and pedagogies and they use different, sometimes incompatible concepts and terms to describe different teaching and learning approaches. Traditional classifications of learning activities (e.g., Bloom's taxonomy [6] and Gagne's nine instructional events [12]) are suitable for describing topic-centered instructional design, but they provide only limited view on task-centered instructional design [22]. In order to enable practitioners to represent, communicate, and share pedagogy-sound and technology-supported learning experience easily, we attempt to provide a set of pedagogy-specific learning design languages by adopting a model-driven architecture. All these pedagogy-specific learning design languages can be regarded as meta-models, which will be specified using the same meta-meta-model. A learning design represented in any pedagogy-specific learning design language can be transformed into a unit of learning (UoL) represented in IMS-LD. As a consequence, all high-level learning designs represented in a pedagogy-specific learning design language can be transformed and then executed in an IMS-LD compatible run-time environment. As the first step towards this goal, we developed a PBL design language and an associated PBL authoring tool by adopting a domain-specific language (DSL) approach. In order to investigate whether the PBL design language and the PBL authoring tool can facilitate the target user in designing a PBL course plan, we conducted a case study as a formative assessment. Our assumption is that after a short training session the teacher without comprehensive PBL knowledge and technical knowledge can create a PBL design by using the PBL design language and the PBL authoring tool. The remainder of the paper is organized in the following sections. Firstly it introduces the PBL design language and the PBL authoring tool. Then a case study is presented. Finally, the paper presents conclusive remarks and provides suggestions for future work.

2 A PBL Design Language

Dr. Howard Barrows, one of the developers of PBL, has defined PBL as a learning method based on the principle of using problems as a starting point for the acquisition and integration of new knowledge. According to [2], students think PBL is a more interesting, stimulating, and enjoyable learning method. It offers a more flexible and nurturing way to learn. The faculty also considers PBL a more nurturing and enjoyable curriculum. In comparison with traditional lecture-based learning, PBL is better with respect to creative thinking, self-directed learning, data gathering, problem-solving, evaluation techniques, and teamwork [3, 16]. However, PBL is not one commonly agreed upon concept, but rather encompasses a number of different interpretations and practices [18, 29]. Based on theoretical work, many PBL process models have been proposed such as Barrows model [3], the McMaster PBL model [32], the Maastricht model [30], and the Aalborg model [13]. Furthermore, each PBL process model can have different implementations. Many factors are influence on choosing a PBL process model and on arranging implementation details such as learning objectives, class and group size, students' characteristics (e.g., motivation, PBL skills, and prior knowledge), and exploited technologies. So far PBL researchers and practitioners usually describe a PBL strategy in natural language. There is no dedicated representation format to describe various PBL strategies.

As mentioned before, the term learning design refers to both the process to structure teaching-learning activities and the result of this process -- a description of a coordinated set of teaching-learning activities. The central concept of a learning design is activity. Our research work is based on activity theory [31] that provides "a philosophical framework for studying different forms of human praxis as developmental processes, both individual and social levels interlinked at the same time" [21]. Based on activity theory, we developed a meta-meta-model that provides basic building blocks for specifying a set of pedagogy-specific learning design languages as meta-models. In this paper we focus on describing the PBL design language – a domain-specific language (DSL). Domain-specific language (DSL) is usually a relatively small, declarative language that just expresses the logic of a computation without describing its control flow. Furthermore, a DSL offers expressive power through appropriate notations and abstractions focused on and usually restricted to a particular problem domain [10]. As van Deursen et. al [10] summarized, DSLs allow solutions to be expressed at the level of abstraction of the problem domain. As a consequence, domain experts themselves can understand, validate and often modify DSL models. The DSL models are concise and self-documenting to a large extent. They enhance productivity, reliability and maintainability.

When applying DSL paradigm in the domain of PBL, we developed the PBL design language by specifying the concepts of PBL that teachers usually use to describe a PBL approach. Using the PBL design language, a PBL design can be represented as a set of phases which can be executed in sequence (as the default structure), in parallel, in branch or in loop. When designing a phase, a teacher should choose one or more phase types from a list: *preparation, problem engagement, problem definition, idea generation, learning issue identification, plan, information sharing, investigation, reasoning, problem resolution, evaluation, application, reflection*, and *report.* In addition, associated phase types such as *facilitation*, *collaboration*, *basic cognition,* and *assessment* will be automatically associated with any phase. In a given phase, only certain types of activities are suggested to be completed and a type of activity may produce a certain type of artifact. For examples, in the phase *problem engagement* the following five types of activities are suggested: *describe case/situation*, *present scenario/phenomenon*, *introduce problem trigger, view,* and *clarify concept*. The artifact types of this phase are *case, scenario, situation, phenomenon*, and *observation*. A phase with a type of *learning issue identification* can contain the following activity types: *identify learning issue, formulate learning issue, organize learning issue,* and *identify knowledge need*. The artifact types of this phase type are *learning issue* and *learning need*. After the teacher defines a phase through choosing one or multiple phase types, the user can further specify the activity structure within the phase in details.

Each phase consists of one or several activities that may be performed in sequence (as the default structure as well), in parallel, in branch, or in loop. Various process structures can be specified using arrows. When designing an activity, one can only choose an activity type from the types specified by the chosen phase types. In addition, the constraints between the type of artifact and the type of activity are specified as well. For example, in a phase with a type of *learning issue identification*, one can arrange an activity by choosing an activity type *formulate learning issue* and define an artifact with a type of *learning issue* as an output. It also enables a detail design of an activity by defining the relations with actors, learning resources, and tools. For example, the teacher can assign the actor of activity with a type of *formulate learning issue* as *a learner*, *a facilitator, a group of learners, all groups in a class,* or *all learners in a class*. It is allowed to further define a learning setting for an activity with appropriate learning resources and tools.

3 PLATE Workbench: An PBL Authoring Tool

In order to facilitate PBL practitioners to design their own PBL strategies, we develop a web-based graphical PBL authoring tool, called PLATE Workbench. Rather than using pedagogy-irrelevant constructs provided by IMS-LD authoring tools such as Re-Course [14] and Prolix OpenGLM [27], the teacher can use the vocabularies and rules specified by the PBL design language. Fig. 1 and Fig. 2 show two screenshots of the tool to edit a PBL design at a high-level and a low-level, respectively. The user interface of the tool consists of five parts. The menu bar on the top lists basic function and the state bar on the bottom indicates the current edit state. The central area contains the file manager (on the left), the graphic edit space (in the middle), and the property edit panel (on the right).

As illustrated in Fig. 1, a PBL design is defined as a set of phases at a high-level. The meta-information about this PBL design can be specified and viewed in the property edit panel. This example PBL design was created by a student in the case study. The participants and their organization were specified as well. The tool enables to edit a PBL design by manipulating diagrams with nodes and links. A phase is created through dragging a phase node and dropping it in the graphic edit space. A dialog window will pop up and the user can choose one or more phase types for specifying this phase. For example, the user can choose a phase type "*problem engagement*". The user can design a title for a phase, but this user simply used the phase type as its title. The user can also type information as the values of attributes of the phase in the property edit panel. The user can define process structure by creating links between phases and specify the start and termination conditions.

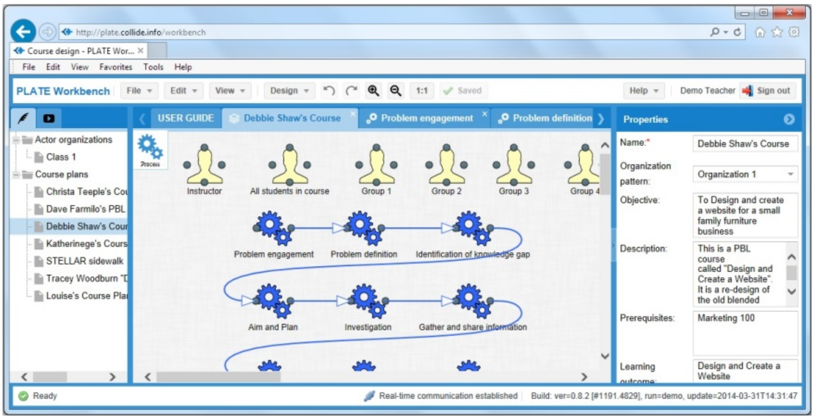

Fig. 1. A high-level PBL design and the associated user interface of the tool

The teacher can define the internal activity structure of a phase by clicking the corresponding phase node (the first phase node *problem engagement* in this case) in the high-level diagram. The tool will enable the teacher to define activities by dragging and dropping an activity node in a similar way to create a phase node as shown in Fig. 2. The type of the activity can be defined by choosing one from a list of activity types (shown in the combo-box) that are specified in the selected phase types (the type of problem engagement in this case) and the associated phase types (facilitation, collaboration, and assessment). The activity can be further defined by assigning values of attributes and by connecting with actor nodes, resource nodes, tool nodes, and artifact nodes. The specified relations between concepts (e.g., which type of activity can produce which type of artifact using which kind of tool) within the PBL design language will be used as constraints to guide and restrict the construction of the diagram.

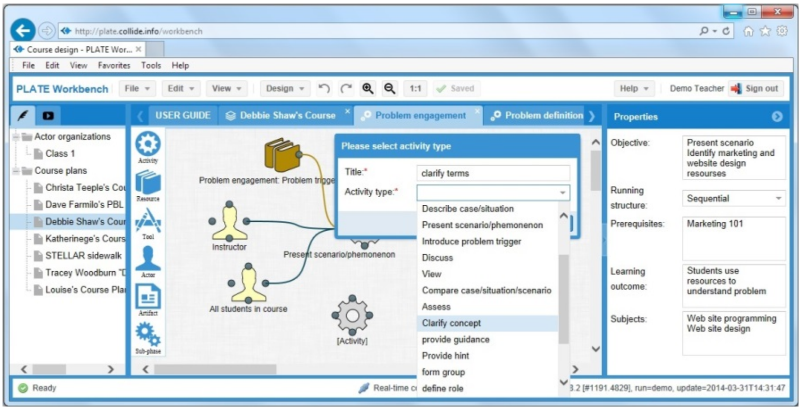

Fig. 2. A part of low-level PBL design and the associated user interface of the tool

4 Method

We conducted a case study at an online university as a formative assessment to determine whether the PBL authoring tool can facilitate the target user in developing a PBL course plan. Participants in the case study were enrolled in a master degree program completing an advanced instructional design course titled "Trends and Issues in Instructional Design". They were working as teachers or in the education and training field. This case study was arranged as a part of the course. The total number of students in the course was 18 who commented that PBL is interesting; however, due to the course schedule restrictions only one-third of the class participated in the study. In the course all participants read two learning materials about PBL and took one hour training on how to use the PBL authoring tool. The training session was recorded and participants were able review the recording at any time. Then the participants did practice in one week with a user manual and five-minute tutorial video. At the end of the course, participants can choose one form of final exam from three alternate assignments. One option is to design and create a blended PBL course called "Design and Create a Website" with the PBL authoring tool. Six participants chose this assignment.

Among them five participants completely and successfully created their own PBL designs using the tool in the exam. After the exam all participants responded to a questionnaire. The questionnaire includes questions on the aspects of background information, the PBL scripting language, the PBL authoring tool, and the general PBL design approach.

5 Results and Discussion

The data show that the case study participants had minimal knowledge of PBL. They had computer experience in terms of using generic computer software such as WinWord and PowerPoint. They also had experience using generic communication tools such as chat rooms, forums, etc. Some had experience using education-specific tools such as digitalized whiteboards or online questionnaire authoring and responding tools. Others had less and even no such experience. However, almost all participants had more or less experience in using learning management systems (LMSs) such as Moodle or Blackboard. The participants reported that they were not skilled at process modelling with UML or computer programming.

When answering the questions about the PBL design language, most participants reported that the two-layer structure of the PBL design is easy to understand and use; the vocabulary used to define the phase or activity in the course plan is understandable and the activity structure that includes actors, resources, output artefacts and their relations is easy to understand; and it is easy to find an appropriate term or vocabulary to represent their design ideas. Some participants provided the following comments:

"*I liked how there were many choices of phases from the drop down menu. This allows for flexibility and customization of the PBL scenario. Linking the phases also allows for different learning outcomes from the PBL format.*"

"*I believe the tool has huge potential for designers to develop a PBL course. It provides a template that even a novice PBL instructor like me can use effectively to produce quality instructional material.*"

However, one participant had opposite thought: "*My greatest difficulty was translating my pen and paper version to the online work area. … I had a hard time figuring out the difference between phases and activities. I was not sure how to construct a phase. I tried to include some activities within phases, but I was not sure how much detail to get into. … I found the phase definition vocabulary very straight forward but the activity definition was not as intuitive.*"

Almost all answers to the questions about the tool are positive. They reported that it is easy to create a phase, an activity, and an artefact by dragging and dropping and to specify their relations by creating a link between two nodes intuitively. It is also easy to learn. The comments from participants include the following.

"*Overall I found the functions of the tool easy to use with the drop and drag features, drop down selections and linking of actors to activities and artefacts.*"

"The PLATE workbench is an excellent tool to create a PBL environment that encourages learner's self-direction and collaborative learning through the use of instructor created and customized PBL learning plans."

"Navigating within the PBL authoring tool was easy."

"The visual representation of the PBL that the PLATE workbench creates really helps the instructor figure out all the steps required for the students to work through the presented problem. The breakdown of all the steps necessary to work through PBL is clearly outlined through the use of the PLATE workbench."

Only one participant commented negatively: "*I did not fully understand why I needed to define Work Mode* and *Complete Condition*."

Participants were asked to provide suggestions to improve the tool. The suggestions are listed below.

"*It would be very beneficial to add a copy and paste function that can allow an instructor to copy a whole phase (including actors, activities, tools, resources, and artifacts) into another phase.*"

"*Improve interface of the three areas to integrate functions of these areas better. One solution is to have the window enlarge when you are typing information so that you can see the whole screen in one view." "More examples would be excellent for novices.*"

Participants were asked to describe their evaluations of the general approach. The comments were collected and listed below.

"*Because the tool is built based on the PBL model and uses the PBL terminology, it is useful in supporting the PBL practice, and provides support for users less familiar with the PBL. However, given that the tool comes with a particular structure, it may not be flexible enough for more experienced PBL users."*

"… The tool is also rigid and restrictive and doesn't give much flexibility in the hands of the teacher. However if the aim is to have a novice like myself create a PBL course easily, it does accomplish that goal."

"*The PLATE workbench was fairly flexible in allowing the author to create the learning plan. The ability to move the elements around within the phase was very beneficial and incorporating the grid to line up the elements was helpful."*

"The potential is definitely there. I think anything that can help a teacher improve learning for students is a step in the right direction."

In summary, the feedback on the tool and the underlying language are quite positive and encouraging. Although one participant did not complete the assignment and had negative feedback, five participants created their own PBL designs. The quality of the created PBL designs was acceptable for the participants who had minimal knowledge of PBL. The participant who did not finish the assignment had less PBL knowledge and less experience in using LMS, and asked for more training. Through analysis, we can have a preliminary conclude that it is not difficult for the target users to develop a PBL design using the tool if they have certain experience in using LMSs and education-specific tools or get enough training. In addition, it seems that participants had opposite opinions about whether the tool is flexible or rigid. Our interpretation is that the guidance and restrictions provided by the PBL design language are useful for the novice. As the user becomes skilled at designing PBL, she or he may need more flexibility and freedom.

6 Conclusions and Future Work

Feedback received from the case study participants indicated that most agreed that the PBL authoring tool is easy to use the function to define groups, create or delete a phase, an activity, an actor, and an artefact, and specify their relations. Participants also reported that it is easy to specify a PBL design using the vocabularies and rules. These results are encouraging since the participants in the case study had minimal knowledge of PBL and this was the first time they were using the PBL authoring tool.

Based on the feedback from the participants, it is important to train potential users on the theory of PBL so that they know what PBL is and what are informed decisions and possible choices. Also, it is important to provide training on how to use the PBL authoring tool and to provide support to users as they develop the PBL course plans. The feedback from participants in this case study indicates that the PBL authoring tool will be useful for teachers and trainers to develop PBL course plans.

As mentioned before, this case study was conducted as a formative assessment. According to the feedback, we have improved the PBL design language and the tool. Since this study involved a small number of participants, we plan to conduct large-scale evaluations to investigate the expressiveness of the PBL scripting language and to which extent the language and the associated tool can facilitate the representation and communication of PBL designs. We are also developing transformation module to map a PBL design into a unit of learning represented in IMS-LD. Then we will apply this approach in other pedagogies and developing an integrated, pedagogy-driven, new generation of learning design environment.

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