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Formal Method of Description Supporting Portfolio Assessment

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ABSTRACT

Teachers need to assess learner portfolios in the field of education. However, they need support in the process of designing and practicing what kind of portfolios are to be assessed. To solve the problem, a formal method of describing the relations between the lesson forms and portfolios that need to be collected and the relations between practices and these collected portfolios was developed. These relations are indispensable in portfolio assessment. A support system for these based on the formal method was also developed. As the formal method of description can precisely and consistently describe these relations, the system makes it possible to support the assessment of portfolios in the design and practice phases.

Keywords

Portfolio assessment, Formal description, Support system, Assessment tool, Educational evaluation

Introduction

Although traditional methods of evaluation based on tests have improved in the field of education, portfolio assessment has attracted attention as a more authentic means of evaluating learning directly. The use of Electronic Portfolios (Digital Portfolios), in which the portfolio is saved electronically, is spreading with computerized learning systems (Mochizuki et al., 2003).

However, portfolio assessment has not been carried out adequately in the educational field because of two problems, and teachers and learners both need support (Morimoto *et al.*, 2005).

- Problem 1: When teachers decide to use portfolios for lessons that they intend to assess, they do not know what kinds of portfolios need to be collected. In other words, they need support in the design phase of portfolio assessment.
- Problemt 2: Learners do not know which collected portfolios should be used for practices. For example, when a learner carries out his or her self-assessment, he or she does not know that he or she should carry out the self-assessment while checking which collected portfolios should be used. In other words, learners need support on which portfolios they need to assess in the practice phase.

Support for portfolio assessment is carried out with tools that treat electronic portfolios (Chang, 2001; Chen *et al.*, 2000; Fukunaga *et al.*, 2001). However, these tools cannot support teachers in selecting which portfolios to assess. Moreover, teachers have to match the type of collected portfolio and the method of practice to the tools being used because these tools individually determine the types of collected portfolios and the practice method. Therefore, support of portfolio assessment in the lesson that the teacher intends to assess cannot be expected. The relation between practices and collected portfolios is not clear, and practices are not supported. These tools cannot solve Problems (1) or (2).

The purpose of this study is to achieve support for portfolio assessment at the design and practice phases, and solve these problems at the same time. We therefore developed a formal method of describing the relations

among elements that are indispensable in assessing portfolios and a support system for these based on this method. As the formal method of description can precisely and consistently describe the relations between the lesson forms and portfolios that need to be collected and the relations between practices and collected portfolios, the system makes it possible to support the assessment of portfolios in the design and practice phases.

First, we outline the support of portfolio assessment that this study is aimed at. Second, we discuss the relations between elements indispensable to the support of portfolio assessment. These relations become the framework for the formal description method that we developed. Third, we explain the formal description method. Finally, we discuss the portfolio assessment support system (PASS), which is based on this method.

Support of portfolio assessment in this study

Requirements for solving problems

To solve Problem (1) in the design phase, we have to extract and clarify the relations between lesson forms and portfolios that need to be collected, and support portfolio-assessment design based on these relations. Moreover, to solve Problem (2) in the practice phase, we have to extract and clarify the relations between practices and collected portfolios, and support user portfolio-assessment practices based on these relations. Here, a person who carries out practices is called a "user". Namely, a user means a learner, a teacher, or others.

To achieve these two phases of support, we need to faithfully express the extracted relations. If a formal method that precisely and consistently describes the extracted relations is developed, a system is possible that systematically supports portfolio assessment based on the formal method. Therefore, the requirements for solving Problems (1) and (2) are as follows.

Requirement(a): Extract and clarify the relations between the lesson forms and portfolios that need to be collected, and develop a formal method of describing these relations (Corresponds to Problem (1)).

Requirement(b): Extract and clarify the relations between a user's practices and collected portfolios that a user needs to carry out practices, and develop a formal method of describing these relations (Corresponds to Problem (2)).

Requirement(c): Develop a system based on the formal method of description developed in (a) and (b) (Corresponds to Problems (1) and (2)).

Blueprints to support portfolio assessment

It is possible to support teachers' designs for assessing portfolios and users' practices by formally describing the relations between the lesson forms and portfolios that need to be collected (PDS: *P*ortfolio assessment *D*esign *S*emantics), which satisfy Requirement (a), and the relations between practices and collected portfolios (PPS: *P*ortfolio assessment *P*ractice *S*emantics), which satisfy Requirement (b), and develop a system based on these relations (see Figures 1 and 2).

Figure 1 outlines a model illustrating how a teacher uses lesson forms to check PDS to select portfolios and how he or she uses portfolios to check PDS to select the lesson forms in the design phase. When he or she specifies the lesson form that he or she intends to teach, the system checks PDS and presents the portfolios that need to be collected dynamically according to this form. Moreover, when a teacher specifies portfolios that users need to collect first, the system presents lesson forms conforming to portfolios according to PDS. Thus, both lesson forms and portfolios are supported using PDS, and teachers can design portfolio assessment more easily. Both Requirements (a) and (c) are satisfied, and a solution to Problem (1) is expected.

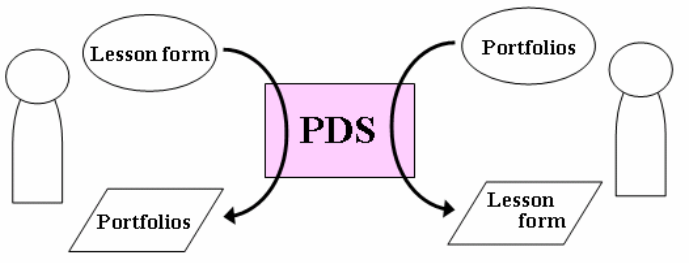

Figure 1. Model supporting teacher's portfolio-assessment design

Figure 2 outlines a model illustrating how a user uses practices to check PPS to select portfolios and how a user uses portfolios to check PPS to select practice in the practice phase. When a user specifies the practice that the user wants to carry out, the system checks PPS and presents collected portfolios that the user needs for the practice. The user can therefore effectively practice by checking necessary collected portfolios. Moreover, when the user specifies a collected portfolio, the system dynamically supports practice that adjusts the portfolio according to PPS. Thus, both practice and portfolios are supported using PPS. Here, both Requirements (b) and (c) are satisfied, and a solution to Problem (2) is expected.

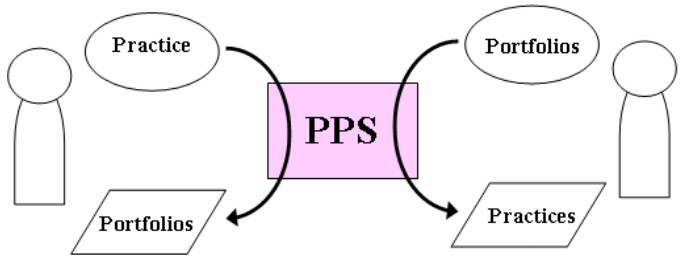

Figure 2. Model supporting user's portfolio-assessment practices

Advantages of formal description

We want to describe the PDS and PPS by using a formal method. The advantages of formally describing PDS and PPS are as follows.

- The relations between elements indispensable to the support of portfolio assessment can precisely be described by removing contradictions and vagueness,
- It is possible for the system developer to develop a support system that works systematically according to semantics formally described by constructing the system, which can interpret the framework for the formal description method and work based on it,
- As a result, a portfolio assessment support system that provides adaptive support according to the lesson form or a user's practices can be achieved, and
- Changing the semantics of the framework with formal description rules can easily change the support methods of the developed system.

Extracting relations to support portfolio assessment

Outline

In this section, we discuss our extraction of the relations between elements indispensable for supporting portfolio assessment, which became the framework for formal description that was developed in this study. PDS and PPS were extracted.

It is necessary to extensively investigate actual portfolios to assess them. However, the ideas and methods for assessing portfolios are inconsistent and varied (Bruke, 1992; Hart, 1993; Barton & Collins, 1996; Puckett & Black, 1999; Shores & Grace, 1998). We therefore focused on assessing indispensable portfolios that teachers actually use. We analyzed 298 practical records such as lesson plans that had actually been used. We extracted and analyzed methods and ideas applied to actual practical portfolio-assessment records, which teachers had obtained by trial and error. This paper discusses support for portfolio assessment based on these extracted results. However, this might be insufficient for extraction. This is because there may be a method of assessing portfolios that has been derived from analytical targets. We used these extraction results to devise a formal method of description. Therefore, although the relations we extracted form the framework for supporting portfolio assessment, which were our study targets, the formal method of description that we developed and discuss in the next section needs to be changed based on the framework.

Extracting PDS

We clarified the relations between lesson forms and portfolios that needed to be collected (Table 1). These relations will be represented by "*P*ortfolio assessment *D*esign *S*emantics (PDS)". The rows in Table 1 are for

lesson forms, and the columns are for collected portfolios. Here, "X" means that the portfolio corresponds to the lesson form that needs to be collected. For example, if a teacher wants to carry out portfolio-assessment design, he or she decides the lesson form and finds the "X" in the corresponding row. Portfolios with "X" need to be collected. Teachers can also identify corresponding lesson forms by specifying portfolios first. Therefore, portfolios that need to be collected according to lesson forms can be adequately identified by PDS.

We found from the rows that lesson forms conforming to the assessment of portfolios changed under three conditions, i.e., the lesson style, the person who set tasks for the lesson, and the person who created rubrics. In extracting lesson styles, we paid attention to learners' behaviors in a class, and classified lesson forms into eleven lesson styles. These were "Lecture", where the lesson is given in the form of a lecture, "Question and Answer", where learners answer a teacher's questions, "Exercise", where learners repeat exercises, "Skill acquisition", where skills are acquired, "Expression", where the body is used to express ideas, "Creation", where something is created, "Discussion", where there is a discussion, "Seminar", where people in a group learn from one another, "Experiment or Observation", where phenomena are verified through experiments or observations, "Experience", where social and technical experience is used, and "Problem Solving", where learners attempt problem solving by themselves. In extracting the "person who assigns tasks (Setting Tasks)", we found that there were two kinds of cases where the teacher set them or the learner set them. In extracting "person who creates rubrics (Rubric Creation)", we found there were three kinds of cases where the teacher created them, the learner created them, or the teacher and the learner collaboratively created them.

Collected portfolios in the columns were classified separately in terms of portfolios concerning records of assessment (Assessment Portfolios), portfolios concerning learners' work (Work Portfolios), portfolios concerning records of learning processes (Process Portfolios), and other portfolios. We classified them according to their original role in learning without getting caught up with the common name for the portfolio. Work Portfolios were classified into ten kinds. We classified Production into two types. The first was "Sample Based", which was based on a sample, the second was "Original Based" which was the learner's original. We also classified Reports and Notes into two types. We called one's own assessments in the Assessment Portfolios with rubrics "Self-assessment", and called looking back on one's activities without rubrics "Reflection". We also called mutual assessments with rubrics "Other-assessment", and called advising one another freely without rubrics "Advice". We classified Process Portfolios into three types. The first was "Learning-record" where the learner objectively describes his or her ongoing learning in a log, the second was "Anecdotal-record" where the teacher describes a learner's spontaneous events and behaviors, and the third was "Conversation-record" which describes conversations. We also classified the Learning-record into two types. The first was "Premeditated-record", which describes premeditation according to lesson plans, and the second was "Situation-record", which describes situations. Other portfolios consisted of records of portfolio conferences ("Portfolio Conference"), learning plans ("Learning Plan"), and learning materials ("Learning Material").

Extracting PPS

We extracted the relations between practices and collected portfolios (Table 2). The relations will be represented by "*P*ortfolio assessment *P*ractice *S*emantics (PPS)". Here, "X" means that the portfolio corresponds to the practices that are necessary to carry it out. For example, when a learner carries out practices, he or she finds an "X" in the corresponding row. Portfolios with "X" are collected portfolios that are needed for carrying out practices. The learner can also identify corresponding practices by specifying portfolios first. Therefore, portfolios that are needed for practices can be adequately identified by PPS.

We found ten kinds of practices that could be carried out during the process of assessing portfolios. These were "Browsing", where collected portfolios were perused, "Self-assessment", where one assesses one's self, "Other-assessment", where others are assessed, "Reflection", where one reflects on his or her learning, "Advice", where advice is given to someone, "Registration of Work Portfolios", where work portfolios are registered, "Selection of Collected Portfolios", where one's collected portfolios are carefully selected, "Process Recording", where process portfolios are recorded, "Rubric Creation", where rubrics are created, and "Portfolio Conference", where the state of the portfolio conference is recorded. We also found teachers, learners, and others (e.g., parents and specialists) were people who carried out practices.

Table 1. Relationships between lesson forms and collected portfolios: PDS

Lesson form				Assessment Portfolios					Work Portfolios										Process Portfolios				Other Portfolios		
Lesson style	Setting Tasks		Rubric Creation	Rubric	Asssessment with rubric		Assessment without rubric		Production		Report		Note		Collection	Test	Presentation	Practical ability	Learning-record		Conversation -record	Anecdotal -record	Portfolio Conference	Learning Plan	Learning Material
					Self-assessment	Other-assessment	Reflection	Advice	Sample Based	Original Based	Conclusion	Impression	Lesson Note	Other Note					Situation -record	Premeditated -record					
Lecture	Teacher	X	Teacher	X	X	X		X						X			X		X			X	X		X
			Collaboration																						
			Learner																						
	Learner																								
Question and Answer	Teacher	X	Teacher	X	X	X		X					X	X	X	X			X		X	X	X		X
			Collaboration																						
			Learner																						
	Learner																								
Exercise	Teacher	X	Teacher	X	X	X		X						X		X			X			X	X		X
			Collaboration	X	X	X		X						X		X			X			X	X		X
			Learner																						
	Learner																								
Skill acquisition	Teacher	X	Teacher	X	X	X		X		X				X		X			X			X	X		X
			Collaboration	X	X	X	X	X	X	X				X		X			X			X	X		X
			Learner																						
	Learner																								
Expression	Teacher	X	Teacher	X	X	X		X									X	X	X			X	X		X
			Collaboration	X	X	X	X	X	X						X		X	X	X	X		X	X	X	X
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X						X		X	X		X		X	X	X	X
			Learner	X	X	X	X	X	X						X		X	X		X		X	X	X	X
Creation	Teacher		Teacher	X	X	X		X		X				X					X			X	X		X
		X	Collaboration	X	X	X	X	X	X	X				X		X			X	X		X	X	X	X
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X	X					X					X		X	X	X	X
			Learner	X	X	X	X	X	X	X					X					X		X	X	X	X
Discussion	Teacher		Teacher	X	X	X	X	X	X		X	X	X		X				X	X	X	X	X		X
		X	Collaboration	X	X	X	X	X	X		X	X	X		X				X	X	X	X	X	X	X
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X		X	X	X		X					X	X	X	X	X	X
			Learner	X	X	X	X	X	X		X	X	X		X					X	X	X	X	X	X
Seminar	Teacher		Teacher	X	X	X	X	X	X		X	X	X		X				X	X	X	X	X		X
		X	Collaboration	X	X	X	X	X	X		X	X	X		X				X	X	X	X	X	X	X
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X		X	X	X		X					X	X	X	X	X	X
			Learner	X	X	X	X	X	X		X	X	X		X					X	X	X	X	X	X
Experiment or observation	Teacher		Teacher	X	X	X		X			X		X						X			X	X		X
		X	Collaboration																						
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X		X	X			X		X			X		X	X	X	X
			Learner																						
Experience	Teacher		Teacher	X	X	X	X	X	X		X	X	X		X				X			X	X		X
		X	Collaboration	X	X	X	X	X	X		X	X	X		X				X	X		X	X	X	X
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X		X	X	X		X		X			X		X	X	X	X
			Learner	X	X	X	X	X	X		X	X	X		X		X			X		X	X	X	X
Problem solving	Teacher		Teacher	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X
		X	Collaboration	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X
			Learner																						
	Learner		Teacher																						
		X	Collaboration	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X
			Learner	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X

Table 2. Relationships between practices and collected portfolios: PPS

Practices	User		Assessment Portfolios					Work Portfolios										Process Portfolios				Other Portfolios		
			Rubric	Asssessment with rubric		Assessment without rubric		Production		Report		Note		Collection	Test	Presentation	Practical ability	Learning-record		Conversation -record	Anecdotal -record	Portfolio Conference	Learning Plan	Learning Material
				Self-assessment	Other-assessment	Reflection	Advice	Sample Based	Original Based	Conclusion	Impression	Lesson Note	Other Note					Situation -record	Premeditated -record					
Browsing	Learner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
	Teacher	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Others	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Self-assessment	Learner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	
	Teacher																							
	Others																							
Other-assessment	Learner																							
	Teacher	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	
	Others	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X	X				
Reflection	Learner	X				X		X	X	X	X	X	X	X	X	X	X	X	X	X				
	Teacher																							
	Others																							
Advice	Learner																							
	Teacher	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Others	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Registration of work portfolios	Learner	X																						
	Teacher																							
	Others																							
Sellection of collected portfolios	Learner	X						X	X	X	X	X	X	X	X	X	X	X	X	X				
	Teacher																							
	Others																							
Process Recording	Learner	X																X	X	X				
	Teacher	X																X	X	X	X			
	Others																							
Rubric Creation	Learner	X																					X	
	Teacher	X																					X	
	Others																							
Portfolio Conference	Learner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Teacher	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Others	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Formal description method

Development policy

This section describes the development of the method for formally describing PDS and PPS. Formal methods of description are currently being developed and used within the syntax definitions of programming languages, the context of software engineering, and other applications. These are necessary and indispensable for achieving systematic processing by computers, and specialists can effectively obtain precise and consistent specifications for system models.

The formal method of description we have aimed at in this study should be able to precisely and consistently describe relations between elements indispensable for supporting portfolio assessment. In other words, the method of formal description can describe the structure and content of the model supporting the design of teachers' portfolio-assessment designs (Figure 1) and the model supporting users' portfolio-assessment practices (Figure 2). Moreover, it is necessary to design description rules to change dynamically to provide further portfolio assessment support in the future. However, a formal method specialized for describing the relations between the elements has not been found. We have therefore aimed at developing an original method for describing the relations between the elements. The framework to describe PDS and PPS precisely and consistently can be acquired by further developing our formal method of description. Therefore, a solution to Requirement (c) can be expected.

Definitions

Here, we provide definitions for PDS and PPS as follows.

Definition 1

PDS is the relation between the set of lesson forms (LF) and the set of collected portfolios (CP). Therefore:

$$LF <=> CP.$$

Here, LF is:

$$LF = LT \times PT \times PR.$$

And, CP is the subset of all portfolios:

$$CP = WP \cup PP \cup AP \cup OP.$$

LT is the set of lesson styles, PT is the set of persons who assign tasks, PR is the set of persons who create rubrics, WP is the set of work portfolios, PP is the set of process portfolios, AP is the set of assessment portfolios, and OP is the set of other portfolios.

The relations between details of lesson forms and the kinds of collected portfolios are:

$$[lt, pt, pr] <=> [wp, pp, ap, op]$$

Here, $lt \in LT, pt \in PT, pr \in PR, wp \subseteq WP, pp \subseteq PP, ap \subseteq AP, op \subseteq OP$ //

Definition 2

PPS is the relation between the set of practices (UP) and the set of collected portfolios (CP). Therefore:

$$UP <=> CP.$$

Here, UP is:

$$UP = PN \times UU.$$

And, CP is the subset of all portfolios:

$$CP = WP \cup PP \cup AP \cup OP.$$

PN is the set of practice names, UU is the set of users, WP is the set of work portfolios, PP is the set of process portfolios, AP is the set of assessment portfolios, and OP is the set of other portfolios.

The relations between details of practices and the kinds of collected portfolios can be written as:

$$[pn, uu] <=> [wp, pp, ap, op]$$

Here, $pn \in PN, uu \in UU, wp \subseteq WP, pp \subseteq PP, ap \subseteq AP, op \subseteq OP$ //

Notation

This section proposes a notation based on the definitions in the previous section. Tables 1 and 2 list the PDS and PPS we extracted. Therefore, the developed notation needs to satisfy the following two Requirements.

i. To be able to freely add and delete items that comprise the table (i.e., lesson form, collected portfolios, and others), and rewrite the relations.
ii. To be able to precisely and clearly describe which computer systems read the text written by the notation and work systematically while checking the correspondence to the description in the text.

The notation consists of three parts: declaring symbols (Symbol), showing the structure of relations (Structure), and describing relations (Relations). Figure 3 shows a concrete example, which describes part of the PDS in Table 1 with the notation.

```
#Symbol:
LT="Lesson type"; PT="Person who sets tasks"; PR="Person who creates rubrics";
AP="Assessment portfolio"; WP="Work portfolio"; PP= "Process portfolio"; OP="Other portfolio";
lec="Lecture"; q&a="Question and answer"; exe="Exercise"; skl="Skill acquisition"; cre="Creation";
dis="Discussion"; sem="Seminar"; eob="Experiment or observation"; exp="Experience"; plb="Problem solving";
tcr="Teacher"; lnr="Learner"; clb="Collaboration by teacher and learner";
rbc="Rubric"; sfa="Self-assessment"; ota="Other-assessment"; ref="Reflection"; adv="Advice";
sam="Sample based"; org="Original based"; con="Conclusion"; imp="Impression"; lnt="Lesson note";
ont="Other Note"; col="Collection"; tst="Test"; prt="Presentation"; pra="Practical ability";
sit="Situation-record"; prd="Premeditated-record"; cnv="Conversation-record"; anc ="Anecdotal-record";
pcf="Portfolio conference"; lpl="Learning plan"; lmt="Learning material";

#Sturcture:
[LT,PT,PR] <=> [AP,WP,PP,OP]
LT={lec,q&a,exe,skl,cre,dis,sem,eob,exp,plb};
PT={tcr,lnr};
PR={tcr,lnr,clb};
AP={rbc,sfa,ota,ref,adv};
WP={sam,org,con,imp,lnt,ont,col,tst,prt,pra};
PP={sit,prd,cnv,anc};
OP={pcf,lpl,lmt};

#Relations:
[lec,tcr,tcr] <=> [{rbc,sfa,ref}, {lnt,tst}, {sit,anc}, {pcf,lmt}];
[q&a,tcr,tcr] <=> [{rbc,sfa,ref}, {lnt,ont,col,tst}, {sit,cnv,anc}, {pcf,lmt}];
[exe,tcr,tcr] <=> [{rbc,sfa,ref}, {ont,tst}, {sit,anc}, {pcf,lmt}];
[exe,tcr,clb] <=> [{rbc,sfa,ref}, {ont,tst}, {sit,anc}, {pcf,lmt}];
[skl,tcr,tcr] <=> [{rbc,sfa,ref}, {sam,lnt,col}, {sit,anc}, {pcf,lmt}];
[skl,tcr,clb] <=> [{rbc,sfa,ota,ref,adv}, {sam,org,lnt,col}, {sit,anc}, {pcf,lmt}];
[exp,tcr,tcr] <=> [{rbc,sfa,ref}, {prt,pra}, {sit,anc}, {pcf,lmt}];
[exp,tcr,clb] <=> [{rbc,sfa,ota,ref,adv}, {col,prt,pra}, {sit,prd,anc}, {pcf,lpl,lmt}];
[exp,lnr,clb] <=> [{rbc,sfa,ota,ref,adv}, {col,prt,pra}, {prd,anc}, {pcf,lpl,lmt}];
[exp,lnr,lnr] <=> [{rbc,sfa,ota,ref,adv}, {col,prt,pra}, {prd,anc}, {pcf,lpl,lmt}];
[cre,tcr,tcr] <=> [{rbc,sfa,ref}, {sam,lnt,col}, {sit,anc}, {pcf,lmt}];
[cre,tcr,clb] <=> [{rbc,sfa,ota,ref,adv}, {sam,org,lnt,col}, {sit,prd,anc}, {pcf,lpl,lmt}];
[cre,lnr,clb] <=> [{rbc,sfa,ota,ref,adv}, {sam,org,col}, {prd,anc}, {pcf,lpl,lmt}];
[cre,lnr,lnr] <=> [{rbc,sfa,ota,ref,adv}, {org,col}, {prd,anc}, {pcf,lpl,lmt}];
```

Figure 3. Description of PDS with notation

For example, when a teacher designs the assessment of portfolios in lesson form that consist of "Lesson Style: Creation", "Setting Tasks: Teacher", and "Rubric Creation: Collaboration by Teacher and Learner",

`[cre,tcr,clb]<=>[{rbc,sfa,ota,ref,adv},{sam,org,lnt,col},{sit,prd,anc},{pcf,lpl,lmt}]`,

which is a rule of notation that specifies that the portfolios that need to be collected are "Rubric", "Self-assessment", "Other-assessment", "Reflection", "Advice", "Production: Sample based", "Production: Original based", "Note: Lesson Note", "Collection", "Learning-record: Situation-record", "Learning-record: Premeditated-record", "Anecdotal-record", "Portfolio Conference", "Learning Plan", and "Learning Material" in Table 1.

Although Figure 3 is a description corresponding to Table 1, the structure of the table can be changed and the relations can also be changed individually. In other words, even if relations are changed and added, the notation can still be expressed.

PPS can be described like PDS. Figure 4 describes part of the PPS in Table 2 with the notation.

```
#Symbol:
PN="Practice name"; UU="User";
AP="Assessment portfolio"; WP="Work portfolio"; PP="Process portfolio"; OP="Other portfolio";
bro="Browsing"; prsa="Self-assessment"; proa="Other-assessment"; prrf="Reflection"; prad="Advice"
rgt="Registration of work portfolios"; slt="Selection of collected portfolios"; prec="Process Recording";
rcre="Rubric Creation"; prcf="Portfolio Conference"; tcr="Teacher"; lnr="Learner"; otr="Other";
rbc="Rubric"; sfa="Self-assessment"; ota="Other-assessment"; ref="Reflection"; adv="Advice";
sam="Sample based"; org="Original based"; con="Conclusion"; imp="Impression"; lnt="Lesson note";
ont="Other Note"; col="Collection"; tst="Test"; prt="Presentation"; pra="Practical ability";
sit="Situation-record"; prd="Premeditated-record"; cnv="Conversation-record"; anc="Anecdotal-record";
pcf="Portfolio conference"; lpl="Learning plan"; lmt="Learning material";

#Sturcture:
[PN,UU] <=> [AP,WP,PP,OP]
PN={bro,prsa,proa,prrf,prad,rgt,slt,prec,rcre,prcf};
UU={tcr,lnr,otr};
AP={rbc,sfa,ota,ref,adv};
WP={sam,org,con,imp,lnt,ont,col,tst,prt,pra};
PP={sit,prd,cnv,anc};
OP={pcf,lpl,lmt};

#Relations:
[bro,lnr]<=>[{rbc,sfa,ota,ref,adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv},{pcf,lpl,lmt }];
[bro,tcr]<=>[{rbc,sfa,ota,ref,adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv,anc},{pcf,lpl,lmt}];
[bro,otr]<=>[{rbc,sfa,ota,ref,adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv},{pcf,lpl,lmt}];
[prsa,lnr]<=>[{rbc,sfa,ota,ref,adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv},{lpl}];
[pros,tcr]<=>[{rbc,sfa,ota,ref,adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv,anc},{lpl}];
[pros,otr]<=>[{rbc,ota},{sam,org,com,imp,lnt,ont,col,tst,prt,pra}, {sit,prd,cnv},{}];
[prrf,lnr]<=>[{ref},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv},{}];
[prad,tcr]<=>[{adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv,anc},{}];
[prad,otr]<=>[{adv},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv},{}];
[slt,lnr]<=>[{},{sam,org,com,imp,lnt,ont,col,tst,prt,pra},{sit,prd,cnv},{}];
```

Figure 4. Description of PPS with notation

As previously discussed, we developed a framework that formally describes PDS and PPS. As the framework can be used to describe the relations between the lesson forms and portfolios that need to be collected and the relations between a user's practices and collected portfolios that a user needs to carry out practices, Requirements (a) and (b) are satisfied.

The system can systematically analyze relations by reading text described with the notation. As a result, we can also expect a solution to Requirement (c).

Portfolio Assessment Support System based on formal method of description

Outline of system

This section discusses our development of the *P*ortfolio *A*ssessment *S*upport *S*ystem, which we called PASS, based on the formal method of description. Figure 5 shows the system configuration. It consists of four subsystems: semantics analysis, design support, practice support, and DB management. Furthermore, each consists of various modules. We used Perl as the development language for the system, and also XMLDB.

- Semantics analysis
  The subsystem consists of PDS and PPS analysis modules. Each module checks PDS or PPS semantics. PDS and PPS are prepared as a text file beforehand.
- Design support
  The subsystem supports teachers' portfolio-assessment designs through cooperation with the design-interface and design-control modules. After receiving the teacher's orders from the design-interface module, the design-control module requests a check of the relations from the semantics analysis subsystem and receives the results. The design-interface module generates dynamically adaptive interfaces according to the results and provides them to the teacher.
- Practice support
  The subsystem supports the user's practice through cooperation with the practice-interface and practice-control modules. After receiving the user's orders from the practice-interface module, the practice-control module requests a check of the relations from the semantics analysis subsystem and receives the results. The practice-interface module generates dynamically adaptive interfaces according to the results, and provides them to the user.
- DB management
  The subsystem consists of a DB control module and Portfolio DB, and reads, writes, updates, and stores portfolios.

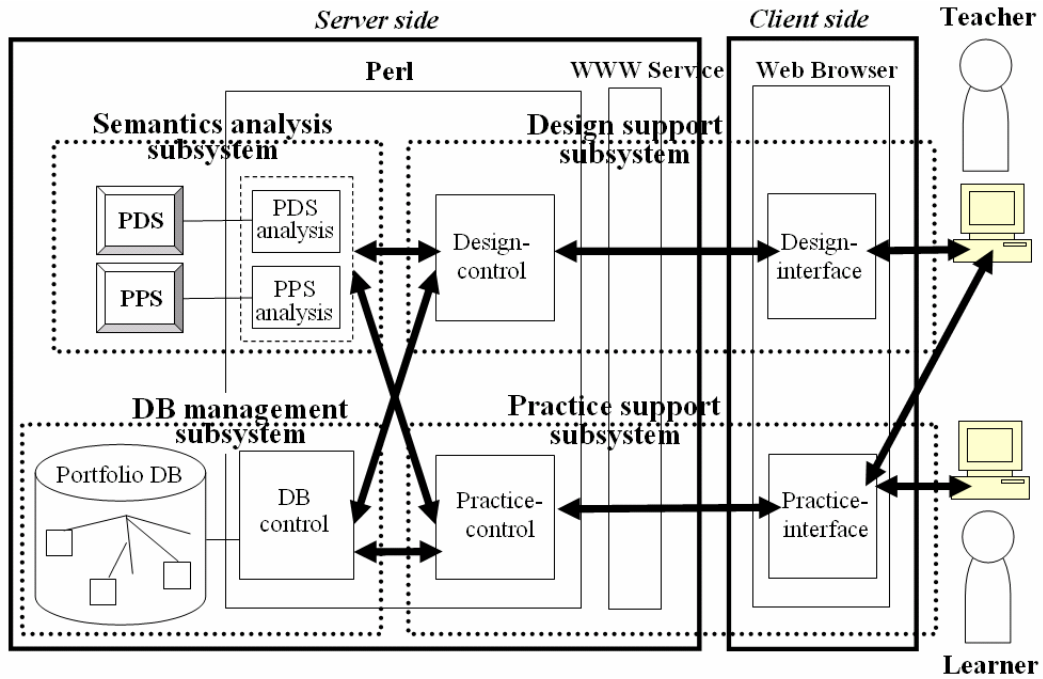

Figure 5. System configuration

Practical example

In the design phase, the teacher decides the lesson style first to support his or her portfolio-assessment design (left screen of Figure 6). He or she then decides who sets tasks and who creates rubrics (right screen). The right screen in Figure 6 shows the interface that the system generated dynamically based on PDS according to the teacher's decisions. This is the case of a lesson form that consists of "Lesson Style: Creation", "Setting Tasks: Teacher" and "Rubric Creation: Collaboration by Teacher and Learner". The system then determines necessary portfolios based on PDS according to the lesson form, generates the adaptive interface, and provides them to the teacher. Thus, the system supports portfolio-assessment designs that adjust to the teacher's intended lesson.

In the practice phase, when the learner clicks the "Self Assessment" button in the menu, the system checks PPS and provides him or her with collected portfolios that he or she needs for self-assessment (Figure 7). The learner can therefore self-assess him or herself efficiently with the collected portfolios.

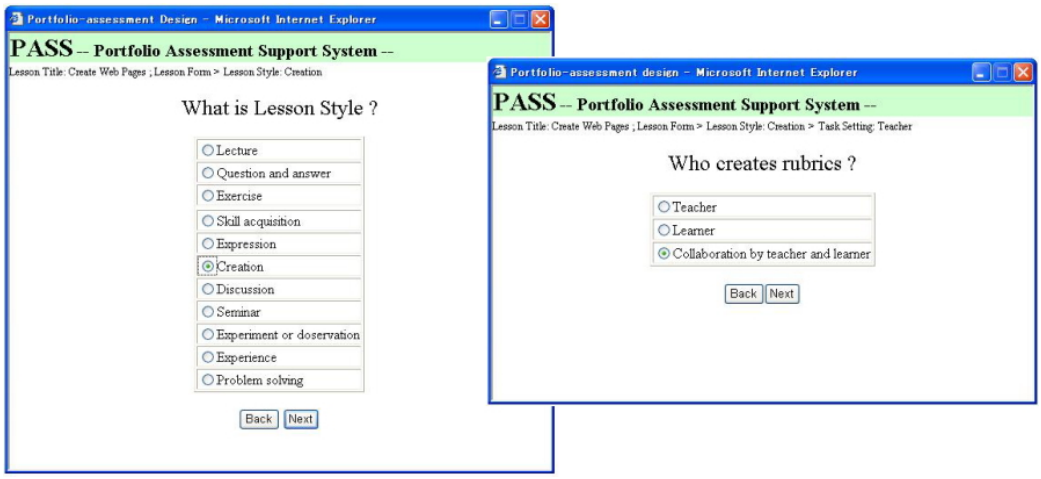

Figure 6. Screen of teacher's portfolio-assessment design

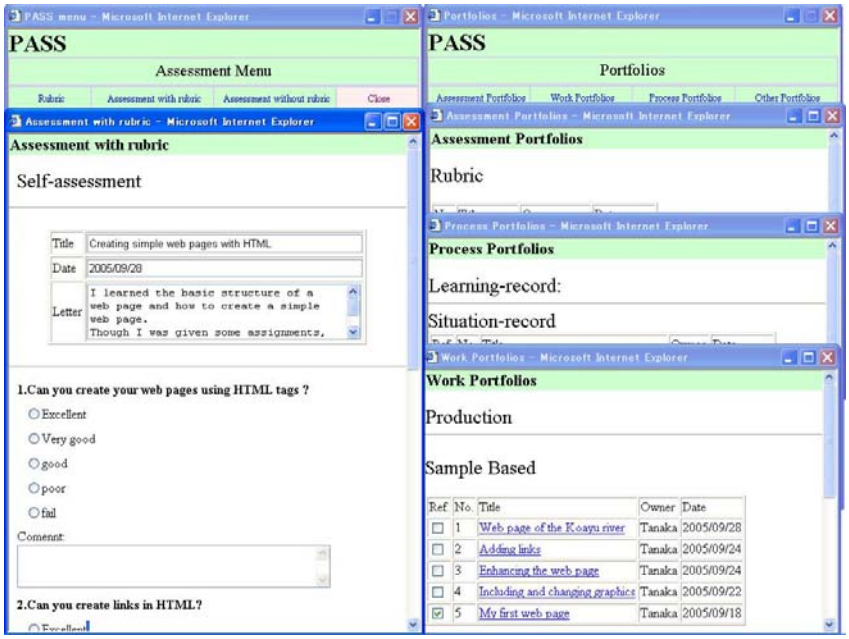

Figure7. Screen of user's portfolio-assessment practice

We developed a system that works systematically based on PDS and PPS, which satisfied Requirement (c). We also developed PASS, which satisfied Requirements (a), (b), and (c). Therefore, Problems (1) and (2) were solved.

Conclusion

We extracted and clarified the relations between lesson forms and portfolios that needed to be collected, i.e., *P*ortfolio assessment *D*esign *S*emantics (PDS) and the relations between practices and collected portfolios, i.e., *P*ortfolio assessment *P*ractice *S*emantics (PPS). We also developed a formal method of describing all relations between PDS and PPS. Moreover, we developed a portfolio assessment support system (PASS) based on the formal description method, which can precisely and consistently describe PDS and PPS. The system makes it possible to assess portfolios according to the lesson forms and practices based on the formal description method. Reusing past lessons has made it possible to design a more efficient way of portfolio assessment by storing past lessons for which portfolios have been assessed as case studies based on the formal description framework.

There are specifications related to assessment. They are QTI (2005) and ePortfolio (2005). QTI (2005) is a specification that enables question and tests to be exchanged, and ePortfolio (2005) is a specification that can

allow comparability of portfolio data across organizations and interoperability of applications with other systems. However, it is impossible to achieve support for portfolio assessment at the design and practice phases by only using these specifications. Therefore, we expect that the formal description method we developed will become useful as a standard for portfolio assessment, and consider that its integration with QTI (2005), ePortfolio (2005), and other e-learning standards (e.g., Learning Design, 2003; SCORM2004, 2004) will make it even more efficient.

We intend to use the system in actual lessons and evaluate it in the near future.

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