Building an e-PBL Platform for the Collaborative Design in Capstone Project

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Abstract: - Capstone project is an important subject that every graduate needs to learn and experience, whose goal is to train students to be able to apply the required knowledge and skill to collaboratively complete the assigned work. The traditional PBL strategy cannot effectively enhance the students' collaborative design abilities without utilizing domain knowledge and previous user experience. In this paper, we develop a spiral e-PBL platform using enhanced CBR (e-CBR) to be able to assist students to brainstorm and design collaboratively. Therefore, the students can inquire similar cases, stimulate creative idea, build consensus, and design in each spiral design activity collaboratively. For retrieving the similar cases in this platform, the similarity functions and similarity-based case retrieval algorithm have been designed according to the project characteristic and the team profile. Then, the case-design portfolio of retrieving similar cases can then be collected and analyzed by our proposed learning scaffolding generation algorithm. The results can be used as the scaffoldings of students' collaborative design and to assist teachers monitor the students' design process and achievements. An experiment has also been done to evaluate the effectiveness of our e-PBL platform. The experimental result shows that the given appropriate learning scaffoldings can guide students to improve the design and problem solving abilities.

Key-Words: - collaborative design, project-based learning, case-based reasoning, capstone project

1 Introduction

The goal of capstone project is to train students to be able to apply the required knowledge and skill to collaboratively complete the assigned work [1,2]. Through the capstone project, students should have the ability to solve complex problems with effective communication ability. As we know, project-based learning (PBL) is a popular strategy used by teachers to motivate students learning and to develop students' professional knowledge and problem solving abilities [3]. So, the PBL strategy is often used to guide students to organize teams to design collaboratively and to enhance students' design abilities in capstone project in the last year of the students' undergraduate study. However, the traditional PBL strategy cannot effectively enhance the students' collaborative design abilities without utilizing domain knowledge and previous user experience [4,5].

Due to the flourishing development of smart phone and mobile learning, capstone project of learning design or e-storybook design has become a hot topic in information science related departments. With our observations, collaborative design in implementing e-storybook cannot be easily done without consensus, because each team member most likely has their own discipline and concern. Due to the difficulty of building the consensus, how to assist students to learn the transdisciplinary thinking and collaborative design in capstone project is a very important issue.

Chinese proverb says, "Good companions have good influence while bad ones have bad influence." It means that providing the previous similar and good cases together with their case-design portfolio can stimulate students' creativity in capstone project [6,7]. The case-design portfolio can then be analyzed and used to discover the design behaviours of students [8]. We believe that if a team follows or imitates the design behaviour of similar cases, the team could easily build the consensus and get high design achievement. Therefore, case-design portfolio consisting of the sequence of design and problem solving activities is used to represent the team design process. For example, the case-design portfolio of e-storybook design consists of not only design activities but also brainstorming and problem solving scenarios in capstone project.

Since some design activities may be iteratively executed several times, in this paper, our idea is to develop a spiral e-PBL platform to be able to inquire similar cases, stimulate creative idea, build consensus, and design the work collaboratively in each spiral. In this platform, the similarity functions and similarity-based case retrieval algorithm are defined for retrieving the similar cases according to the project characteristic and the team profile. Then, the case-design portfolio of retrieved similar cases can then be collected, and analyzed by our proposed learning scaffolding generation algorithm to generate the scaffoldings of students' collaborative design, and assist teachers to monitor the students' design process and achievements.

Although PBL is indeed a good learning strategy, applicable techniques or tools are still needed to improve the learning effectiveness [9,10]. Case-based reasoning (CBR) consisting of cases retrieve, reuse, revise and retain can be used to model the computer reasoning [11]. Therefore, an enhanced CBR (e-CBR) is proposed by additionally collecting and analyzing the case-design portfolio of similar cases to assist students collaboratively design in design process of the capstone project. Using the e-CBR, the e-PBL platform is then built to provide the case scaffoldings according to the case-design portfolio stored in case profile. The case profile consists of project characteristic, team profile, and case-design portfolio, where the project characteristic is used to represent the characteristic of the project, the team profile is used to represent the characteristic of the team, and the case-design portfolio is used to represent the sequence of design activities. The suggested design scaffoldings can be used to assist students to brainstorm and design collaboratively. The project similarity function, team similarity function, and case similarity function are defined to assist students to retrieve the most similar cases.

We believe that novice users can easily develop the capstone project if they follow or imitate the design behavior from previous similar cases. Furthermore, the common case-design pattern of the retrieved similar cases can be treated as the common case-design pattern which can help users to develop the capstone project. Therefore, the learning scaffolding generation algorithm based upon the longest common subsequence (LCS) is proposed to generate the scaffoldings to assist capstone project developing.

An experiment consisting of two teams has been done to evaluate the effectiveness of our learning platform to complete the e-storybook creative design in capstone project. One team used the e-PBL platform in e-storybook design process and the other only used the traditional PBL learning strategy to develop their e-storybook. The experimental result shows that the given appropriate learning scaffoldings can guide students to improve the design and problem solving abilities.

2 Related Works

2.1 Collaborative design

Collaborative design is an effective design strategy to improving students' motivation, achievements and peer relations in design process [12], where the required knowledge can be created from peers, classmates, or colleagues interact by sharing experiences [13,14]. So, collaborative efforts are usually required to successfully build the consensus for some transdisciplinary projects. Therefore, the collaborative ability becomes an indispensable ability to maintain competitiveness for individuals [15].

Computer-supported collaborative learning (CSCL) is a relatively new learning direction which uses technology in a learning environment to assist students in creative thinking and problem solving in a collaborative learning context [16]. The PBL using CSCL can be used to assist students develop their abilities and skills [17,18]. Product Data Management (PDM) is a technology which integrates all information and support collaborative design during design process [19,20]. Computer supported collaborative design (CSCD) and computer supported cooperative work (CSCW) are also applied to support collaborative design performances [21]. Applying modern information and communication technologies (ICTs) (e.g. Wiki, Facebook, forum, and so on) can assist students to collaboratively design, share, and discuss [22]. Since traditional CSCD approaches did not fully utilize the previous case-design portfolio, they can hardly assist students to stimulate idea, build consensus, and design collaboratively in project design process.

2.2 e-PBL

Capstone project is an important subject that every graduate needs to learn in one or two semesters. The enrolled students may select an interesting topic, conduct research and create their learning results on the subject in capstone project. The project-based learning (PBL) has been proved to be an effective learning strategy [23]. Since developing a good capstone project usually requires multiple domain knowledge and experience sharing and fusion, the team members need transdisciplinary thinking to develop the theme and core concept of the capstone project. In design process, the teacher can assist students to develop their core abilities through interaction and collaboration with other team members [24]. With the progress of new era, e-PBL (PBL joins the IT technology) is used as a powerful tool to provide scaffolding to assist students learning and enhance students problem solving ability in capstone project [25-29]. The e-PBL can improve the effectiveness of learning steps [30]; e.g., collect various materials, reflect about the original subject, select the appropriate solution, present the project result, analyze the process, discuss the results, and share the findings.

But, without good platform, the previous good cases and their case-design portfolio cannot be properly stored, referred, and shared. As we know, the similar cases can assist students to develop their product in the capstone project. Therefore, in the design process, the e-PBL platform can retrieve the similar cases and generate the design scaffolding to assist students design collaboratively and assist teacher to monitor students' design process.

3 e-PBL Platform

Good strategies with the appropriate design scaffolding can allow students to obtain the creative design and abilities with the consideration of the viewpoints of person, the process, the product, and the environment [31,32]. Creative thinking, which is the first task in capstone project, should be free and unrestricted in theory. But, the learning resources are limited in the school's learning environment in reality. With our observations, students can hardly complete their project in e-storybook design collaboratively due to the difficulty of brainstorming and building the consensus in collaborative design [33]. Therefore, e-PBL platform is built to retrieve the similar cases, analyze their case-design portfolio to assist students to brainstorm and design collaboratively in design process.

The e-PBL platform consists of four steps: similar case inquiry, idea stimulating, consensus building, and collaborating with portfolio.

Step1. **Similar case inquiry**: According to the project characteristic and team profile, case retrieve is used to inquire the most similar cases whose case-design portfolio will be analyzed and used as the design scaffoldings.

Step2. **Idea Stimulating**: According to the design scaffoldings, case reuse or case revise is used to assist students to stimulate or imitate in design process, and the progress in the students' design process will be stored for further use.

Step3. **Consensus Building**: Case retain is used to assist students to discuss and share their design idea and experience to build consensus in the design process.

Step4. **Collaborating with portfolio**: According to the consensus, the students design and implement the project collaboratively and the case-design portfolios of the design process are maintained. Go to Step1 to do more iterations, if needed.

3.1 Spiral model

The e-PBL platform is a spiral model, where each spiral consists of four steps: similar case inquiry, idea stimulating, consensus building, and collaborative design, as shown in Fig.1. In the model, all the four steps can be iterated several times, if needed. Finally, the e-PBL platform will recommend the most similar cases according to the requirements of students in each spiral.

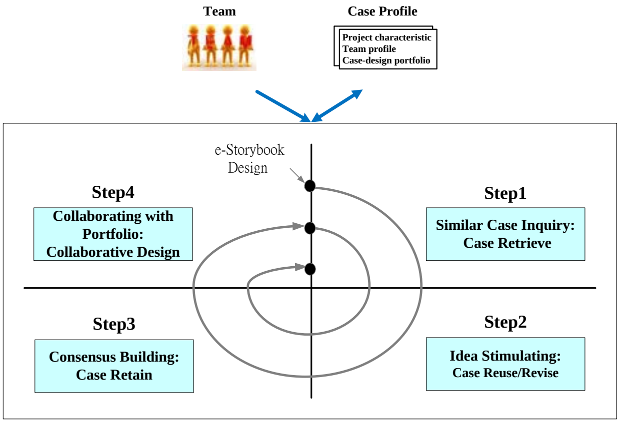


Fig.1. Using e-CBR to build e-PBL platform

Before conducting the capstone project, the teams have to be formed according to students' ability, knowledge, and so on. Basically, it is difficult to generate creative idea by transdisciplinary thinking in capstone project without scaffolding. For enhancing students' design achievements, the e-PBL platform provides the case scaffolding from previous case profiles. The case profile consists of the project characteristic, the team profile, and the case-design portfolio of the capstone project, where the project characteristic is used to represent the characteristic of the project, the team profile is used to represent the characteristic of the team, and the case-design portfolio is used to represent the sequence of design and problem solving activities. The team members can follow or imitate the case-design portfolio to collaborative design. The case profile will be formally defined in section 4.

3.2 Enhanced CBR (e-CBR)

Case-based reasoning (CBR) is a popular methodology of solving the new problems through the solutions of the similar previous problems. CBR has been formalized as case retrieve, case reuse, case revise, and case retain [11]. The CBR is enhanced by including additional building consensus to help students' collaborative design in design process. In this paper, we build an e-PBL platform using e-CBR to not only retrieve similar cases but also provide the scaffoldings from analyzing the previous case-design portfolio in assisting students to build consensus and for collaborative design, and maintain the case-design portfolio of the capstone project.

For building e-PBL platform, we firstly define the case representation. In the rest of this paper, we will use the fairy tale e-storybook design capstone project as an example to elaborate our method.

4 Case Representation

For facilitating the retrieval of the similar cases, the case is represented as the case profile which consists of project characteristic, team profile, and case-design portfolio, where the related project, team, case similarity functions and similarity-based case retrieval algorithm are defined for retrieving the similar cases. The project characteristic consists of type, protagonist, plot, scene, drawing, and interactive attributes. The team profile consists of planning, learning, scripting, drawing, and reporting attributes. The case-design portfolio is used to represent the sequence of design and problem solving activities. The definition of case profile is described as follows.

Definition 1: **Case Profile**

Case profile C = (Proj, TP, CDP), where

$\text{Proj}_i = <p_{i1}, p_{i2}, p_{i3}, p_{i4}, p_{i5}, p_{i6}>$ denotes a vector of project characteristic for case i, where
p_{i1} is the value of type attribute,
p_{i2} is the value of protagonist attribute,
p_{i3} is the value of plot attribute,
p_{i4} is the value of scene attribute,
p_{i5} is the value of drawing attribute, and
p_{i6} is the value of interactive attribute.

$\text{TP}_i = <t_{i1}, t_{i2}, t_{i3}, t_{i4}, t_{i5}>$ denotes a vector of team profile for case i, where
t_{i1} is the value of planning attribute,
t_{i2} is the value of learning attribute,
t_{i3} is the value of scripting attribute,
t_{i4} is the value of drawing attribute, and
t_{i5} is the value of reporting attribute.

$\text{CDP}_i = <d_{i1}, d_{i2}, \ldots, d_{ij}, \ldots>$ denotes a vector of case-design portfolio of a project during design process for case i, where d_{ij} is used to present the design activity in j-th week.

4.1 Project characteristic

For the project characteristic Proj, the values of the attributes type, protagonist, plot, scene, and drawing attributes are shown in Table 1.

Table 1. The project characteristic of an e-storybook capstone project

Attribute	Value
Type	**W**: Warm, **N**: Nature, **H**: Humor, **T**: Thriller, **F**: Fantasy
Protagonist	**F**: Family members, **A**: Animals/Pet, M: Monsters/Aliens, **P**: Palace members, **S**: Anthropomorphic
Plot	**F**: Family love, **S**: Friendship, **L**: Learning, **H**: Helping others, **C**: Care for others, **T**: Treasure hunt, **A**: Adventure
Scene	**H**: Home, **S**: School, **P**: Park, **G**: Grasslands, **R**: River/Sea/ Lake, **L**: Planet, **M**: Mountains/Forest/Jungles
Drawing	**R**: Realism, **P**: Perfection, **L**: Lovely, **S**: Sketch, **T**: Retro, **Q**: Q style
Interactive	**Y**: Yes, **N**: No

Assume two favorite preferences are allowed in each attribute. A two-char string is used to denote the values of each attribute, where the first is the most favorite preference. For the project characteristic vector Proj = <WH, FA, FC, HP, LQ, N>, WH denotes the type of the e-storybook is Warm and Humor, where Warm is the most favorite preference. The other attributes have been similarly defined.

4.2 Team profile

In this paper, the e-storybook design process consists of five design activities [34,35]:

1. *Planning*: Planning the work flow of the project design processes
2. *Learning*: Learning tools for project design process
3. *Scripting*: Writing the script of e-storybook
4. *Drawing*: Drawing the e-storybook
5. *Reporting*: Reporting and document recording

In design process of the capstone project, some design activities are often iteratively performed. For example, the team having low planning ability is apt to spend more time on planning. In this paper, the team profile TP denotes a vector of the characteristics of the team. According to the e-storybook design, the values of the attributes of team profile planning, learning, scripting, drawing, and reporting attributes are shown in Table 2.

Table 2. The team profile of an e-storybook capstone project

Attribute	Value
Planning	H: High, M: Medium, L: Low
Learning	H: High, M: Medium, L: Low
Scripting	H: High, M: Medium, L: Low
Drawing	H: High, M: Medium, L: Low
Reporting	H: High, M: Medium, L: Low

For example, the vector TP= <H, H, M, H, H> shows that the planning, learning, drawing, and reporting abilities of the team are High and scripting ability is Medium.

4.3 Case-design portfolio

We believe that if a team follows or imitates the design behavior of similar cases, the team could build consensus and get high design achievement. The case-design portfolio CDP denotes a vector consisting of a sequence of design and problem solving activities. According to the project characteristic and team profile, each team has its own case-design portfolio. In this paper, the time window is a week. We would like to explore the associations between the team profiles and their case-design portfolios. The following example is given to show the case profile in case base.

Example 1

Assume the design process of the e-storybook capstone project lasts for 18 weeks. There are ten previous good cases stored in case base. $Proj_i$, TD_i, and CDP_i are used to represent the project characteristic, team profile, and case-design portfolio of i-th case, respectively, as shown in Table 3.

The vector CDP_1 = <PP, PL, PS, SL, LS, DS, DP, SP, LL, SD, DD, DD, DD, DS, DR, RR, DR, RR> shows that the first week design activity is Planning, the second week design activities are Planning and Learning, and so on. Since Drawing design activity appears in 9 weeks, it can be easily understood that the team spent a lot of time in drawing. We can guess that the drawing design activity is more difficult or important for the team.

Table 3. The case profiles in case base

ID	Project characteristic $Proj_i$	Team profile TP_i	Case-design portfolio CDP_i
1	<FO, MS, LF, RH, LT,Y>	<M, H, H, M, H>	<PP, PL, PS, SL, LS, DS, DP, SP, LL, SD, DD, DD, DD, DS, DR, RR, DR, RR>
2	<NF, FP, SA, PS, PL, N>	<H, H, H, H, H>	<LP, PL, SS, LL, PS, SD, LL, DD, DS, SD, LD, DS, DP, DR, DL, DR, RR, RR>
3	<FW, AS, SF, HG, QR, N>	<H, M, H, M, M>	<PP, PS, PL, LS, SP, DL, SD, LL, DS, LD, DD, DL, DD, DL, DR, RR, DL, RR>
4	<TF, FA, LH, LM, PR, Y>	<H, H, H, H, M>	<LP, SL, LD, PP, PS, PD, DS, LS, LS, DD, DS, DD, DR, DL, RD, RD, RR, RR>
5	<HW, PM, SC, HL, QP, N>	<M, M, H, H, M>	<LL, PP, PL, SP, SS, SP, LS, DS, LD, LL, DR, DD, SD, DL, DD, DR, RR, DR>
6	<FT, PA, AT, MG, PQ, N>	<H, M, M, M, H>	<LP, PL, DS, PL, PS, SS, SD, DD, DL, LL, DL, DD, DD, DS, DR, DR, RR, LR>
7	<FN, AF, LA, GS, PR, Y>	<H, M, H, H, H>	<LS, SL, PL, SD, PP, PS, SS, SD, DL, DD, DL, LD, SL, LR, DD, DL, DR, RD>
8	<WT, PA, FC, LM, PQ, N>	<M, M, H, M, M>	<LP, PP, PL, LL, LS, DS, SD, LD, LL, DD, DL, DR, DD, DS, DR, RL, RR, RR>
9	<HF, SS, SC, HP, LQ, Y>	<M, H, M, M, M>	<SP, PD, LS, PP, PS, SS, LL, LD, LD, LL, DD, DD, DD, DR, LR, DS, RD, RR>
10	<OT, FA, CH, PS, SP, N>	<M, M, H, H, M>	<PL, PL, DL, PP, PS, SS, LD, LL, DS, DD, DD, SL, DS, RL, DR, DD, RD, RR>

5 Similarity-based Case Retrieval

5.1 Similarity measurement

For retrieving the similar cases, the similarity-based case retrieval algorithm is proposed to assist students collaboratively design the capstone project. The case similarity function is defined to measure the similarity of two cases. The case similarity function consists of project similarity function and team similarity function. The project similarity function and team similarity function are defined to measure the similarity of two project characteristics and the team profiles, respectively. The attribute similarity function is defined to measure the similarity of two attribute values. The project similarity function and the team similarity function are given to define the similarity between two projects and between two teams, respectively.

In case similarity function, the similarity weight α is used to set the similarity weight of the project similarity function. The value of the similarity functions and similarity weight α are all between 0 and 1. The higher the value is, the greater the similarity. To simplify our discussion, we assume that all the weights of attributes are equal and the default value of the similarity weight α is 0.5.

Definition 2: Attribute Similarity Function

Assume we are given two vectors V_i and V_j, where V_i=<v_{i1}, v_{i2}, v_{i3}, … >, V_j=<v_{j1}, v_{j2}, v_{j3}, … >, each attribute value v_{ik} is a two-char string, and

First(v_{ik}) denotes the first char of v_{ik} ,

Second(v_{ik}) denotes the second char of v_{ik} .

AttributeSimilarity(v_{ik}, v_{jk}) denotes the similarity of v_{ik} and v_{jk}

(a). If {First(v_{ik}), Second(v_{ik})} is equal to {First(v_{jk}), Second(v_{jk})} then AttributeSimilarity(v_{ik}, v_{jk})=1

(b). If First(v_{ik})=First(v_{jk}) and Second(v_{ik})≠Second(v_{jk}) then AttributeSimilarity(v_{ik}, v_{jk})=0.9

(c). If First(v_{ik})=Second(v_{jk}) and Second(v_{ik})≠ First(v_{jk}) then AttributeSimilarity(v_{ik}, v_{jk})=0.8.

(d). If First(v_{ik}) ≠First(v_{jk}) and Second(v_{ik})= Second(v_{jk}) then AttributeSimilarity(v_{ik}, v_{jk})=0.6

(e). Otherwise, AttributeSimilarity(v_{ik}, v_{jk})=0

The following example is given to elaborate the Definition 2.

Example 2

Assume $Proj_i$ and $Proj_j$ are two project characteristic vectors, where $Proj_i$ = <FW, AS, SF, HG, QR, Y> and $Proj_j$ = <NF, FP, SA, PS, PL, Y>.

According to Definition 2, we have First(p_{i1})='F', Second(p_{i1})='W', First(p_{j1})='N', Second(p_{j1})='F'

Then AttributeSimilarity(p_{i1}, p_{j1})=0.8.

Definition 3: Project Similarity Function

Assume we are given two project characteristic vectors $Proj_i$ and $Proj_j$

$$\mathrm{ProjectSimiarity}(\mathrm{Proj}_i, \mathrm{Proj}_j)$$
$$= \frac{1}{6}\sum_{\mathrm{k=1,6}} \mathrm{AttributeSimilarity}(p_{\mathrm{ik}}, p_{\mathrm{jk}})$$

Definition 4: Team Similarity Function

Assume we are given two team profile vectors TP_i and TP_j

$$\mathrm{TeamSimiarity}(\mathrm{TP}_i, \mathrm{TP}_j)$$
$$= \frac{1}{5}\sum_{\mathrm{k=1,5}} \mathrm{StringCompare}(t_{\mathrm{ik}}, t_{\mathrm{jk}})$$

Definition 5: Case Similarity Function

Assume we are given two case profile C_i and C_j, and the similarity weight α.

CaseSimilarity(C_i, C_j)

= α *ProjectSimilarity($Proj_i$, $Proj_j$)+

(1-α)*TeamSimilarity(TP_i, TP_j), 0<=α<=1

5.2 Similarity-based case retrieval algorithm

For obtaining the case-design portfolio of similar cases, the following similar-based case retrieval algorithm is given to retrieve the similar cases.

Similarity-based Case Retrieval Algorithm

Input: The values of project characteristic, team profile, and the similarity weight α of the given project.

Output: The recommended case set.

Step1: The recommended case set is empty. For each case stored in the case base, repeatedly execute Step 2, Step 3, and Step 4.

Step2: Evaluate the project similarity function between the case and the given project according to Definition 3.

Step3: Evaluate the team similarity function between the case and the given project according to Definition 4.

Step4: Evaluate the case similarity function between the case and the given project according to Definition 5. If the case similarity function value is greater than the threshold, then append the case into the recommended case set.

Step5: Output the recommended case set.

Example 3

This example is given to elaborate the similarity-based case retrieval algorithm.

Assume there is a team consisting of four female senior students wants to complete an e-storybook capstone project in 18 weeks. The team members have high scripting ability and medium planning, learning, drawing, and reporting abilities. The e-storybook introduces a warm story about a lot of cute animals in the grasslands on a planet in a humorous way. The animals go on adventures together and help each other in the process of exploration. Finally, they generate a profound friendship. The team members draw with the Q and lovely style and set the similarity weight with 0.6.

Let $Proj_0$ and TP_0 denote the project characteristic and team portfolio of the team, respectively, where

$Proj_0$ = <FW, AS, SA, LG, QL, N>

TP_0 = <M, M, H, M, M>

$\alpha = 0.6$

The project similarity function ProjectSimilarity($Proj_0$, $Proj_i$) between $Proj_0$ and $Proj_i$ given in Table 3 can be evaluated, as shown in Table 4.

Table 4 The project similarity function of each case

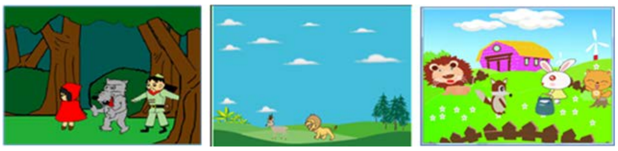
ID	Project characteristic $Proj_i$	ProjectSimilarity ($Proj_0$, $Proj_i$)
1	<FO, MS, LF, RH, LT,Y>	0.38
2	<NF, FP, SA, PS, PL, N>	0.57
3	<FW, AS, SF, HG, QR, N>	0.90
4	<TF, FA, LH, LM, PR, Y>	0.42
5	<HW, PM, SC, HL, QP, N>	0.70
6	<FT, PA, AT, MG, PQ, N>	0.82
7	<FN, AF, LA, GS, PR, Y>	0.53
8	<WT, PA, FC, LM, PQ, N>	0.72
9	<HF, SS, SC, HP, LQ, Y>	0.55
10	<OT, FA, CH, PS, SP, N>	0.30

The team similarity function TeamSimilarity(TP_0, TP_i) between TP_0 and TP_i given in Table 3 can be evaluated, as shown in Table 5.

Table 5. The team similarity function of each case

ID	Team profile TP_i	TeamSimilarity(TP_0, TP_i)
1	<M, H, H, M, H>	0.6
2	<H, H, H, H, H>	0.2
3	<H, M, H, M, M>	0.8
4	<H, H, H, H, M>	0.4
5	<M, M, H, H, M>	0.8
6	<H, M, M, M, H>	0.4
7	<H, M, H, H, H>	0.4
8	<M, M, H, M, M>	1.0
9	<M, H, M, M, M>	0.6
10	<M, M, H, H, M>	0.8

The case similarity function of each case will be evaluated with α =0.6. Assume the threshold is 0.7, following the similarity-based case retrieval algorithm, the case similarity function CaseSimilarity(C_i, C_j) can be evaluated according to Definition 5 and the e-PBL platform will recommend C_3, C_5 and C_8 to students, as shown in Table 6. The screenshots of case 3, case 5, and case 8 are shown in Fig.2(a), Fig.2(b), and Fig.2(c), respectively.



(a). Case 3 (b). Case 5 (c). Case 8

Fig.2. The screenshots of Case 3, Case 5, and Case 8

Table 6. The recommended case set with α = 0.6 and threshold = 0.7

ID	Project characteristic $Proj_i$	Team profile TP_i	Case-design portfolio CDP_i
3	<FW, AS, SF, HG, QR, N>	<H, M, H, M, M>	<PP, PS, PL, LS, SP, DL, SD, LL, DS, LD, DD, DL, DD, DL, DR, RR, DL, RR>
5	<HW, PM, SC, HL, QP, N>	<M, M, H, H, M>	<LL, PP, PL, SP, SS, SP, LS, DS, LD, LL, DR, DD, SD, DL, DD, DR, RR, DR>
8	<WT, PA, FC, LM, PQ, N>	<M, M, H, M, M>	<LP, PP, PL, LL, LS, DS, SD, LD, LL, DD, DL, DR, DD, DS, DR, RL, RR, RR>

The story of Case 3 describes a little girl wants to visit her grandmother's house. The way to her grandmother's house is very far. She gets some helps to deal with a lot of difficulties encountered. Finally, she arrives at grandmother’s house safely. The story of Case 5 describes a greedy lion wants to eat a little rabbit, but also wants to catch a little sheep. Finally, the rabbit and sheep have successfully escaped from being captured by the lion. The story of Case 8 describes a cunning fox often deceive other cute little animals. These animals lesson the fox together. Finally, the fox mends his ways.

6 LCS-based Learning Scaffolding

Based upon the generalized longest common subsequence algorithm, the learning scaffolding generation algorithm is proposed to generate the scaffoldings to assist capstone project developing.

Definition 6: Longest Common Subsequence (LCS) Function [36]

Assume we are given two vectors D_a and D_b, where $D_a=<d_{a1}, d_{a2}, \ldots, d_{am}>$, $D_b=<d_{b1}, d_{b2}, \ldots, d_{bn}>$

$LCS_{m,n}(D_a, D_b)$ denotes the longest common subsequence of D_a and D_b

$$LCS_{m,n}(D_a, D_b) = \begin{cases} \max\{LCS_{m-1,n}(D_a, D_b), LCS_{m,n-1}(D_a, D_b)\}, & \text{if } m, n>0 \text{ and } d_{am} \neq d_{bn} \\ LCS_{m-1,n-1}(D_a, D_b), & \text{if } m, n>0 \text{ and } d_{am} = d_{bn} \\ \phi, & \text{if } m=0 \text{ or } n=0 \end{cases}$$

Definition 7: Generalized LCS
Assume there are x vectors $D_1, D_2, \ldots, D_x$ in case set CS, where $D_1=<d_{11}, d_{12}, d_{13}, \ldots >$, $D_2=<d_{21}, d_{22}, d_{23}, \ldots>$, …, $D_x=<d_{x1}, d_{x2}, d_{x3}, \ldots >$
Based upon Definition 6, **G-LCS(CS, x)** denotes the longest common subsequence of x vectors in CS.

In order to find more appropriate scaffolding, MCD is defined to indicate the most concerned dimension in case profile which can be used to guide the selection of recommended cases. In this paper, the MCD could be Proj, TP, or CDP and the default value of MCD is CDP. The students can input MCD according to their requirement. For obtaining the learning scaffolding, the following learning scaffolding generation algorithm is given to evaluate the common case-design pattern between case-design portfolios of similar cases as learning scaffolding to assist student developing.

Learning Scaffolding Generation Algorithm

Input: The recommended case set CS, the most concerned dimension MCD, and the number of cases to be processed k.
Output: The learning scaffolding.
Step1: The T-CL is empty.
Step2: Sort CL according to MCD in descending order.
Step3: Store the top k cases into T-CL.
Step4: Output the learning scaffolding G-LCS(T-CL, k) according to Definition 7.

The following example is given to illustrate the learning scaffolding from learning scaffolding generation algorithm.

Example 4
Assume the most concerned dimension MCD is Proj, k is 2. For the data in Table 6, executing the learning scaffolding generation algorithm, we have the learning scaffolding is <PP, PL, LS, SD, LL, DD, DL, DD, DR, RR, RR>.

In Example 4, we can observe that the teams spent a lot of time in drawing design activity to complete their e-storybook. There are several possible reasons; for example, drawing could be one of the most difficult design activities for the team, the team members could not build consensus while drawing, the team members could be unfamiliar with drawing tools, and so on.

In accordance with the learning scaffolding, the student can prepare or adjust team's weekly design activity according to teams profile in advance. They can spare more time in the most concerned design activities. For example, if team's scripting ability is medium, they can spare more time in scripting. The teacher can monitor students' learning process and achievements and give them assistance.

7 Experiment
Two teams (Team-A and Team-B) have been chosen to participate in the experiment of e-storybook design process in capstone project with the following project characteristics and team profiles.

The project characteristic of Team-A
= <FW, AS, SA, LG, QL, W, N>
The project characteristic of Team-B
= <FN, MA, AT, LM, PR, N>
The team profile of Team-A
= <M, M, H, M, M>
The team profile of Team-B
= <H, H, H, H, M>

In the experiment, the design process period lasts for a semester, where Team-A used the e-PBL platform in design process and Team-B only used the traditional PBL learning strategy to design their e-storybook. During the design process, we can observe the creative ideas and design results of two teams. The experimental result shows that the final product of creative design of Team-A is significantly better than that of Team-B in design process. The screenshots of e-storybook by Team-A is shown in Fig.3.

(a) (b) (c)
Fig.3. The screenshots of e-storybook by Team-A

According to learning scaffolding, Team-A learns the script writing and problem solving scenarios and imitates some scenes and roles design from Case 3, as shown in Fig.3(a) and Fig.3(b). Team-A follows the drawing style and scene arrangement from Case 8, as shown in Fig.3(c).

8 Discussion and Findings

8.1 Discussion

For understanding the students' inner thoughts and feelings, we design a questionnaire and perform an in-depth interview about the design process. The questionnaires consisting of 6 items were revised version of [37,38] questionnaires. The questionnaire result shows that the Team-A thought that the learning scaffolding could benefit the brainstorming and help keeping the final result of the design consistent with the transdisciplinary design idea. With the guidance of learning scaffolding, the pressure of the students in design process have been reduced, and the Team-A felt more confident than before during the design process. Such a feeling is very important for e-storybook production. In particular, the students also believed that the relationship among the team members is better than before.

According to the in-depth interview results, the Team-A thought that in the beginning of the design process, the creativity is not easy to present due to the difficulty of use of the unfamiliar software. The students are more proficient and good to generate more creative idea after applying the e-PBL platform. We may conclude more learning scaffoldings are needed to inspire students thinking and to motivate the frequent interaction between the team members.

During the design process, the Team-A is apt to help each other to create a number of different schemes due to the understanding of each member's status. In some design iterations, the team members follow or imitate the scenarios of case-design portfolio and then collaborative work out the final solution. During the discussing step, students express their views and ideas as the reference in the next design process.

On the contrary, the Team-B said they sometimes could not easily show up their ideas and could not design the outcome that they desired. Students sometimes asked the teacher to give advises, but most of the time they searched the relevant works to reference. The Team-B could complete the design activities finally without collaboration in the design process, so their design products are most likely worse than those of the Team-A's.

8.2 Findings

We have three findings:

1. The students sometimes have insufficient creativity in the capstone project, and they need good learning scaffolding as a seed to inspire. Thus, exploring an appropriate case as learning scaffolding can inspire students' creativity and problem solving brainstorming.
2. In capstone project, the consensus is not easy to build. Sharing and reusing similar case can convince others to respect other students' ideas to build team consensus.
3. The team follows or imitates the design pattern of case-design portfolio of similar cases can get high design achievement.

9 Conclusion

For design and problem solving abilities learning, we have developed a spiral e-PBL platform using enhanced CBR (e-CBR) to be able to assist students to inquire similar cases, stimulate creative idea, build consensus, and collaborative design in design process. For retrieving the similar cases in this platform, the similarity functions and similarity-based case retrieval algorithm are designed according to the project characteristic and the team profile. The case-design portfolio of retrieved similar cases can then be collected, and analyzed by our proposed learning scaffolding generation algorithm to generate the scaffoldings of students' collaborative design, and assist teachers to monitor the students' design process and achievements. For novice users developing the capstone project easily, the learning scaffolding generation algorithm based upon the longest common subsequence (LCS) is proposed to generate the scaffoldings. The experimental result shows that the given appropriate learning scaffoldings can guide students to improve the design and problem solving abilities. In the near future, we will focus on improving the data acquisition and analysis of the case-design portfolio.

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