國立交通大學

資訊科學與工程研究所

碩 士 論 文

建構一個合作式與適性化教學設計模型

Constructing a Collaborative and Adaptive Instructional Design Model

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摘　　要

教學設計是一個由老師專業知識與教學經驗衍生而來的抽象教學知識，在數位學習的環境中，數位課程也需要教學設計來增強教學的效果，所以，如何在數位學習中建立教學設計模型是一個重要的研究課題，對於這個課題，資訊科學領域提出了相當多的方法，但這些方法不是花費龐大就是不易了解，老師要將高階的教學知識實作於資訊系統中仍舊是件困難的事，因此我們使用知識技術方法在電腦系統中建立高階知識模型。在這篇論文中，我們提出了一個合作式與適性化教學設計模型(CAID)，此模型以一個有限狀態機(FSM)描述學習活動流程，FSM 中的狀態(State)為一個用來描述教學活動資訊的框架實體，而轉換函數(Transition)是一個可以被框架實體觸發的教學導引規則。老師可以藉由設計一個簡單的 FSM、選擇適當的框架實體化、並指定導引規則來建立一個數位課程，而這些框架與導引規則來自於經過分析先前教學設計研究而建立的框架階層架構與導引規則樣板。我們利用 CAID 模型實作精熟學習法、拼圖學習法與鷹架式學習法來評估此模型的表現能力。最後我們請教學專家來確認這些教學設計，而他們認為用 CAID model 設計出來的課程是正確且容易被了解的。

關鍵字：教學設計、知識技術方法、框架、有限狀態機

Constructing a Collaborative and Adaptive Instructional Design Model

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ABSTRACT

Instructional design is tacit knowledge of teaching approach with teachers' domain knowledge and teaching experience. In E-learning environment, instructional design is required to be used to improve the efficacy of learning. Therefore, it is an important research issue to model instructional design in E-learning. Although many systems and researches have been proposed, with large cost and non-user-friendly interfaces, the high-level knowledge is still difficult to apply in IT environment. Therefore, we use knowledge-based approach to model high-level knowledge in computer systems. In this thesis, we propose a Collaborative and Adaptive Instructional Design (CAID) model, in which the learning process of a pedagogical approach is modeled as a finite state machine, where the states of the FSM are frame instances to describe the information of learning activities, and the transitions of FSM are guidance rules triggered by those frame instances. Accordingly, a digital course can be constructed by designing a simple FSM, selecting appropriate frames, instancing the frames and specify guidance rules. These frames and guidance rules are selected from frame hierarchy and guidance rule templates, which are constructed from analyzing previous researches of learning. To evaluate the model's expressive power, we have implemented courses of Mastery Learning, Jigsaw Learning, and scaffolding instruction with CAID model. Finally, pedagogical experts conclude that the courses of CAID model are correct and easy to understand after checking these courses.

Keywords: Instructional design, Knowledge Based Approach, Frame, Finite state machine

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Chapter 1. Introduction

With the rapid growth of Internet, E-learning systems have become more and more popular because they can enable learners to study at any time and any location. However, the sharing and reusing of teaching materials among these systems is difficult because the formats of the teaching materials in different E-learning systems are usually defined according to their specific requirements. In order to solve this issue, several standard formats, such as SCORM [1], QTI [2], IEEE LOM [3], AICC [4], ARIADNE [5], etc., have been proposed by international organizations.

Instructional design (ID), which makes large influence of the learning efficacy, is a pedagogical approach with teaching theories. With good ID, learning becomes easier and more efficient for learners. Therefore, to preserve and reuse good ID in E-learning can help teachers to construct a learning activity (LA) with higher quality. However, ID pattern is the complex and abstract knowledge based on teachers' domain knowledge and teaching experience. Due to lacking the effective knowledge representation of ID, it is difficult for teachers to construct and reuse their ID patterns in E-learning.

Adaptive learning [6-10], which provides learners with appropriate learning materials according to learners' capabilities and requirements, and collaborative learning [11-14], which makes learners learn together in communication and cooperative learning tasks, are becoming the popular topics in the researches of ID. In [15], the Learning Design (LD) standard of IMS [16] has been proposed to represent the higher-level ID pattern. Although the specification of LD can express various LAs, the representations of LA units, e.g., conference, E-mail, and files, are too technique-oriented to understand for authors and teachers. Therefore, some authoring tools using straightforward approach to model LD have also been proposed to assist users who should be familiar with LD in designing the LD compliant LA.

In addition, Pedagogical pattern [12, 14, 17] can't be processed and reused directly due to nature language input format, and SCORM Sequence and Navigation (SN) [1], being capable of describing the learning activity and learning situation, is difficult for teachers to edit, reuse or maintain without better authoring tool [18-20] due to its complex definition of control rules and structures. Moreover, the expressive capability of SN is limited to model the collaborative and adaptive LA flexibly. Therefore, the design of LAs with pedagogical theory is hard to incorporate with SCORM standard and it is important to provide teachers a powerful ID model with a user-friendly interface to assist them in dealing with the complex LA.

However, some ID models in previous researches using low-level representation were too IT-oriented to understand for teachers, and the others using high-level were powerful less in expressive capability. Therefore, we apply the knowledge-based approach, which can model the ID knowledge by means of a variety of knowledge representations, and propose a Collaborative and Adaptive Instructional Design Model (CAID model) to help teachers design LA easily. In order to provide a user-friendly interface to visualize the complex learning sequence design, we represent the Learning Activity Structure (LAS) by means of a Finite State Machine (FSM), where the states are the LA units and transitions are the guidance rules. The LA units can be constructed by means of the LA unit templates represented as frames, which can be selected from a predefined hierarchical frame structure called the instructional design ontology (IDO), to assist teachers in realizing their abstract teaching concepts, where each frame describing a kind of LA unit contains the slots of necessary attributes, procedures, and rules which can be inherited by the sub-frames, to implement the LA unit. With the IDO to provide many kinds of predefined LA unit frames, it is easy for teachers to construct a LA unit by means of selecting the appropriate frames and specifying values to the necessary slots defined in frames. And then the designed LAs can be applied in IT environment with a frame inference engine.

In order to evaluate the model's expressive power, a classic adaptive learning approach, Mastery Learning proposed by Benjamin Bloom[21], a popular pedagogical approach of collaborative learning, Jigsaw Learning [22], and Scaffolding Instruction [23], have been used to implement courses based upon CAID. Finally, after reviewing these courses, pedagogical experts conclude that the courses constructed by CAID model are workable and beneficial for teachers.

Chapter 2. Related Work

In this section, we will discuss the previous researches, including instructional-design-specific E-learning system, Standard-based E-learning system, and the representation of learning processes.

2.1. Instructional-design-specific E-learning system

In most of the previous researches of instructional design in E-learning, the e-learning systems proposed are instructional-design-specific. It means that these systems are constructed based upon a predefined instructional design. For example, MATLAB [24], music [25], and field trips [26] are learning-subjects-specific and project based learning [13] is pedagogical-approach-specific. These researches are the pioneers to bring instructional design to E-learning. The reprogramming of the system may be required when the instructional design needs to be modified.

2.2. Standard Based E-learning System

To solve the above issue, standard based E-learning systems use the standard specification to help teachers realize their instructional design concept. And the instructional design can be exchanged and reused in standard format.

2.2.1. SCORM (Sharable Content Object Reference Model)

Among those existing standards for learning contents, SCORM, which was proposed by the Advanced Distributed Learning (ADL) organization in 1997, is currently the most popular one. The SCORM specification is a composite of several specifications developed by international standards organizations, including the IMS [16], IEEE LOM [3], SCORM [1], AICC [4] and ARIADNE [5]. In a nutshell, SCORM is a set of specifications for developing, packaging and delivering high-quality education and training materials whenever and wherever they are needed. The advantages of SCORM-compliant courses are reusable, accessible, interoperable, and durable.

At present, the Sequencing and Navigation (SN) in SCORM 2004 adopts the Simple Sequencing Specification of IMS. It relies on the concept of organizing learning activities into a hierarchical structure, namely activity tree (AT). Each activity node refers contents. As the AT example shown in Figure 2.1: The Activity Tree of SCORM SN, each learning activity node (such as A, AA, AB, AC, etc.) includes one or more child activities and associates a set of sequencing behaviors, defined by the Sequencing Definition Model (SDM). Finally, the SN uses the defined sequencing rules to control the sequencing, selecting and delivering behaviors of activities to the learner. The sequencing rules is as "***if*** *<condition set>* ***Then*** *<actions>*" format. Therefore, the rule-based inference engine seems appropriate to implement the sequence behavior of learning activities.

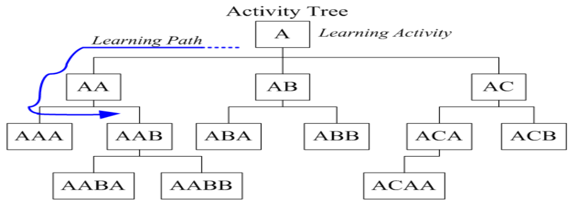


Figure 2.1: The Activity Tree of SCORM SN

2.2.2. IMS LD

The most popular standard of instructional design is IMS LD (Learning Design) specification [15]. LD was firstly called Educational Modeling Language (EML), which was proposed by Open University of the Netherlands. The LD specification concerns the definitions of role, activity, time and environment of learning. The condition rule and property of LD are also defined to control the behavior of learning activity. CopperCore [27] is the engine of IMS LD, and many authoring tools are constructed by different organizations, for examples, Reload [28], CopperAuthor [29], LAMS [30], ASK-LDT [31], Collage [32], and MOT+LD [33].

Since IMS LD standard is constructed with the viewpoint of information technology, it is difficult for teachers to understand and use it. The complex scope definitions of Properties and complex expressions of Conditions in IMS LD make IMS LD specification hard be done by teachers without the support of knowledge engineers.

2.3. Related Learning Platform

Brusilovsky [34] proposed a distributed intelligent learning system called KnowledgeTree, which emphasized on the combination of current web-based education technology and reusable system components. Four parts of this system are portal, activity server, value-adding server and student modeling server. Portal is the UI and course management for students and teachers. Activity Server is designed for the registration of learning content and learning activity. Value-Adding Server applies special functionality on learn resources, such as Adaptive Sequence, Annotation, Visualization and Content Integration. Student Modeling Server stores the student portfolios and provides inference engine for different queries of server. The module design of KnowledgeTree provides better maintainability of sub-system. However, the mechanism is still difficult for teachers to design the desired learning activity. Furthermore, it is neither SCORM nor LD compliant.

Fischer [35] developed a Multibook learning system with the extended LOM [3] metadata. It can (semi-) automatically generate the sequence of course and exercises using the knowledge ontology architecture. However, the generating mechanism is limited to fulfill the practical pedagogical needs.

The Learning Activity Management System (LAMS) [30] is a system for the design and management of online collaborative learning activity. It provides a user-friendly GUI for users to design a customized collaborative learning activity using its tools such as chat room. The design of teacher's environment can monitor the learning status of students. However, the lacks of editing the sequence or guidance of learning activity result in the difficulty to fulfill the practical pedagogical design. Furthermore, it is neither SCORM nor LD compliant.

Chapter 3. Collaborative and Adaptive Instructional Design Model

Due to lacking the effective knowledge representation of ID, it is difficult for teachers to construct and reuse their ID patterns in E-learning. Therefore, we apply the knowledge-based approach, which models the ID knowledge by means of knowledge representation mechanism, and propose a Collaborative and Adaptive Instructional Design Model (CAID model) to make teachers design LA easily.

In traditional courses, the LASs are always linear. However, since the requirement of adaptive LA, teachers need to design complex LASs to provide learners with different learning materials according to their requirements and capabilities. Therefore, in order to visualize the LAS design, we represent it by means of Finite State Machine (FSM), where states are the LA units describing the behavior of teaching and transitions are the guidance rules guiding learners to the next one after finishing a LA unit.

FSM is a model of behavior composed of states, transitions and actions, where state stores information about the situation, a transition indicates a state change and is described by a condition that would need to be fulfilled to enable the transition, and an action is a description of an activity that is to be performed at a given moment.

The modern LA units also need more complex functionalities. Personalized learning needs different learning resources and services to assist learners. Collaborative learning needs to manage learners with different roles and groups. The test needs to choose questions according to different concepts and difficulties. Thus, it is too complex for teachers to design all kinds of LA units with necessary attributes, rules, and procedures. In CAID model, The LA units can be constructed by means of the LA unit templates, which represented as frames can be selected from the predefined instructional design ontology (IDO). IDO is a hierarchical frame structure where each frame describing a kind of LA unit contains the slots of necessary attributes, procedures, and rules, which can be inherited by the sub-frames, to realize the LA unit. Since the IDO can provide many kinds of predefined LA unit frames, it is easy for teachers to construct a LA unit by means of selecting the appropriate frames and specifying values to the necessary slots defined in frames.

A frame [36-38] is a sort of knowledge skeleton with many slots to be filled. We can extend the representation and control over slots using facets. Frames structure is usually represented as ontology and they can have a kind-of slot, which allows the assertion of frame taxonomy. This hierarchy can then be used for inheritance of slots. As well as frames representing concepts, a frame-based representation may also contain instance frames, which represent particular instances.

The CAID course can be represented as a frame based representation, where the LA units are instances of frames in IDO, and the guidance rules can be appended to them. The learner models recording the learners' information and referred by guidance rules are also represented as frame instances. Therefore, it is workable with a frame inference engine in E-learning.

3.1. Definition of CAID model

In this section, we will discuss the definition of CAID model as shown in Figure 3.1.

1. CAID = (LAS, IDO) consists of learning activity structure (LAS) and instructional design ontology (IDO). In LAS, teachers can design a LA as a FSM, where the LA units are represented as the states and the guidance rules are represented as the transitions. The LA units of LAS are the instances of frames in IDO, which is a predefined frame hierarchical structure to provide teachers with LA unit templates represented as frames. The features of LA unit templates can be inherited by the sub-templates according to the "a kind of" relations.
2. LAS = (S, F, LAU, G, LM) consists of states, including a start state (S), a finish state (F), and LA units (LAU), transitions, which are the guidance rules (G) to assist learners in selecting the next LA unit, and Learner Model (LM), which record the information of learners including name, concepts, groups, roles, and some detail information.
3. LAU = $\{lau_1, lau_{2, \ldots,} lau_n\}$ is a finite set of LA units which are the instances of the LA unit templates represented as frames in IDO. These frame instances contain slots of attributes, rules, and procedures to describe the features of LA units.
4. G = $\{g_1, g_{2, \ldots,} g_n\}$ is a finite set of guidance rules, where $g_i \subseteq (s \times A) \cup (A \times A) \cup (A \times f)$. A guidance rule contains of a constraint defined as "if (condition) then nextLAU = target" where condition is referred to the information of Learner Model

which record the personal data and scores from LA units.

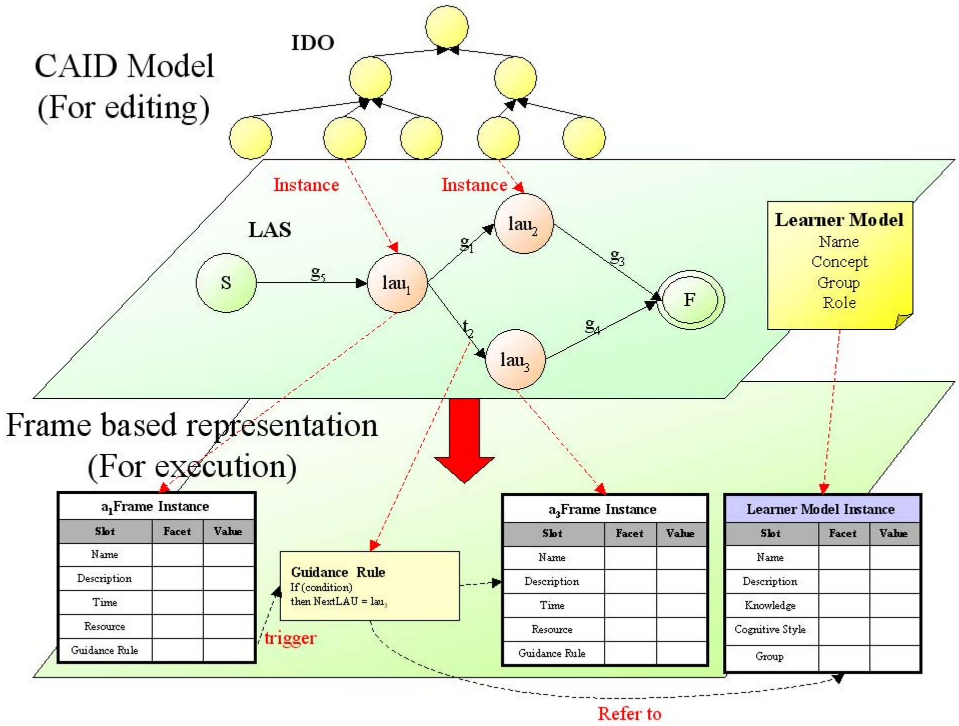


Figure 3.1: CAID model

In the following sections, we will discuss the IDO, LA unit templates, guidance rules, and the frame based representation of CAID course.

3.2. Constructing IDO

The two categories of instructional design are adaptive learning and collaborative learning. Test activities and Personal learning activities are needed in adaptive learning process. Test activities are used to evaluate learners' abilities, which are referred by guidance rules. Personal learning activities are provided for individual learning. Collaborative learning consists of collaborative learning activities, where learners will learn together, and tutoring learning activities, where learners will learn with tutors' help. All activities can be divided into several sub-activities. We construct the ontology of learning activities as shown in Figure 3.2.

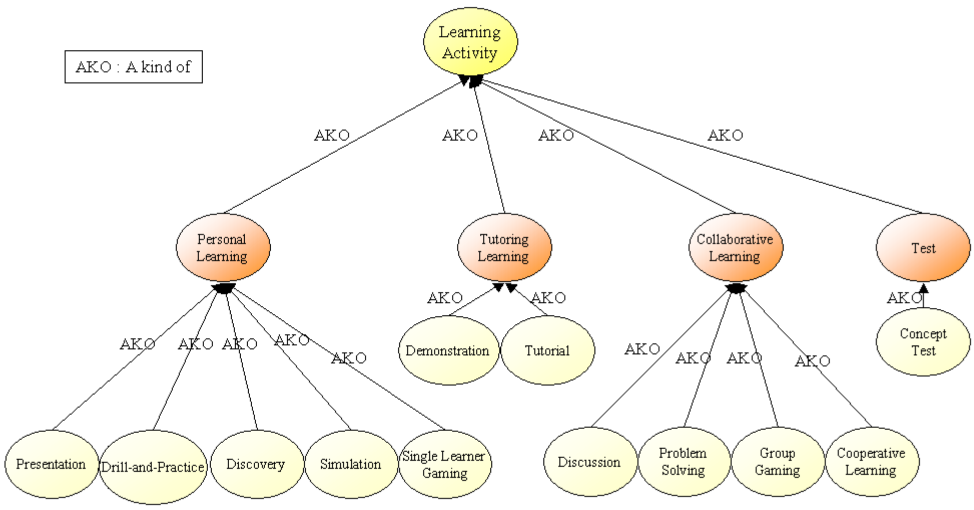


Figure 3.2: learning activity ontology

R. Heinich, et al. [39] differentiates between instructional methods into Presentation, Demonstration, Discussion, Drill-and-Practice, Tutorial, Cooperative Learning, Gaming, Discovery, and Problem Solving. In [40], the tests are important activities in pedagogical approaches. Personal learning activity, e.g., Presentation activities, Drill-and-Practice activities, single learner gaming activities, Discovery activities, and Simulation activities, is a type of learning activity in which learners study with only learning materials. In Presentation activities, learners study with some documents or multimedia learning resource. In Drill-and-Practice activities, the exercising tools are used. In single learner gaming activities, learners learn by playing with a game. In Discovery activities, the learners use an inductive approach with appropriate applications. Finally, in Simulation, the simulators provide a virtual environment for learners to learn and exercise.

Moreover, tutoring learning activities, which is a learning approach with a tutor to help learners, includes Demonstration activities and Tutorial activities. In Demonstration activities, the real examples are shown to learners and a tutor must answer questions to resolve misperception of learners. In Tutorial activities, a tutor must present the content, pose a question, request a learner response, analyzes the response, supply appropriate feedback, and provides practice.

Collaborative learning activities make learners learn by means of communication and cooperative working, such as Discussion activities, Group Gaming activities, Cooperative learning activities, and Problem Solving activities. In Discussion activities, learners discuss a topic together to exchange ideas and skills. Group gaming activities is a game for a group of learners, where learners must play competitively or cooperatively. In Cooperative learning activities, learners must work in team to accomplish a project. Problem solving activities is similar as Cooperative learning activities where a group of learners must solve a challenging problem collaboratively.

Test activity is an activity to evaluate learners' concepts, which can be referred to choose appropriate learning materials in adaptive LA.

3.3. LA unit templates

In IDO, each node is a LA unit template, which defined the necessary attributes given by teachers and predefined structure to form an executable learning activity. Table 3.1 shows the attributes of each LA unit template with the provider, who should determine the values of attributes. Because the IDO is a hierarchy, the sub-templates will inherit the attributes of the parent templates, e.g., the attributes of Learning Activity template appear in Personal Learning template. Therefore, all the leaf templates have the same attributes as their parent templates.

Table 3.1: Templates list of learning activities

LA unit Template	Attributes	Assign value	Description
Learning Activity	Name	Teacher	The name of this learning activity
	Description	Teacher	A text describing this activity
	Time	Teacher	The starting time of this learning activity
	Duration	Teacher	The duration of this learning activity
	Execution	System	It is a procedure to fire all the procedures and rules to execute the LA unit. The sub-LA units will overwrite this slot.
	Guidance rule	System	It is a set of Guidance rules defined as transitions of FSM in LAS. After the LA unit, these rules will be trigger to select the next unit
Personal Learning	Title	Teacher	The title of the personal learning activity unit

Tutoring Learning	Participant	Teacher	Type of tutees. It can be single learner, a group, or all learners
	Grouping	Teacher	If the Participant type is group, the kind of group needed to be denoted
	Tutor Type	Teacher	The tutor can be a teacher or a learner with specific role
	Tutoring Pair	Teacher	Determine the tutor-tutee relations
	Tutorial Tool	System	A tool of Q&A and controlling resources
Collaborative Learning	Rule of Activity	Teacher	A text of rule describing how to learn together
	Grouping	Teacher	The kind of group referred in this activity
	Role	Teacher	The kind of role referred in this activity
	Result	System	To store the result of the activity unit
	Record Result	System	It is a rule to record the result in Learner Model if Result is added
Test	Score	System	Score of this test
	Question Source	Teacher	The sources can be fixed questions or to select questions randomly with specific concepts from Item Bank
	Resources	Teacher	The questions used when the question sources are fixed questions
	Item Bank	System	It is a procedure to connect to item bank
	Contribution	System	It is a rule to record score to the Learner Model if the score is added
Presentation	Content	Teacher	The presented content
Drill-and-Practice	Practice service	Teacher	The practice service
Discovery	Media	Teacher	The discovery media
Simulation	Simulator	Teacher	The simulator
Single Learner Gaming	Game resource	Teacher	The game
Demonstration	Resources	Teacher	Resources for tutor to demonstrate

Tutorial	Resources	Teacher	It can be contents, questions, and practices
Discussion	Chat Room	System	A chat room service for discussion
Problem Solving	Service	System	A problem solving service
Group Gaming	Game resource	Teacher	The game
Cooperative Learning	Service	System	A service for learners to run a project
Concept Test	Concept	Teacher	The concepts needed to test

3.4. Guidance rules

The guidance rules, in Table 3.2, consist of Adaptive Learning guidance, which guides learners according to their concept scores, Collaborative Learning guidance, which is used to group learners for group activities, and No Constraint guidance, which is a default path or makes learners choose their own learning paths.

Table 3.2: Template List of Guidance rules

Adaptive Learning Guidance
(Concept Guidance) if (<concept > <op> <threshold>) then nextLAU = <target LA unit> – *If the concept score fits the constraint, the user can pass to the target LA unit.*
Collaborative Learning Guidance
(Grouping Rule) if (<Group type> = <Group>) then nextLAU = <target LA unit> – *If the user is a member of the specific group, the user can pass to the target LA unit.*
No Constraint Guidance
(Default Path) if (the rule is triggered) then nextLAU = <target LA unit> – *The target LA unit is default for learners.* **(User Selection)** if (the rule is triggered) then nextLAU = <selected LA unit> – *The learner can pass to the LA unit which is selected.*

Chapter 4. Application of CAID model

In this section, we model Mastery Learning, Jigsaw Learning, and pedagogical approaches described in pedagogical patterns by means of CAID model.

4.1. Mastery Learning

The FSM of CAID model, consisting of LA units and guidance rules, can be represented as frame-based representation, which can be applied with frame based inference mechanism. In this section, we will construct a LA of Mastery Learning[21] as a frame based representation example of CAID model.

Mastery Learning, which is proposed by Benjamin Bloom, has following five steps:

1. Give students an introduction lesson to introduce the objective of the course.
2. Divide the course into several learning units. Every learning unit contains a Lesson
3. There is a diagnostic test in every learning unit to exam the Capability of concept obtained from the lesson.
4. If the student can't pass the test, a supplementary instruction is selected according to the lacked Capability. And then the students will have another diagnostic test.
5. The student can't enter the next learning unit until pass the diagnostic test.

Mastery learning is a popular pedagogical approach of adaptive learning, where make learners learn in their own speed to master the knowledge. We can easily construct this LA by means of CAID model because the FSM of CAID can flexibly represent the adaptive learning sequence of Mastery Learning.

In Figure 4.1, the course of Mastery Learning, including two learning units, is modeled with LA units of Presentation, Test, and Tutorial. After study in Presentation activity unit, a Test is given to evaluate the learner's learning performance, and Tutorial of supplementary instruction or next learning unit is provided according to the learning performance of learners.

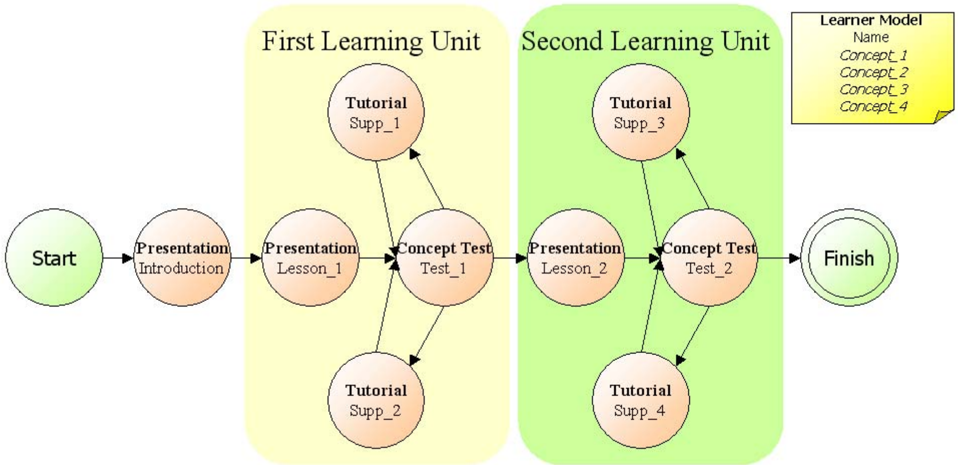
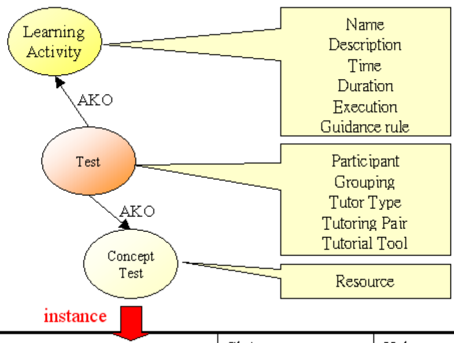


Figure 4.1: LAS of Mastery Learning

The frame instance in Figure 4.2 is an example of LA unit, which contains the inherited attributes from Learning Activity frame and Test frame.



Slot	Value	Slot	Value
Name	Test_1	Score	
Description	Diagnostic test 1	Question Source	Item Bank
Time		Resources	
Duration		Item Bank	Connect to Item Bank
Execution	1. Fire tem Bank with Concept 2. Trigger Contribution	Contribution	If score is added then set score to LM
Guidance rule	If Concept_1 >= 0.9 and Concept_2 >= 0.9 then NextLAU = Lesson_2 If Concept_1 < 0.9 then NextLAU = Supp_1 If Concept_2 < 0.9 then NextLAU = Supp_2	Concept	*Concept_1, Concept_2*

Figure 4.2: The frame of Test_1 LA unit

The example in Figure 4.3 shows how to execute the frame instances of CAID LA. When a learner enter Test_1 LA unit, the Execution procedures will be fired in order. The first procedure fires the Item Bank procedure, which selects questions from IB and provides them to learners. After learners answer the questions, the second procedure will be fired to trigger the Contribution rule, which will record the scores to LM. After finishing this LA unit, Guidance rules, which are represented as the transitions of FSM, will be triggered to select the next LA unit according to learners' LMs.

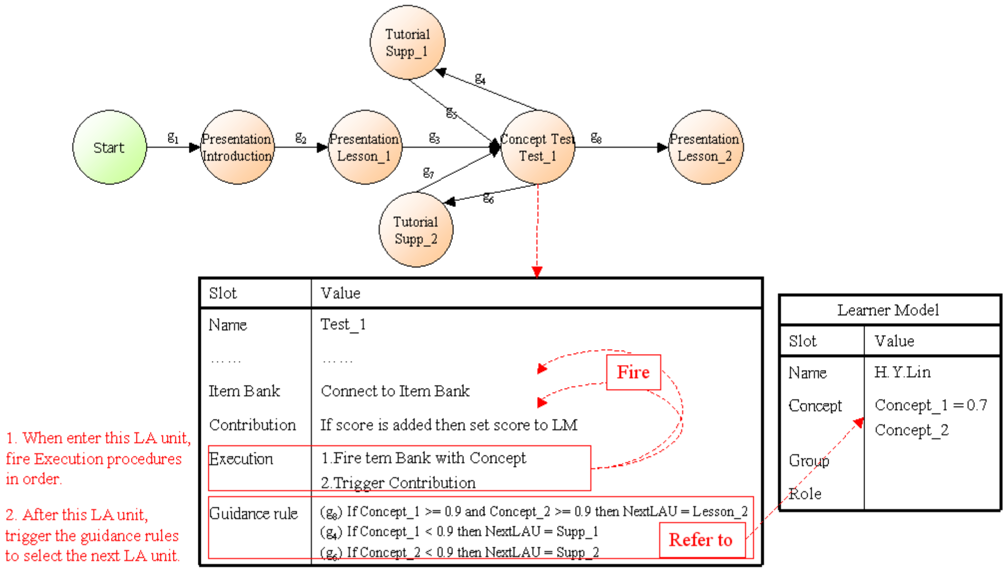


Figure 4.3: Execute CAID frame

Figure 4.4 shows the execution process of Mastery Learning activity. First, a learner enters the LA and receives the learning materials from LA units of Introduction and Lesson_1. After Lesson_1, a test is given to evaluate the concept of Concept_1 and Concept_2. Because the score of Concept_1 got by the learner is lower then 0.9, the threshold of adaptive learning guidance rule appended to Test_1, a supplementary instruction is provided. After the supplementary tutorial, the learner has a test again. In the meantime, the learner gets a score higher than the threshold of guidance rule, so he can enter the next learning unit.

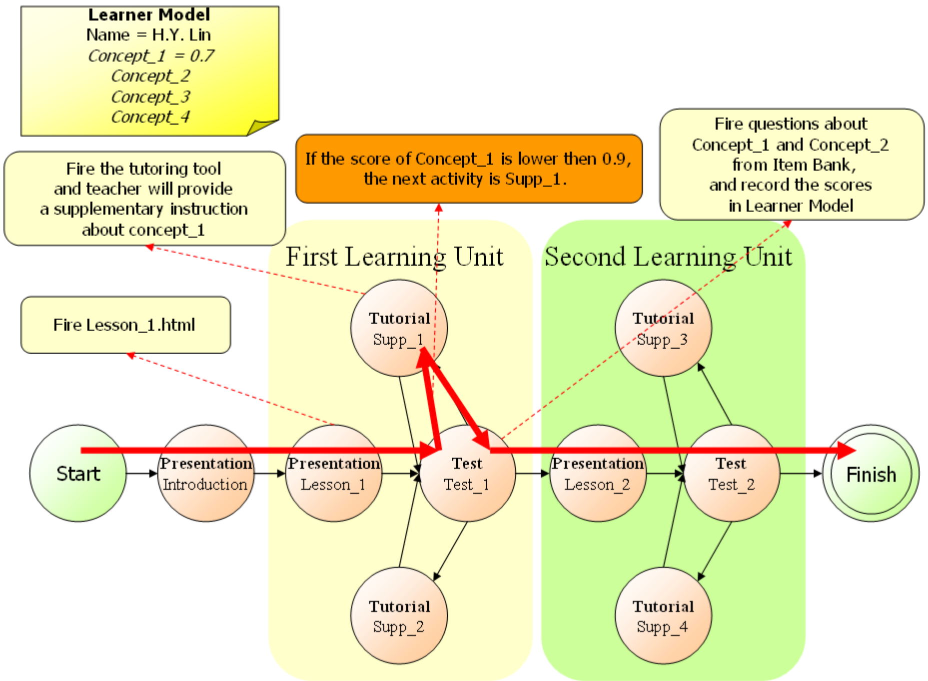


Figure 4.4: Implement a course of Mastery Learning

4.2. Jigsaw Learning

Jigsaw Learning [22] is a famous pedagogical approach of Collaborative Learning. The features of Jigsaw Learning are shown below:

1. Divide learning objective into several segments
2. A learner should be assigned Jigsaw group and Expert group. In every Jigsaw group, there should be one expert of each Expert group.
3. Group learners into Expert group and teach, discuss the knowledge of segment assigned to the Expert group.
4. Then, group learners into Jigsaw group and all the experts from different Expert groups should present the corresponding segment knowledge to others.
5. After the presentation of each segment, the learner can obtain the complete knowledge of learning objective.
6. At last, give learners a quiz.

In Jigsaw Learning, learners, grouped into Expert groups and Jigsaw groups, study and discuss together in Expert groups, and teach one another in Jigsaw groups. We can use the guidance rules and Collaborative learning activity templates in CAID model to represent those features.

The FSM of Jigsaw Learning is shown in Figure 6. The LAS of Jigsaw learning consists of expert group step and jigsaw group step. After Introduction activity unit, the learners will be grouped according to their Expert Group and study different knowledge segments assigned to each group. After expert group step, learners will be reorganized into Jigsaw group. In jigsaw group step, the experts in the same Expert group should be separate into different Jigsaw Groups and present the knowledge segments, studied in Expert Groups, to one another. After the two steps, a Test activity unit is given to evaluate the learning performance.

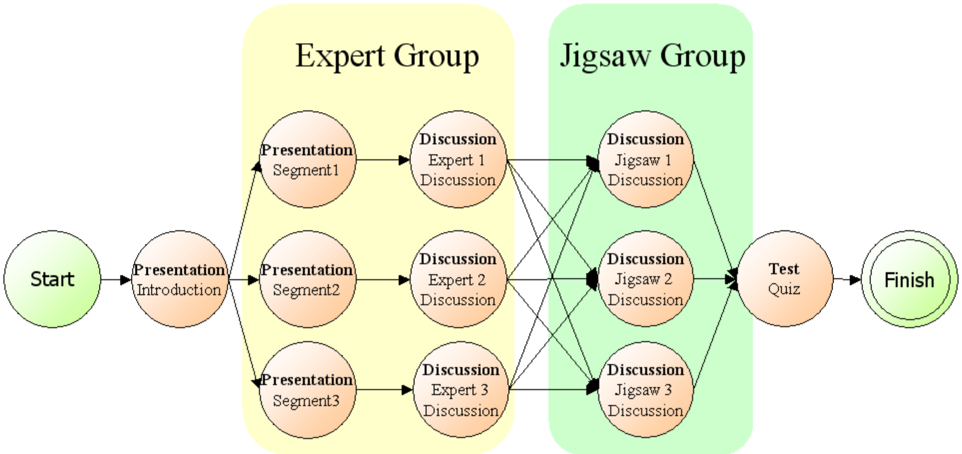


Figure 4.5: FSM of Jigsaw Learning

Introduction is a Presentation frame instance shown in Figure 4.6. It will fire Introduction.ppt for learners to study. After finishing Instructional activity, the three Guidance rules are triggered. These rules group learners into different Expert Groups in which different learning materials and discussion topics are provided.

Introduction (Presentation)		
Slot	Facet	Value
Name		*Introduction*
Description		*A introduction to this whole course*
Time		*2006/05/07 11:00*
Duration		*50 min*
Resource		*Introduction.ppt*
Finishing Rule	If needed	
Guidance Rule	If needed	*If ExpertGroup = Ex1 then Next = Segment1* *If ExpertGroup = Ex2 then Next = Segment2* *If ExpertGroup = Ex3 then Next = Segment3*

Figure 4.6: Frame instance of Introduction

Expert Discussion, shown in Figure 4.7, is a Discussion frame instance, in which learners should be grouped according to their Expert Groups and discuss the segment of knowledge assigned to the group. After Expert Discussion activity, learners should be grouped into Jigsaw Groups with the Guidance rules appended to Expert Discussion frame.

Expert Discussion		
Slot	Facet	Value
Slots of Learning Activity		
Rule of activity		*Discuss the segment assigned to the expert group*
Grouping		*ExpertGroup*
Role		
Result		
Record result	If add Result	*if Result is added, record the result in Learner Model*
Resource	Procedure	*URL of a Discussion Tool*
Guidance Rule	If needed	*If JigsawGroup = Ji1 then Next = Jigsaw1Discussion* *If JigsawGroup = Ji2 then Next = Jigsaw2Discussion* *If JigsawGroup = Ji3 then Next = Jigsaw3Discussion*

Figure 4.7: Frame instance of Expert Discussion

Jigsaw Discussion frame is shown in Figure 4.8. In this frame, each learner from different Expert Groups should present the mastered knowledge segment to others. With all of the presentations, everyone can dominate the whole knowledge in the course. In every Jigsaw group, a learner is assigned to be a leader who must control the process of the discussion. In the frame, a discussion tool with parameters of group, role, and rule of activity is provided for learners to present and discuss. After Jigsaw Discussion, the next activity is a final test.

Jigsaw Discussion		
Slot	Facet	Value
Slots of Learning Activity		
Rule of activity		*all the experts from different Expert group should present the corresponding segment*
Grouping		*JigsawGroup*
Role		*RoleofJigsawGroup*
Result		
Record result	If add Result	*if Result is added, record the result in Learner Model*
Resource	Procedure	*URL of a Discussion Tool*

Figure 4.8: Frame instance of Jigsaw Discussion

The Quiz frame, shown in Figure 4.9, defines the information of the final test. The test assesses the concepts of ConceptofSegment1, ConceptofSegment2, and ConceptofSegment3 with Questions.html. The scores will be assigned to Learner Model by Contribution rules.

Quiz		
Slot	Facet	Value
Slots of Learning Activity		
Concept		*ConceptofSegment1* *ConceptofSegment2* *ConceptofSegment3*
Score		
Question Source		*fix question*
Resource	Procedure	*Questions.html*
Item Bank	Procedure	
Contribution	If Score is added	*Add score to the learner model*

Figure 4.9: Frame instance of Quiz

Frame instance of Learner Model, shown in Figure 4.10, defines three knowledge segments studied by different Expert Group, Expert Group, Jigsaw Group, and the role in Jigsaw Group. Before the course starts, teachers should predefine all learners' Expert Group, Jigsaw Group, and role, which can be leader or learner, in Jigsaw Group.

Learner Model		
Slot	Facet	Value
Name		*H.Y. Lin*
Detailed Information		...
Knowledge		*ConceptofSegment1* *ConceptofSegment2* *ConceptofSegment3*
Scores of Knowledge		
Cognitive Styles		
Scores of Cognitive Styles		
Group Type		*ExpertGroup* *JigsawGroup*
Group		*ExpertGroup = Ex1, JigsawGroup = Ji1*
Role Type		*RoleofJigsawGroup*
Role		*RoleofJigsawGroup = Leader*
Other records		

Figure 4.10: Frame instance of Learner Model

Figure 4.11 shows implementation of Jigsaw Learning with CAID model. First, a learner enters the course and receives the learning materials from activities of Introduction. After Introduction, the learners will be grouped according to their Expert Group. The learner in each Expert Group should study with learning materials to teach different knowledge segments and discuss with learners in the same Expert Group. After Expert Discussion, learners will be grouped again into Jigsaw Groups. In Jigsaw Group, learner should present the mastered knowledge segments to others with discussion tool. Finally, all learners need to have a quiz to evaluate the learning performance in this course.

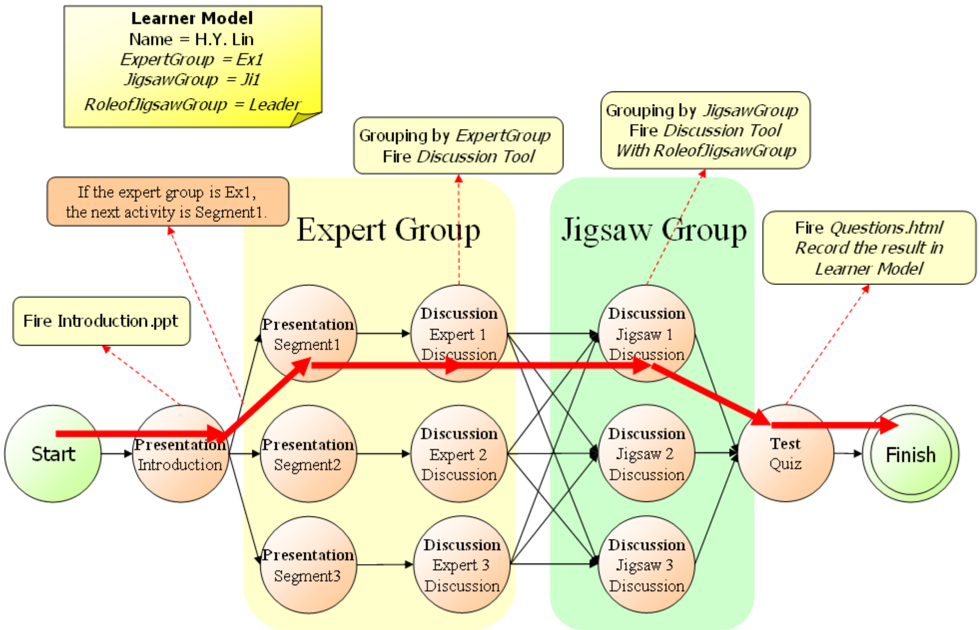


Figure 4.11: Implement a course of Jigsaw Learning

4.3. Pedagogical approach in pedagogical pattern

In Figure 4.12, we also model Early bird, Spiral, and Consistent Metaphor [41] described in Pedagogical pattern.

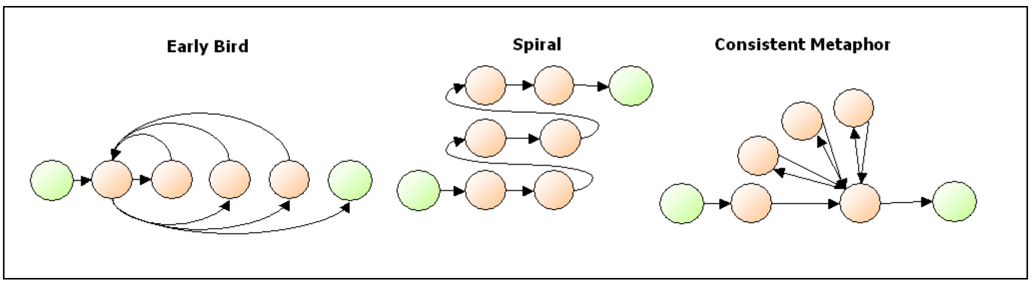


Figure 4.12: The design of pedagogical approach in pedagogical pattern

Chapter 5. Experiment

For evaluating the CAID model, the teaching strategy of Scaffolding Instruction [23] has been implemented by means of the prototyping system shown in Figure 5.1. The scaffolding teaching strategy provides individualized support based on the learner's *zone of proximal development* (ZPD). "*The zone of proximal development is the distance between what children can do by themselves and the next learning that they can be helped to achieve with competent assistance*" [23, 42]. Experiments about learning topic "*The evaporation, condensation and boil of water*" among 4th, 5th and 6th graders are investigated.

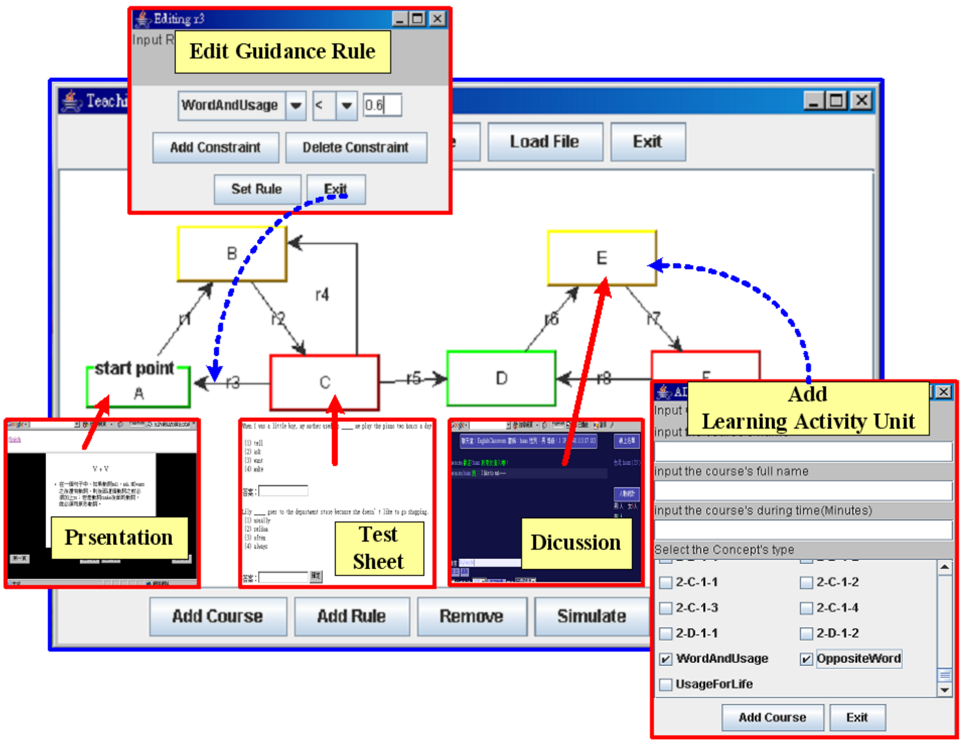


Figure 5.1: The prototyping system of CAID model

5.1. The design for Scaffolding Instruction

The E-learning system replicates the actions of a teacher. Its role is to determine the learning achievement level of students by quizzes. With the test results, the system can give them the appropriate learning objects as *Scaffolding Instruction*. An example of learning activity is shown in Figure 5.2. For each learning concept, e.g., C_1, $C_{1\text{-}1}$, $C_{1\text{-}2}$ and C_2, the *Scaffolding Instruction* learning activity is starting with the knowledge test activity as a pretest. If the student passes the quiz, the system will guide him/her to learn the next concept. Once the student failed in some exam assessment activity, he/she will receive the corresponding remedial learning object as *Scaffolding Instruction*. The online courses of the subject "*The evaporation, condensation and boil of water*" are provided to 62 students.

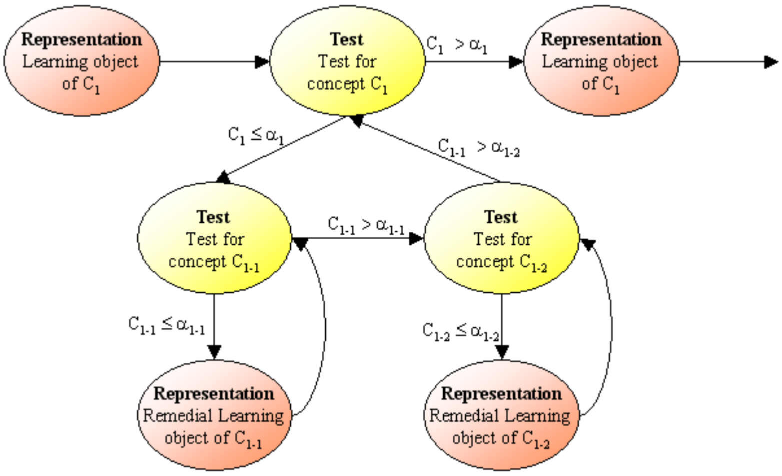


Figure 5.2: Design of Scaffolding Instruction

5.2. Experimental result

To evaluate the effectiveness of the CAID course, we apply the one-group pretest-posttest design for 62 students of 5th graders in a Taiwan elementary school. Firstly, the pretest examination score of concepts of "*The evaporation, condensation and boil of water*" is the covariate variable. After one month learning with the CAID course, the posttest examination score of the same scope is the dependent variable. Referring to the pretest result, the students are partitioned into high-grade group and low-grade group. The pairwise t-test and discussion of all students, high-grade group and low-grade group are as follows.

5.2.1. The pairwise t-test of all students

Table 5.1: The pretest-posttest of learning achievement

Student Group		Mean	Size	Standard Deviation	Mean difference
Learning	pretest	25.7419	62	3.1516	.4002
Achievement	posttest	28.1290	62	4.1429	.5261

Table 5.2: The one-group pretest-posttest t-test

Pairwise t-test	Variance of Paired Difference			t value	Sig. (2-tailed)
	Mean	Standard Deviation	Standard Error of Mean		
Pretest-posttest	2.3871	3.9187	.4977	4.797	.000*

*P < .05

In Table 5.1and Table 5.2, the value $t = 4.797$ (p value = .000 < .05) shows that the pretest-posttest has significant difference. It deduced that the Scaffolding Instruction designed by CAID model is effective for students.

5.2.2. The pairwise t-test of high grade group

Furthermore, referring to the pretest result, the students are partitioned into high-grade group and low-grade group. The pairwise t-test in each group is also investigated to analyze the pretest-posttest of learning achievement.

Table 5.3: The pretest-posttest of learning achievement of high-grade group

Student Group		Mean	Size	Standard Deviation	Mean difference
Learning	pretest	28.3548	31	1.5822	.2842
Achievement	posttest	29.1290	31	3.5846	.6438

Table 5.4: The one-group pretest-posttest t-test of high-grade group

Pairwise t-test	Variance of Paired Difference			t value	Sig. (2-tailed)
	Mean	Standard Deviation	Standard Error of Mean		
pretest-posttest	.7742	3.5657	.6404	1.209	.236

*P < .05

In Table 5.3 and Table 5.4, the value t = 1.209 (p value = .236 > .05) shows that the pretest-posttest doesn’t have significant difference. It deduced that the Scaffolding Instruction is not effective for high-grade students.

5.2.3. The pairwise t-test of low grade group

Table 5.5: The pretest-posttest of learning achievement of low-grade group

Student Group		Mean	Size	Standard Deviation	Mean difference
Learning	pretest	23.1290	31	1.8928	.3400
Achievement	posttest	27.6452	31	3.3221	.5967

Table 5.6: The one-group pretest-posttest t-test of low-grade group

Pairwise t-test	Variance of Paired Difference			t value	Sig. (2-tailed)
	Mean	Standard Deviation	Standard Error of Mean		
pretest-posttest	4.5161	3.6503	.6556	6.888	.000＊

*P < .05

In Table 5.5 and Table 5.6, the value t = 6.888 (p value = .000 < .05) shows that the pretest-posttest has significant difference. It deduced that the Scaffolding Instruction designed by CAID model is effective for low-grade students.

After further discussion with students, we found that the high-grade students tend to learning by interaction with other students or teachers. Therefore, the lack of instructor to discuss may cause their unobvious learning improvement. On the contrary, the low-grade students tend to find the solutions from learning objects. It results in that the Scaffolding Instruction of CAID model can assist them in finding the learning objects based on their misconception. Therefore, the Scaffolding Instruction of CAID model is effective especially for low-grade students.

Finally, the teachers comment on this system as below:

1. By means of this system, teachers can edit and modify instructional design pattern, integrate share and reuse many kinds of learning resources easily.
2. The learners' learning portfolios, which can help teachers analyze learners' learning status, can be recorded in the system.
3. The user interface of this E-learning system is friendly for students and teachers.
4. The monitoring mechanism should be improved to assist teachers in checking the learner's learning status and performance.

Chapter 6. Conclusion

In this thesis, we apply knowledge-based approach to propose CAID model, where we apply FSM and learning activity ontology to model the instructional design knowledge, to overcome the gap between teachers' high level domain expertise and IT environment. The model provides teachers with a graphic representation of learning process and learning activity templates to simplify the instructional design and they can be transformed to a frame based system, which can be applied in computer systems with frame based inference mechanism. Therefore, with CAID model, teachers can construct a digital course by means of selecting appropriate learning activity templates, instancing them and specifying guidance rules to form a FSM of learning process.

In the near future, we will discuss the checking methods of the extended FSM in CAID model to help teachers correcting their ID patterns, and the learners' information gathering mechanism will be provided to collect and analyze the learning behaviors. Since to modify ID patterns of CAID is easy, the feedback mechanism above can make teachers evaluate and improve their ID efficiently. Moreover, we will construct a method to transform the course of CAID model to the IMS LD compliant document, which can be applied in E-learning widely. The further goal is integrating more kinds of learning resource and service repositories into CAID E-learning system to construct a powerful E-learning environment.

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