

The Granularity of Collaborative Work for Creating Adaptive Learning Resources

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Abstract: Recent developments in the field of learning systems have led to adaptive learning which considers learner models when performing pedagogical decisions. Problems emerge in providing knowledge spaces of adaptive learning systems. As a knowledge space consists of pedagogical model, learner model, and adaptation model, teachers need much effort to create it. This paper focuses on the authoring of the knowledge spaces of adaptive learning systems and proposes a collaborative authoring approach for creating pedagogical, learner, and adaptation models. The proposed approach combines asynchronous collaborative work with Notes and History to support implicit coordination and workspace awareness. It applies IMS Learning Design to represent the aforementioned models. To validate it, qualitative and quantitative experiments were conducted. The experiment results indicated the high granularity of authoring, which means that learning designers can efficiently and effectively work in an asynchronous collaborative environment with Notes and History.

1 PROBLEMS IN AUTHORIZING FOR ADAPTIVE LEARNING

Learning is a process to build knowledge and enhance skills through studies, practices, experiences, social interaction, lectures, or tutorials. With many students registering in a course, teachers are faced with various learners' characteristics differs. To accommodate the diversity, recent developments in the field of learning systems have led to adaptive learning which considers learner models when performing pedagogical-related decisions.

Along with its advantages, adaptive learning system gives teachers or learning designers a consequence to prepare a sheer sized and complex learning space, consisting of domain, pedagogical, learner, and adaptation models. Hence, it is difficult for just one or two teachers to develop such a space. Teachers need to work collaboratively to reduce individual effort. Although teachers can work individually on preparing courses, they should team up with other teachers to check material consistency and reliability, or to maintain learning resources which are not fixed at certain stages, and to be kept continuously updated.

A very common collaboration among teachers or learning designers is on creating and reusing learning content. It rarely happens on creating pedagogical knowledge regarding how learning content is delivered. This is contrary to the premise suggesting that learning must be socially developed (McDaniel and Colarulli, 1997). The collaboration of learning designers involves multiple dimensions (pedagogical, social, disciplinary, competency, cultural, et cetera) which potentially improve learning and benefit learners. Learning designers themselves can get advantages from the collaboration as they can learn new knowledge on respective fields from their colleagues.

The collaboration, however, potentially fails when learning designers can not gain concensuses on various pedagogical preferences (Eisen and Tisdell, 2013). Considering the potential advantages and the possible failure of learning designer collaboration, this paper discusses our study on the collaborative work for authoring adaptive learning resources. The study is motivated by a basic question whether learning designers can or cannot collaboratively work on authoring pedagogical, learner, and adaptation models.

In this paper, we propose a collaborative work

model for authoring learning designs. In the rest of this paper, we discuss former studies on computer-supported collaborative work (CSCW) and IMS Learning Design (IMS LD) which is the only learning standard supporting adaptation and personalisation. Afterwards, research questions, experiments, and data analysis results are described. The contribution of this paper is presented in the form of a demonstration showing that learning designers can efficiently and effectively work in an asynchronous collaborative environment with Notes and History for creating adaptive learning resources represented in IMS LD.

2 THEORETICAL BACKGROUND

This paper concerns two issues in authoring learning designers: learning standards to represent adaptive learning resources and computer-supported collaborative work to be applied.

2.1 Computer-Supported Collaborative Work for Learning

CSCW has been successfully applied in various areas for authoring various objects, such as hypermedia documents (Haake, 1993), courseware (Dicheva et al., 2002; Ras et al., 2008), academic writing (Dimitrova et al., 2008), papers (Liccardi et al., 2007), and ontology (Noy and Tudorache, 2008). CSCW in particular enables social collaboration and evolves knowledge on a large scale. It reduces individual efforts, provides different insights, and enhances the quality of output by enabling authors from different expertise to work together (Noël and Robert, 2004). Multiple persons who collectively contribute their thoughts could surpass the achievements of someone who works individually (Dicheva et al., 2002; Posner and Baecker, 1992). However, collaborative work may potentially generate less positive output than individual work. This would be more likely to be the case when inappropriate communication and coordination mechanisms are applied or workspace awareness is limitedly supported (Gutwin and Greenberg, 2002; Kittur et al., 2009; Lowry et al., 2005).

Communication and coordination methods applied in online authoring are different from those applied in traditional collaboration. In a traditional collaboration, careful planning is important. It is supported by face-to-face meeting, which is beneficial to the authors as it offers interactive and direct communication. In contrast, a careful plan is

not considered necessary in an online collaboration where contributors have the freedom to do what they consider important. Until recently, there have been numerous research studies into how communication mechanisms affect the authoring process and output. It was found that the proper use of communication method could improve the quality of artefacts (Kittur and Kraut, 2008).

Workspace awareness is important for managing coupling between working alone and working together, simplifying communication, coordinating actions, anticipating other authors' actions, and assisting authors (Gutwin and Greenberg, 2002). Workspace awareness must be maintained, not only in synchronous collaborative work, but also in asynchronous collaborative work. Research on workspace awareness in asynchronous collaborative authoring was carried out with the same motivation as in synchronous collaborative authoring (Dourish, 1997). Workspace awareness in asynchronous collaborative work is related to the history of occurrences, including actions, artefacts, events, and authors' presence and locations (Gutwin and Greenberg, 2002).

2.2 IMS LD Supports for Adaptive Learning

Learning design is motivated by a pedagogic consideration that learning is not merely about a set of learning objects, or simply content to be presented to learners, but learning is also more about how the materials are delivered to learners and how learners can gain knowledge. People learn better if they are actively involved in learning processes (Bonwell and Eison, 1991). Hence, learning is carried out according to a flow of learning activities, called learning design, which consists of a structured set of learning activities to be done by learners and support activities to be carried out by teachers.

The need for learning design standards emerges along with requirements to keep learning designs consistent for all students. In addition, the use of technologies for learning has raised the need for reusable and interoperable digital learning designs. Learning design standards, such as IMS SS and IMS LD (Grocott et al., 2012), present some advantages as they have well structures and abilities to include learning objects as materials in order to support lessons or learning activities.

In term of adaptive learning, IMS LD offers wider adaptation and personalisation than IMS SS. It supports flow-based adaptation, content-based adaptation, and interactive problem solving-based

adaptation (Kravcik et al., 2008). ‘Hide’ and ‘Show’ are applied to lessons and activities for flow-based adaptation and to resources for content-based adaptation. Furthermore, they are applied for adaptive problem solving assistance which is an extension of flow-based adaptation. It provides incremental-adaptive assistances, for example, by applying time and/or the number of remediation. The structure of IMS LD is presented in Figure 1.

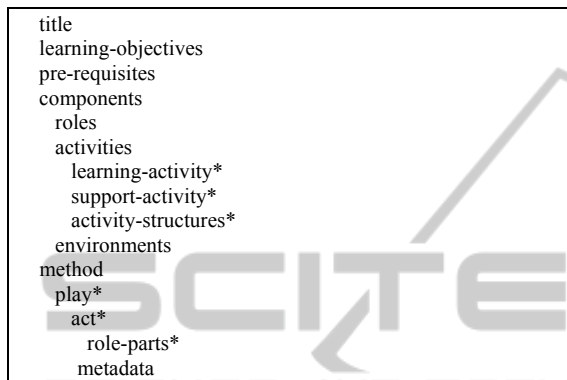


Figure 1: The structure of IMS LD (Grocott et al., 2012).

There has been an authoring tool of IMS LD. It is called ReCourse (<http://tencompetence-project.bolton.ac.uk/ldauthor/>), that provides functionalities for authoring and visualizing IMS LD. In addition, there is CopperCore for validating and delivering IMS LD.

3 RESEARCH QUESTIONS

Regarding the organisation of IMS LD which is hierarchically structured, asynchronous collaborative authoring with implicit coordination was considered suitable. Former research has proved that implicit coordination is more suitable for hierarchical tasks or documents rather than explicit coordination (Lowry, 2002; Lowry et al., 2005). Hence, we hypothesise that learning designers do not need intensive communication for coordination. The hierarchical structure of IMS LD will make authoring task division and assignment not too complicated. In addition, standard meanings and formats for all types of adaptive learning artefacts in IMS LD will prevent a learning designer from misunderstanding other authors' work.

To test the suitability of the proposed method, two experiments were conducted. They addressed two research questions.

Question 1. *With IMS LD that is hierarchically structured, in which level of granularity is the collaborative authoring carried out?*

The proposed collaborative method is suitable for authoring IMS LD if learning designers can collaboratively work on the high and low levels of learning designs, and also on adapting materials. Accordingly, the observation identified the contribution of authors in authoring three kinds of pedagogical elements:

1. *Plays and acts.* Plays and acts are IMS LD elements for pedagogical knowledge. Learning designers' contribution in authoring these elements indicates that they can work collaboratively on the high level of pedagogical knowledge, which means that the granularity of authoring is low.
2. *Activities and Role-parts.* In designing role-parts, learning designers have to assign learning roles to activities. Updates on learning activities, support activities, activity groups, and role-parts indicate that learning designers can work collaboratively on the low level of pedagogical knowledge. It means that the granularity of authoring is high.
3. *Properties and conditions.* Participants' contribution in authoring properties and conditions indicates that they can work collaboratively on adapting materials. An example of conditions is presented in Figure 2.

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<imsld:conditions>
  <imsld:if>
    <imsld:not> <imsld:or>
      <imsld:no-value>
        <imsld:property-ref ref="P-completion-test-
          advising"/>
      </imsld:no-value>
      <imsld:no-value>
        <imsld:property-ref ref="P-completion-test-
          anticipating"/>
      </imsld:no-value>
    </imsld:or> </imsld:not>
  </imsld:if>
  <imsld:then> <imsld:show>
    <imsld:learning-activity-ref ref="LA-request-
      grade"/>
    <imsld:environment-ref ref="E-background"/>
  </imsld:show> </imsld:then>
</imsld:conditions>

```

Figure 2: An example of adaptation rule in IMS LD.

Question 2. *Are Notes suitable for implicit coordination and, with History, suitable for workspace awareness in collaborative authoring of IMS LD?*

Experiments to answer this question would refer to former studies on CSCW which have confirmed that coordination mechanisms are group sized-specific.

They have examined the influence of the number of contributors and the independency of collaboration tasks (Kittur et al., 2009). Kittur and Kraut (Kittur and Kraut, 2008) highlighted the correlations between implicit coordination, early stages of authoring, and the quality of articles. The advantages of implicit coordination are greater during the early phases of authoring, when the article is in its earliest versions. During these phases, outlining the article structure by a subset of authors will lead to greater increases in quality. When the authoring work is carried out by the small subset of authors, the quality of articles will increase and is better than articles produced by group where the work is evenly divided amongst all authors.

4 THE EXPERIMENTS

Two experiments were conducted to answer the research questions: a qualitative inquiry with observation and interview and a between-group quantitative inquiry with questionnaires. The proposed collaborative authoring model was implemented by extending ReCourse, a stand-alone open sourced tool. The main functionalities of ReCourse can be classified into five groups:

1. Manage domain model implemented in resources.
2. Manage goal model implemented in learning objectives, pre-requisites, course overview, role, plays and acts, learning and support activities, activity groups, role-parts, conditions, and environments.
3. Manage learner model implemented in global-personal properties for learners' profiles and local-personal properties for learners' progress.
4. Manage adaptation model implemented in pre-defined and user-defined conditional rules.
5. Validate learning designs.

For the experiments, ReCourse was extended with supporting functions for collaboration. The new functionalities in Collaborative ReCourse consist of (Nurjanah, 2013):

1. User group management. The first author is assigned as the coordinator who has an authority to add new members into the group; the others are called members. These are the only role assignments in the proposed authoring method.
2. Notes. Notes were provided in three types based on the types of comments possibly posted by learning designers. First, Note is attached to the whole learning design. It is provided for learning designers to share comments about the learning

design itself, learning objectives, pre-requisite courses, completing rules, or other general comments. Second, Note is attached to History, called History's Note, which is aimed to maintain learning designers' comments regarding updates they made. Third, Notes are attached to IMS LD elements, called objects' Notes. One object's Note attaches to one play, act, learning or support activity, activity group, property, condition, role, role-part, or resource. Objects' Notes aim to maintain authors' comments regarding particular elements. The Observation investigated which type(s) of Notes participants prefer.

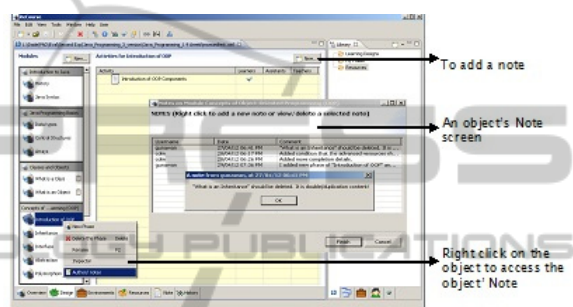


Figure 3: A screenshot of Collaborative ReCourse prototype with objects' Notes.

3. History, a feature to record provenance information about changes, the types of changes, the affected objects, and the learning designers who made the changes.
4. Existing learning content gallery. This is an additional feature in which authors can select, add, or tag learning materials. This feature aims to decrease authors' effort when creating learning content and to enhance authors' awareness of the availability of learning materials to be reused.

The architecture of Collaborative ReCourse prototype can be found in Figure 4.

4.1 Qualitative Inquiry: Observation and Structured Interview

This experiment aimed to observe the granularity of collaborative authoring of learning designs. It investigated how learning designers did collaborative work and on which elements the collaboration was carried out. It investigated whether they could collaboratively work only on the top level of pedagogical resources (plays and acts) or on the low level (role-parts) as well. Furthermore, it observed authors' contribution in authoring adapting materials (conditions and properties). At

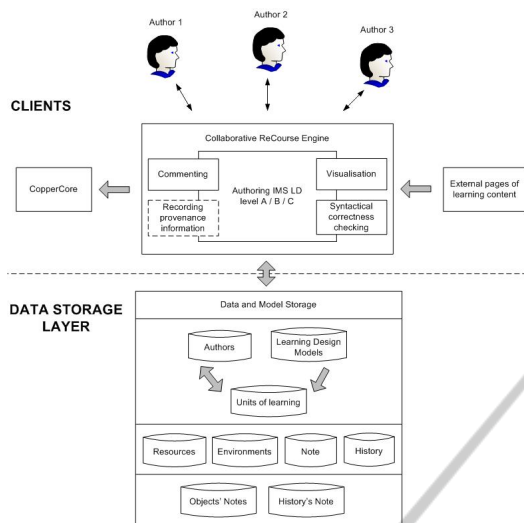


Figure 4: The architecture of Collaborative ReCourse.

the end, a structured interview was conducted after the observation to gather participants' opinion about the authoring process and the collaboration features: Notes and History.

As this is a qualitative experiment, a limited number of participants were required; too many participants will lead to divergent results (Marshall and Rossman, 2006). There were 12 people participating in the experiment. They were recruited by personal email invitation. To select participants, purposeful sampling as opposed to random sampling was used. Participants were selected by considering:

- Gender. Since collaborative authoring of learning designs is not gender specific, male and female participants in a balanced composition were involved in this experiment.
- Teaching experience. Participants were those who had teaching experience in classrooms or laboratories.
- Java knowledge. It was needed because participants were required to develop a learning design of Java programming.

Observation. All participants were assigned to work in asynchronous collaborative authoring environments. They were divided evenly into four groups. In the observation, participants 1 to 3 worked as group A, participants 4 to 6 worked as group B, participants 7 to 9 worked as group C, and participants 10 to 12 worked as group D. Each group was required to create a learning design of Java programming in nine sessions of 60 minutes. Each participant was required to work in three non-consecutive sessions. There was no authoring scenario to be followed by participants; they were free to make any update.

All participants worked in the similar environment: asynchronous collaboration. The only difference is that group C and D were supported by workspace awareness features in the forms of Notes. They could communicate through Notes and access provenance information (History), such as what recent updates that have been made, by whom and when. Such features were disabled for group A and B. Although participants worked collaboratively, the focus of the observation is individual actions in the collaborative work.

Results. The results obtained from the observation were presented in the following graphs. First, the contribution of authors in authoring the aforementioned three kinds of pedagogical elements is presented in Figure 5. As shown in the graph, all participants contributed in the authoring. However, there were two participants in group A and B, participants 2 and 4, dominant over the others in their own groups.

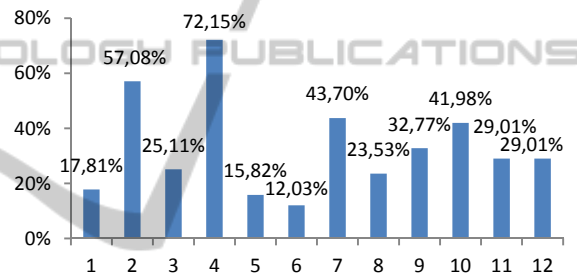


Figure 5: Participants' contribution in authoring all pedagogical resources.

Second, we broke down the data to see the granularity level of authoring which is indicated by the contribution of authors in authoring learning activities and role-parts. As we have discussed, the contribution of authors in authoring learning activities and role-parts indicates the high granularity level of authoring. As shown in Figure 6, all participants participated in authoring learning activities and role-parts in various contribution. Like in the previous finding, there were participants who contributed more than fifty percents in group A and B.

The last focus of the observation is authoring learner model in the form of properties and adapting elements which consist of predefined- and user-defined conditions. As shown in Table 1, all participants contributed in the authoring. However, participants 7 to 12 supported with Notes and History presented better contribution as there were not properties and neither rules which were individually authored by sole participants.

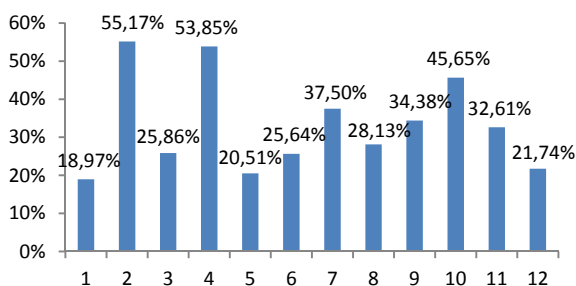


Figure 6: Participants' contribution in authoring activities and role-parts, the lowest level pedagogical resources.

Table 1: Participants' contribution in authoring learner model and adaptation rules.

Participants	Learner model and adapting materials		
	Properties	Predefined Rules	User-defined Rules
1	25.0%		100.0%
2		60.0%	
3	75.0%	40.0%	
4	81.0%		100.0%
5		100.0%	
6	19.0%		
7	16.7%	50.0%	14.3%
8	50.0%	50.0%	57.2%
9	33.3%		28.5%
10	33.3%	50.0%	18.0%
11		40.0%	64.0%
12	66.7%	10.0%	18.0%

Discussion. The observation has investigated how learning designers work in asynchronous collaborative environments with features for limited communication (Notes) and awareness supports (Notes and History). It revealed a fact that learning designers can work collaboratively in authoring all IMS LD elements. The granularity of authoring is high as they can work collaboratively from plays to role-parts and from non-adapting to adapting materials. In term of the usability of Notes, the observation shows that among the aforementioned three kinds of Notes, History's Note is the least accessed one. Participants prefer to use Note and objects' Notes as they thought that the function of History's Note has been covered in Note.

4.2 Quantitative Inquiry: Between-Group Questionnaires

IMS LD offers advantages for adaptation and interoperability. IMS LD, however, does not provide an element or any space for learning designers to put notes or comments, such as to explain what the objectives of learning activities, why a particular topic is important, et cetera. We proposed Notes to

enable learning designers to put comments regarding the authoring process or the authored artefacts and History that, with Notes, describes how the authoring process is going on. The second experiment aimed to investigate whether Notes and History give positive impacts in authoring IMS LD. **Method.** Adaptation model is one component of adaptive learning resources that is considered to be more difficult to understand than other resources. In this study, a comparison between Group 1 and Group 2 was drawn to see if implicit coordination and workspace awareness features is suitable for authoring adaptive learning resources. Both groups are assigned to work in asynchronous collaborative environments, but Group 2 was supported with features for communication and workspace awareness, while Group 1 was not. It could be concluded that Notes and History give positive impacts to authoring, if Group 2 presented better workspace awareness than Group 1.

There were 44 participants who participated in the experiment. The number of participants was estimated by G*Power software (Hendrix et al., 2008). They had teaching experience and Java knowledge. Like in the first experiment, they were required to involve in collaborative authoring of learning designs in asynchronous-collaborative environments.

Participants were divided into two groups. One group was supported with Notes and History, while the other group was not. To guarantee that participants have the same profiles regarding their teaching experience, IMS LD authoring experience, and Java knowledge, we conducted a MANOVA test to see if there is a significant difference between the groups. The test comprising Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root confirmed that there is no significant difference between the profiles of Group 1 and Group 2.

Table 2. The MANOVA results for participants' profiles.

Effect	Value	F	df	Error df	Sig.
Pillai's Trace	.244	2.449 ^a	5.000	38.000	.051
Wilks' Lambda	.756	2.449 ^a	5.000	38.000	.051
Hotelling's Trace	.322	2.449 ^a	5.000	38.000	.051
Roy's Largest Root	.322	2.449 ^a	5.000	38.000	.051

Contrary to the first experiment, this experiment required participants to follow artificial authoring scenarios. To give participants knowledge about IMS LD and ReCourse, we arranged a 45-minute introduction session that all participants had to attend. In this session, participants were free to explore the tool and examples of IMS LD.

The questionnaires were reviewed by two senior

experts and one junior expert from related fields. The aim of this review was to ensure that targeted information could be gained through all the questions, and to avoid ambiguity of words in the questionnaires that possibly cause misunderstanding. All reviewers had similarity profiles with participants that they have teaching experience as well as educational backgrounds in engineering. As this experiment was carried out not only in the UK, but also in Indonesia, it was essential that at least one reviewer was fluent in both Indonesian language and English.

Results. All participants were required to find information in a predefined unit of learning of Java Programming. They were free to explore the UoL. There was no guidance given to Group 2 participants as to where to find notes written by previous learning designers. Afterwards, all participants were asked a number of questions related to adapting materials. The questions covered five cases; each case employed simple rules and logic that learning designers could easily follow. Participants were required to observe the case and answer questions related to the case. One example of the questions is presented below:

*Please find rules. You will find one rule:
"Rule 1". What is the objective of the rule?*

Participants' answers indicated their workspace awareness. The questions used three nominal values to classify users' answers: wrong answers, no answers, and correct answers. A comparison between the number of correct answers given by Group 1 and Group 2 is described in Figure 7 (Nurjanah and Davis, 2012). In each case, Group 2, which supported with Notes and provenance information, gave a higher percentage of correct answers than Group 1.

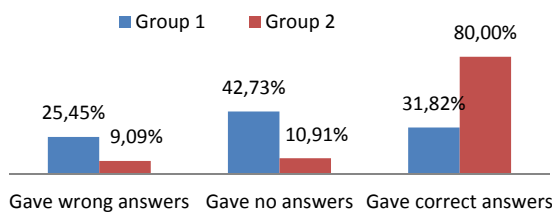


Figure 7: A comparison of users' understanding between Group 1 and Group 2.

Further study was carried out to Group 2. The same approach was conducted to Group 2 in authoring two other courses: Introduction to Biology and Web Programming. A classification of authoring processes were applied to find out whether the

proposed authoring approach is suitable only for a particular stage or for all stages. Authoring Biology and Web Programming were in early stages of authoring, while authoring Java Programming was in an advance stage. The experiment result shows that the proposed authoring approach is suitable for both early and further stages of authoring.

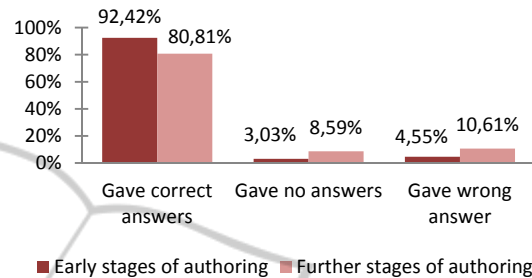


Figure 8: Participants' awareness.

Discussion. In the second experiment, learning designers were required to make some updates in ongoing collaborative authoring. They were required to understand how the authoring was going on. Group 1 could gain awareness only from the current states of the authored learning designs, while Group 2 could also learn from the provided Notes and History. The experiment result presents an evidence that Notes and History give positive implication to learning designers' awareness in early and further stages of authoring.

5 CONCLUSIONS

The granularity of authoring indicates that implicit coordination is appropriate for collaborative authoring of IMS LD. The data analysis results showed that participants worked collaboratively in authoring pedagogical knowledge, including adapting materials. The granularity of authoring is high since they did collaboration in authoring all IMS LD elements, including plays and the underlying elements (acts and role-parts), learning/support activities and activity groups, properties, and conditions. As former studies on adaptive learning have proved that people can work collaboratively in authoring learning content, this experiment confirms that they also can collaboratively work in creating pedagogical knowledge (**Conclusion 1**).

Second, the usability of Notes and History was tested through a between-group quantitative study. The study compared the workspace awareness and

the contribution of two groups of learning designers; one group was supported with Notes and History, while the other was not. Learning designers supported with Notes and History presented better contribution and higher workspace awareness than the others. They understood what updates had been made, what other authors had done, what the reasons of updates, and who made update. To conclude, the experiment results present evidence that Notes and History give positive impacts in authoring IMS LD (**Conclusion 2**). Another finding was about the importance of Notes. Learning designers considers that Notes and objects' Notes are more necessary than History's Note (**Conclusion 3**).

Finally, although the experiments have confirmed that asynchronous collaborative authoring method with features for limited communication (Notes) and workspace awareness (Notes and History) is suitable for authoring learning designs, further studies to compare this approach with other approaches are required to find the best approach for collaborative authoring of IMS LD.

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