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Development and Implementation of a Web-based Tool to Support Creative Problem Solving (CPS)

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The purpose of the study was to develop and implement a web-based support tool to be used in the Creative Problem Solving (CPS) processes, which were integrated with the elementary school social studies classes. The tool design strategies were formed by analyzing the related previous studies. Various teaching models, which were used to enhance the CPS skills and the CPS model based teaching plans for the fifth grade social studies classes, were analyzed. Based on the analysis, a number of design strategies for the web-based support tool were established and also a detailed system specification was developed. The strategies and the specifications were verified by the subject matter experts. The multimedia contents and the teaching materials were also developed and integrated into the tool. The tool was verified again then implemented. The web-based support tool was used in three CPS fifth grade classes for a semester at an elementary school located in Seoul, Korea. By analyzing the data collected from the teacher and student surveys, observations, and focus group interviews, the tool was found to be satisfactory by both teachers and the students. From the problems reported by the study participants, a few improvement suggestions were developed to enhance the tools.

Keywords: creative problem solving (CPS), CPS model, web-based support tool, web-based problem based Learning (PBL), thinking tools

INTRODUCTION

There had been active discussions among the educational technology researchers with the purpose of defining and implementing the creativity trainings. These increased interests were due to the recognition of improving students' creativity as one of the important goals of the formal education. One view is that creativity can be fostered. The other perspective is that creativity can only be manifested with the knowledge of the relevant subject areas. Based on these ideas, Choi & Choi (2001) suggested a CPS model, which utilized the curriculum-based knowledge and learning capabilities of the students, as a specific formal creativity education method.

CPS is a process of solving the unstructured problems through the steps such as problem analysis, data collection, data analysis, solution generation, and solution verification. During the problem solving process, the students acquire the necessary knowledge and/or utilize previously acquired knowledge. The CPS emphasizes students' voluntary search for the problems to solve then solving the found problems (Treffinger, Isaksen, & Dorval, 2000) as well as the intentional and systematic applications of creative thinking, such as divergent, logical, and critical thinking, in each problem solving step to generate innovative and useful solutions (Kim, 2004, Lee & Koo, 2007).

Seo et al. (2001) found that the teachers neither understood nor carried out CPS education well although it is regarded as an important practice in Korean schools. According to Cho (2006), most Korean schools operated ad-hoc and short-term creativity improvement programs that were independent from the regular instructional curriculums. These programs might have contributed in improving the general creativity to some degree. However, the programs were regarded as less useful in improving CPS capabilities, which required professional knowledge.

The Web is now used as a vehicle for facilitating communications for learning, explorations for discovery, and experiences to form knowledge. Thus, the Web has received increased interest as a medium, which

can overcome the limitations of the traditional classroom lectures and also provide a constructivist type learning environment (Grabe & Grabe, 2000; Jonassen, 1996). These attributes of the Web were well incorporated as a part of the Web-based Problem Based Learning (PBL), whose purpose was to improve problem solving capabilities (Karen, 2003; Malopinsky et al., 2000; Sage, 2000). Especially, the educational aspects of the Web such as, providing multimedia information, accessing information in a non-linear manner, supporting interactive communication, and integrating various information types, can effectively support learning activities, which promote and foster divergent and critical thinking. Divergent and critical thinking was one of the cognitive components of creativity, which can be operationalized as learners encounter a variety of perspectives, expand their reasoning, and classify & criticize varying perspectives during the CPS processes (Jonassen, 1994).

In comparison to the general practice of PBL utilizing the Web extensively, there had been limited attempts to use the Web to improve CPS in Korea. Kim (2007) reported that a couple of Korean creativity education websites such as 'Creativity Net' and 'Ask Science Creativity Class' provided one-time use information or a limited set of thinking methods, which were applicable in only a few stages of the CPS.

In this study, we developed a web-based support tool to assist the activities of the teachers and students during formal education curriculum-based CPS classes. The web-based support tool was a type of learning management system as well as a learning website, which was developed to provide real-time assistances for the teaching and learning activities in the teacher-led online and offline combined curriculum-based CPS classes. It was possible for teachers and students to conduct various after-class activities by asynchronously accessing the tool.

To accomplish the goals of this study, we established design strategies for the web-based support tool then developed the tool based on the strategies. At the end, we deployed the tool for field testing. Through these action sequences, we were able to generate a list of improvement suggestions to better satisfy the tool users. There was also a suggestion to better integrate the tool as a part of the regular school curriculums. Our research questions were how the curriculum-based CPS support tool needs to be designed and developed and what the improvement suggestions for the curriculum-based CPS support tool were after its deployment in the field.

DESIGN STRATEGY FOR SOCIAL STUDIES CPS SPPORT TOOL

Curriculum-based CPS and its Model

It was possible to improve the curriculum-based CPS capabilities by using the models by Osborn (1963), Parnes (1963), Lurnsdaine & Lurnsdaine (1995), Feldhusen (1993), Isaksen & Treffinger (1985), and Puccio et al. (2005). Torrance (1972) claimed that the CPS model by Osborn-Parnes and their variants had a more than 90% success rate in improving CPS capabilities (Lee, 2005).

The CPS models of Osborn (1963) and Parnes (1963) were further developed into a six stage model by creativity researchers such as Feldhusen (1993) and Isaksen & Treffinger (1985). The six stages consist of discoveries of 1) interested subjects; 2) data; 3) problem; 4) idea; 5) solution; and 6) acceptance. One of the recent CPS models developed by Treffinger et al. (2000) is shown in the Table 1.

We proceeded with the divergent and logical & critical ideas separately in each stage of the CPS model as shown in Table 1. This is based on Osborn's claim that there will be a higher success rate for the capabilities improvements when two types of ideas were intentionally applied independently rather than simultaneously.

Table 1. *CPS Model*

Process	Stage	Divergent Stage	Logical & Critical Stage
Understanding the Challenge	1st Stage: Composing Opportunities	Discover experiences, roles, and contexts to find the subjects of interests; Explore the openness about experience and opportunities	Accept the challenges and begin the systematic efforts to react to the challenges
	2nd Stage: Exploring the Data	Collect facts and investigate the contexts from multiple perspectives; Collect information, impression, and emotion	Confirm the most important facts and analyze them
	3rd Stage: Composing the Structure of Problem	Generate as many problems and sub-problem statements as possible	Select or compose the realistic problem statements
Generating Ideas	4th Stage: Generating Ideas	List many alternatives and possibilities of the problem statements	Select the most useful and interesting ideas
Preparing for the Actions	5th Stage: Developing Solutions	Reconfirm ideas and generate as many evaluation criteria as possible	Select the important criteria to evaluate the ideas then use the criteria to evaluate, strengthen, and refine ideas
	6th Stage: Establishing the Base for Acceptance	Consider potential agreements and objections about the solutions; Confirm potential action steps	Focus on the most realistic solution then prepare to put it into action; Form specific plans to execute the solutions

The CPS model-based class sessions included alternating individual and group learning modes. In most cases, the beginning of the classes and the presentation parts were operated in the lecture-based learning mode. However, Sternberg (1996) and Kim (2004) emphasized the effectiveness of group learning in the solution presentation activities after finding solutions from the given problem contexts. These claims were based on the ideas that divergent and logical & critical thinking provoking techniques were more effective when applied in the group learning rather than the individual learning mode.

Lesson Plan Analysis for the Social Studies CPS Instruction Sessions

To develop a web-based support tool for the curriculum-based CPS instructions, we analyzed the lesson plans for the second semester curriculum of fifth grade social studies classes from the instruction restructuring criteria, teaching & learning activities, and teaching & learning materials perspectives. The lesson plans that we analyzed were the products of restructuring the existing plans under the direction of Korea Education & Research Information Services (KERIS). For the analysis, the elementary school teachers prepared nine social studies lesson plans under the guidance of three creativity education experts. The completed lesson plans were thoroughly verified by the same creativity education experts (Lee et al. 2005a; Lee et al. 2005b). Table 2 shows the instruction restructuring criteria, which were applied in preparing the lesson plans.

The CPS model described in Table 1 was used in the restructured instructions by considering the actual instruction environment at the schools. Table 3 shows the important teaching-learning activities in each stage.

Table 2. *Instruction Restructuring Criteria for Improving the Curriculum-based CPS Capabilities*

Present the unstructured problem context, which are related to the subjects of the chapter in consideration, then follow all stages of the CPS model in principle
Provide various creative thinking techniques and learning activities at each stage of the CPS
Clarify the relationship between each stage of the CPS and its corresponding activities as well as make the stages and the activities connected to each other
Compose the group activities and evaluative activities to enable the students to experience the importance of solving problems actively and coming up with unique ideas
Present the prompts and the guidelines, which can provoke students' divergent and logical & critical thinking
Clearly present the evaluation methods after completing the activities or providing solutions as the evaluation is important in the instructional sessions with the goal of improving the CPS capabilities

Table 3. *Important Teaching-Learning Activities and Materials for Each Stage of the CPS Model*

CPS Stage	Important Teaching-Learning Activities	Teaching-Learning Materials
1st Stage: Context Recognition	Understanding and analyzing the problem contexts through teacher-led whole class or group learning	Learning activity sheets and thinking tools
2nd Stage: Information Confirmation	Explanation of the problem context related knowledge by the instructors Acquisition and collection of related knowledge via individual and group learning	Textbooks and learning activity sheets
3rd Stage: Problem Search	Statements of the problems to solve and selection & composition of specific problems through the group discussions	Learning activity sheets and thinking tools
4th Stage: Solution Discovery	Generation of many diverse and unique problem solving ideas via the group discussions and refinement of the interesting ideas	Learning activity sheets and thinking tools
5th Stage: Solution Selection	Organize, analyze, improve, and strengthen promising ideas through the group discussions Combine, evaluate, prioritize, and select promising solutions through the group discussions	Learning activity sheets and thinking tools
6th Stage: Planning	Consider activities needed to execute and risk factors via the group discussions Establish specific plans by the group or individually Share and evaluate the results via the presentations	Learning activity sheets and thinking tools

The following were the factors to consider when designing the curriculum-based CPS support tool. The factors were the products of analyzing the lesson plan design principles and the major teaching and learning activities related data.

1) The classes should be conducted by following all stages prescribed in the CPS model.
2) The classes should be conducted under the supervision of the teachers. The team-based learning should be the dominant form of the classroom activities while other forms of learning activities such as individual and whole class learning can occur as well.
3) At each stage of the CPS, the students will be provided with the learning activity guides; thinking tools; and worksheets including the thinking techniques.
4) During the mess-finding stage, the teachers should provide the problem contexts, which include the subjects and the contents of the corresponding course, to the students. The students will be expected to comprehend and analyze the problem contexts as a whole class and/or by the problem solving teams.

5) During the fact-finding stage, the students will be expected to acquire the problem solving knowledge using various resources such as the textbooks, multimedia contents, and web-based information.

Design Strategy for Curriculum-based CPS Support Tool

Recently, there have been increased uses of the web-based PBL in conjunction with face-to-face instructions to raise the education quality in comparison to the exclusive PBL uses with online instructions (Chung, 2007, Karen, 2003, Malopinsky et al, 2000, Sage, 2000). Choi (2002) and Choi & Sung (2004) suggested the following four design strategies and the attributes of the websites to be used as a part of the web-based PBL in elementary schools.

1) The teachers should apply the educational methods based on the learning principles of Behaviorism and Cognitivism as needed to enable typical elementary school students, who lack the mature self-directed learning capacity, to cope with the difficulties in learning.
2) The teachers should come up with the methods, strategies, and activities to motivate the students to learn.
3) The teachers should avoid providing pre-structured learning contents to the students. The learners should be expected to study independently with the given instructional materials such as textbooks, Internet sites, multimedia contents and newspaper articles.
4) The learners should be given tools to collaborate with other learners as part of a team.

Park (2005) suggested a list of basic menu items for a website to conduct web-based PBL successfully. They were announcements, learning objectives, student introductions, learning resources, questions & answers, free discussion board and learning activities.

Especially, the learning activities section plays the central role of supporting the PBL related activities. This section is composed of the problem contexts, group discussion, output submission and resource sharing functions. Initially, a student will be expected to read the description of the problem contexts. Then, the student will try to define the problem and then to come up with solutions individually while referring to the learning resources. After this stage, the student will post his/her opinions in the group discussion section to exchange ideas with other group members.

Hannafin, Land, & Oliver (1999) emphasized the importance of various guides, which can facilitate the ill-structured problem solving. They described a conceptual guide as a tool for helping the learners understand what to consider during problem solving processes. A metacognitive guide was explained as a specification of how the learners should think while the problem solving process is in progress. Lastly they described a strategy guide as information about how to access and analyze the learning tasks and problems.

Additionally, Kim and Kim (2002) presented the importance of tools supporting metacognition, which is required during the learners' problem solving processes during the web-based PBL at the elementary school level. Park (2000) claimed that metacognition capability enables a learner to control and manage his/her knowledge, thoughts and cognitive activities. Furthermore, he stated that the capability is also a working strategy, which determines the operational effectiveness of simplifying the problems at hand, searching for the problem solutions and generating plans to execute the solutions. Thus, we concluded that support for the promotion of the effective use of metacognition, is an essential attribute of the web-based support tool for the CPS.

In summary, we were able to come up with the following implications for the web-based curriculum-based CPS support tool design from the analysis of the curriculum-based CPS capabilities, the CPS models, instruction contexts, textbooks, and previous researches on the web-based PBL.

1) As the users of the web-based support tool were the elementary school students, the tool should be usable in the class instructional instances led by the teachers. At the same time, the tool should be used to provide conceptual, metacognitive, procedural, and strategic guidelines to the students during

the CPS.

2) The web-based support tool should enable the students to use the multimedia contents to raise the students' interests and also to help them to comprehend the information needed for the CPS.
3) The tool should provide menu items and various resources to enable the students to form knowledge independently by exploring the curriculum related information during the CPS.
4) The tool should provide the virtual spaces for the students to work independently and/or as a part of a team.
5) According to the CPS steps, the tool should provide the corresponding menu items for the students to work on the appropriate learning activities.
6) Most of the previous researches on the web-based PBL and the creativity education related websites rarely considered support for divergent and logical-critical thinking, which are the core attributes of the CPS models. However, the web-based support tool described in this paper was designed to support the promotion of divergent, logical-critical thinking activities in each stage of the CPS model.

Based on the six implications described above, Table 4 shows the design strategies for the web-based support tool.

Table 4. *Web-based Support Tool Design Strategies for CPS*

■ Devise menu items to support the sequential activities based on the six stages described in the CPS model
■ Provide conceptual, metacognitive, procedural, and strategic guides suggested by Hannafin et al. (1999) , to support the CPS activities of the learners
■ Incorporate various learning resources and multimedia contents, which can be used to support the subject knowledge applied to CPS
■ Provide thought-provoking prompts as part of the web-based support tool and allow the students to utilize the divergent and logical-critical thinking multimedia tools
■ Design the web-based support tool functionalities to accommodate the whole class, team-based, and individual learning activities within the teacher-led classroom instructions (in principle, provide one computer to each group as it is practically impossible to have one computer for each student)

RESEARCH METHOD

Design and Development of the Curriculum-based CPS Support Tool

To develop a web-based support tool, we conducted the literature review on Social Studies curriculum-based CPS capabilities, the CPS models, and web-based PBL design. We also analyzed the CPS model applied to Elementary School Social Studies lesson plans as previously described in the Social Studies CPS support tool design strategies section. From the outcomes of the literature review and the analysis, we derived the implications for the web-based support system design as shown in Table 4. The web-based support tool design strategy was verified by three active elementary school teachers, three educational technology experts, two creativity experts and one system expert.

By following the web-based support tool design strategy, two education technology experts and one creativity expert determined the functionalities and the menu structure of the support tool as shown in Table 6. To do this, the experts considered the general educational attributes of the Web, the basic menu structure of the virtual instruction space for the web-based PBL reported by Choi (2002), and the KISTI proposed ideal web-based PBL site structure (Park, 2005). Then, two education technology experts verified the appropriateness of the support tool's functionalities and the menu structure in lieu of the design strategy. Furthermore, a storyboard for the contents of the Social Studies CPS classes, a reference sites list and various learning activity sheets were designed by the researchers for this study. An education technology software development company was assigned to implement the support tool. After the implementation and debugging of the support tool, the tool and its associated contents were opened as

part of a single website. Finally, the experts, who worked on the tool design, verified the tool's functionalities.

Field Tests

Participants

The web-based support tool that we developed was field-tested in three fifth-grade Elementary School classes. Three teachers and 92 students participated in the tests. The teachers had teaching experiences ranging from seven years to 25 years. They all had recognized the importance of creativity education. They also had positive attitudes and a willingness to use the web-based support tool in the CPS classes.

Test procedures

During a semester before the field tests, the researchers had met the fifth-grade homeroom teachers and the school administrators, who participated in the study, a few times to discuss the logistical issues related with the tests. There were three training sessions for the study participating teachers to help them understand the goals of the study, curriculums, lesson plans, and use of the web-based support tool. At the beginning of the semester, we provided the students with the support tool access rights and also a two-hour web-based support tool training session, before the field tests took place. In addition, we attended the CPS sessions for the first chapter of the curriculum to monitor and also to help the teachers and the students in terms of using the web-based support tool.

The class sessions had taken place in the group study room where one personal computer was assigned per group. Each group consisted of five to six students. The students accessed the Internet through the personal computers assigned to their groups. They watched the multimedia contents using the 20-inch monitors and the sound sharing devices. In a group, each student member was assigned with a specific role to carry out the learning activities. At the end of the activities, the students prepared one group learning activity report. With respect to the individual learning, the students were encouraged to use the learning activity notebooks for the individual idea generations and/or organizations, as it was not possible for more than one group member to access the personal computer at the same time, although all students were able to use the personal computer via the wireless keyboards.
The homeroom teachers taught the students according to the social studies CPS lesson plans provided by the researchers. The lesson plans consisted of the detailed reorganized learning goals by each chapter, teachers' question prompts, learning activities, time schedule, and support tool use guides. The lesson plans also included the organization of the lessons, ideas to consider, evaluation metrics and miscellaneous reference materials.

Data collection and analysis

To collect the opinions about the web-based supporting tools from the actual users from various viewpoints, we conducted the participant observations and also conducted surveys with three participating classroom teachers and 92 students after completing each lesson. In addition, we conducted the focus group interviews with the teachers, administrators and the researchers.

Specifically, three participation observation sessions were carried out to collect in-depth information about the web-based support tool uses in the CPS classes. We selected three lessons out of nine CPS model based lessons. The first lesson was conducted at the beginning, another in the middle, and the other at the end of the semester. The recorded narratives of the three researchers were about: 1) how the web-based support tool was used for the major activities outlined in each CPS stage during a particular lesson; 2) overall reactions regarding the support tool; 3) the frequency and appropriateness of the support tool use; and 4) any errors or problems discovered about the web-based support tool which were recorded in the field notes. Each observed class session was also video tape recorded. The video recording was reanalyzed from the perspectives of teaching & learning activities using the support tool as well as the errors & problems encountered. During the participant observation sessions, the researchers maintained

the passive observer mode to minimize the interference to the activities of the teachers and students. With respect to achieving the goals of the observations, the validity of the items included in the field notes were verified by three education technology experts. We conducted nine surveys during the semester. The teachers and the students were the survey respondents. Table 5 shows the survey contents.

Table 5. *Post Lesson Survey Contents*

Respondents	Survey Contents	Type & Number of Questions
Teacher	■ Overall effectiveness of the web-based support tool ■ Effectiveness of the learning activities by stage, worksheet, and multimedia thinking tools ■ Usage related problems and improvement suggestions for each major menu items	Free form narrative answer (ten questions)
Student	■ Overall effectiveness of the web-based support tool ■ Effectiveness of the learning activities by stage, worksheet, and multimedia thinking tools ■ Usage related problems and improvement suggestions for each major menu items	Free form narrative answer (six questions)

The focus group interviews were conducted three times. One was conducted before the CPS classes using the web-based support tool. Another one was during the classes while using the tool. The other was after the classes when using the tool was completed. The participants were two school administrators, three fifth-grade classroom teachers, one school wide research activity leading teacher and five researchers. Each focus group interview lasted for one to two hours. The format of the interviews was a free form discussion. The topics of the discussions were the progress status and the outcomes of the classes using the web-based support tool. The discussions were not voice recorded but written down by three researchers due to the low quality of the voice recording.

We generated the suggestions to refine and improve the web-based support tool through the following two-stage subject analysis of the data collected from the post lesson surveys and the focus group interviews with the teachers and the students. By reading the data, we discovered that it was possible to classify the data according to the initially developed web-based support tool design strategies. Thus, data was classified as such. Then, we coded each classified data according to the usage effectiveness, difficulty, problem and improvement suggestions regarding the menu items and functionalities of the web-based support tool. The analysis results of the data collected from the nine lessons studied in three classes, especially about the reactions, opinions, and suggestions related to the web-based support tool design strategies, were aggregated. They are presented in the following section.

RESEARCH RESULT

Curriculum-based CPS Support Tool Design and Development

Based on the design strategies, which were generated by analyzing the previous studies, we developed a web-based support tool with separate modes for the students, teachers, and the administrators. This structure is similar to how the web-based PBL systems are organized. In the teacher mode, we provided a learning environment setting such as a set up for the learning activities by each chapter, selection of the learning data, set up for the groups, and monitoring, evaluation, & feedback of the learning activities as well as the learning management functionalities. In the student mode, we provided the problems to solve creatively and the corresponding problem contexts, descriptions of the activities according to the six stages of the CPS, learning activity sheets, multimedia thinking tools, reference materials, and related site links. Figure 1 shows the menu items for the student mode of the web-based support tool.

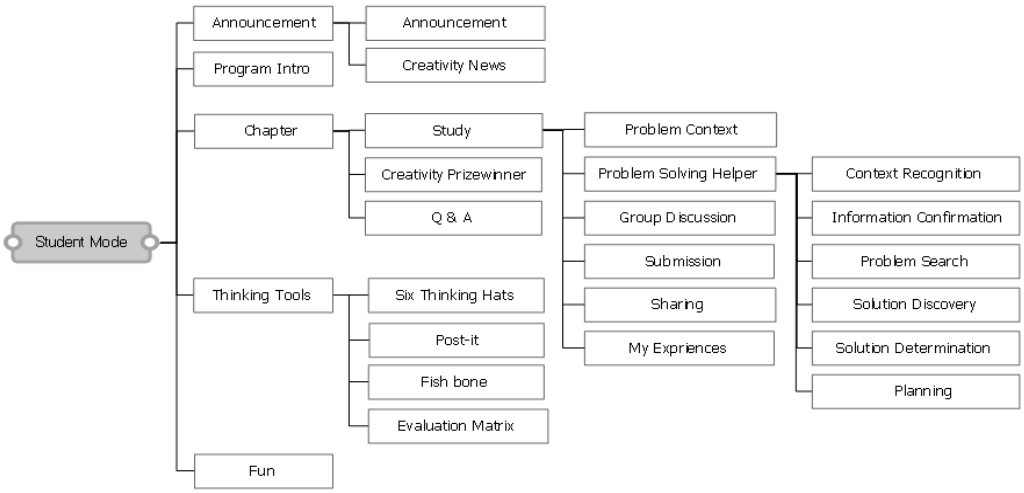

Figure 1. *Student mode menu items of the web-based support tool*

Table 6 shows the main functionalities and the menu items of the web-based support tool developed based on the design strategies, which were described in Table 4.

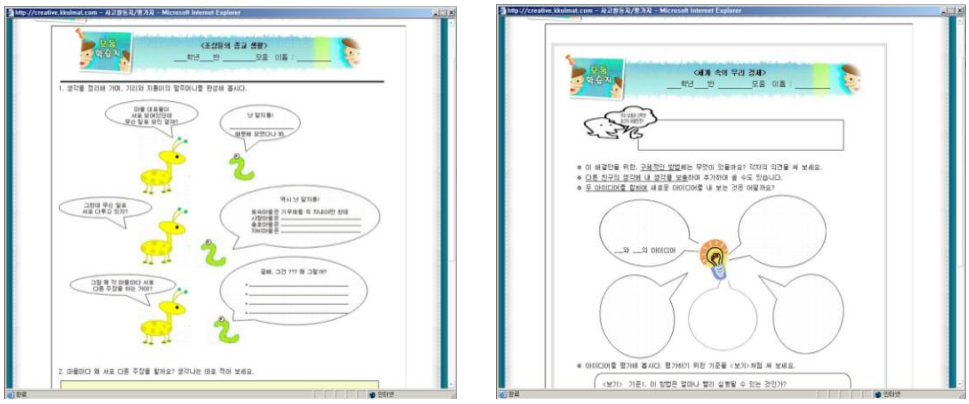

Figure 2. *Learning activity worksheets*

Figure 3. *Thinking tools: Six Thinking Hats and Post-it*

Table 6. *Main Functionalities and Menu Items of the Web-based Support Tool*

CPS Support Functionality		Menu	Major Functionalities
Support whole class, individual, and team-based learning	Supports and Provides Guidelines for the Six Stages of Activities in the CPS Model	Problem context	Provides multimedia materials, such as videos or Flash animations, to describe the problem contexts
		Problem solving helper	Consists of independent lower-level menu for each stage based on the six-stage CPS model
			Suggests activities to conduct in each stage of the CPS Model
			Provides necessary learning activity worksheets and thinking tools
			Provides standards and/or criteria to evaluate the output from each stage
			Complete all activities required in each stage then proceed to the next stage after marking its completion
	Provides subject-based multimedia contents and resources	Problem solving helper / fact finding	Incorporate links to the related reference sites and multimedia contents during the two-stage fact finding process
		Problem solving helper / learning activity worksheet	Suggest questions, guidelines, and appropriate creative thinking techniques, which are designed to promote divergent and logical-critical thinking
			Provide teachers' feedback after the learning activity worksheet was prepared and submitted individually or based on team efforts
	Provides multimedia thinking tools	e-Thinking tools	Provides multimedia thinking tools such as Mindmap, Post-IT and Six Thinking Hats to promote divergent and logical-critical thinking
			Provide teachers' feedback after the learning activity worksheets were prepared and submitted individually or based on team efforts
	Instructions and feedback from the teachers	Monitoring learning activities	Teacher assess learning activity progress of the learners at each stage of the CPS Model
			Provide feedback individually or based on team efforts after reviewing the learning activity worksheets and outputs

Table 7 shows the important teaching and learning activities, which uses the web-based support tool, as well as the menus that were utilized in the instructions carried out according to the stages described in the CPS model. At each stage, the students record, store and submit the outcomes of the activities in the learning activity sheets. The students move on to the next stage after they evaluate and confirm the completion of the learning activities suggested in each menu item or as instructed by the instructors.

Table 7. *Important Teaching and Learning Activities and the Menus Utilizing the Web-based Support Tool*

CPS Stages	Important Teaching and Learning Activities	Utilization Type	Used Menu
1st stage: context recognition	Viewing the multimedia presentation, which describes the problem contexts	Whole class or group studies	Problem collection, context recognition by the problem solving helper
	Comprehend and analyze the problem contexts according to the instructions from the teachers and/or the prompts as well as the guidelines in the learning activity sheet		
2nd stage: information confirmation	Problem contexts related knowledge acquisition & collection by using the data, such as the multimedia contents and/or the site links, provided in the information confirmation menu	Individual or group studies	Information confirmation by the problem solving helper
	Teachers' additional explanations about the problem context related knowledge		
3rd stage: problem search	Generation, narration, selection and composition of the problems to solve by the groups according to the prompts and the instructions in the learning activity sheets	Group studies	Problem search by the problem solving helper
4th stage: solution discovery	Generation and refinement of the ideas to solve through the discussions according to the thinking tool use prompts and the instructions in the learning activity sheets and/or given by the teachers	Group studies	Solution discovery by the problem solving helper
5th stage: solution decision	Organization, analysis, improvement, or strengthening of the problem solving ideas as well as combining, evaluating, prioritizing, or selecting the promising solutions, which were refined during the solution discovery stage through the discussions according to the thinking tool use prompts and the instructions in the learning activity sheets and/or given by the teachers	Group studies	Solution discovery by the problem solving helper
6th stage: planning	Finding out the risk factors to consider and necessary activities to execute solutions, which were determined through the discussions according to the thinking tool use prompts and instructions in the learning activity sheet or given by the teachers	Group, individual, or whole class studies	Planning by the problem solving helper and information sharing space
	Presentation, sharing and evaluation of the submitted results		

DEPLOYMENT OF THE CURRICULM-BASED CPS SUPPRT TOOL

Supporting the Six Stages of the CPS Activities

Problem context

While the teachers described the social studies subjects to improve the students' understanding of the important conflicting issues, all students watched the multimedia problem contexts, which were stored as part of the problem collections, and re-watched the problem contexts as a group if needed. The multimedia problem contexts were useful in raising students' curiosity and also helping them to focus on

the stories.

Observer #2: "Before watching the flash animation, the teacher explained the storyline of animation to the students. After watching the animation, the teacher asked questions about the subjects of the animation to increase the level of understanding about the problem situations by the students. The teacher instructed the students to watch the animation again with the instruction to fill-out the learning activity sheets by group."
Teacher #2: "The students liked the flash animations. The animation also enabled the students to focus on the conflict situations and thus helped the students to have increased interests on the subjects."
S*tudent #3-8': "It was possible for us to think about the problem while re-watching the animation, which was a part of the problem collection."*

However, there was an issue of slow loading of the problem contexts in the moving image format. It could have been better if there was a pause function to include additional explanations during the playback of the problem contexts. This type user-centered interface could have helped the students better understand the subjects.

Teacher #1: "It took too long to load the problem contexts moving images to view."
Teacher #3: "There should have been pause and rewind-then-playback functions."

Problem solving helper

The conceptual, meta-cognitive, procedural, and strategic guidelines, which were provided as part of the problem solving helper, enabled the students to recognize and carry out the learning activities needed for each CPS stage. The guidelines were also helpful for the teachers in instructing about the CPS.

Teacher #1: "It was helpful to have a description of the learning activities for the students to conduct in the six stages of the CPS model in terms of managing the classroom sessions. It was also good to have the students check and evaluate their activities by themselves before going from one stage to the next."
Student #3-16: "It was good to confirm what to do and how to do it with the computer during the group activities after listening to the teachers' explanations."

However, it was difficult for the teachers to modify the problem solving helper, which was provided as part of the web-based support tool, to meet the needs of their classroom sessions. Given this problem, we recognized the need to have flexible access to the CPS model and also to improve the delivery methods of the guidelines for each CPS stage.

Teacher #2: It will be crucial to reduce some of the core learning activities to focus on the improvement of the CPS capabilities in the overall perspective."

In the problem solving help, each stage of the CPS model was made up of an independent screen. It was only possible to move on to the next stage after completing the each stage. However, we discovered that it is better for the lower-level menu items to be linked for easier navigation as it is important to re-check the learning activities occurred in the previous stages. This is due to the interconnected nature of the CPS model stages.

Teacher #1: "The CPS model should help the students to think about the stage they are working on in conjunction with the previous stage as the quality of the CPS model will not be maintained if the interrelationship among the stages is not recognized."
Teacher #3: "There are many cases where the students need to confirm the results from the previous stage as they learn by going through the stages one at a time. However, it was a bother to open and close many windows to check the results."

Multimedia Contents and Resources

Information confirmation functionality of the problem solving helper

Students had effectively used various multimedia resources, which were provided by the information confirmation functionality of the problem solving helper, to gather necessary information for the CPS.

> *Student #3-15: "It was easy to find the information and it was also easy to find the meaning of the words."*
> *Teacher #1: "It was convenient to confirm the information right away in the classroom by using the web-based support tool."*

Most of the linked sites included the essential information for the CPS. However, there were a few sites, which were not reachable or disappeared. There were also sites, which included the information that was difficult for the students to comprehend. Thus, we realized that it is necessary to allow the teachers to check the linked sites before the class sessions. Furthermore, we also found out that the teachers should be able to restructure the contents so that the students can understand them easily.

> *Teacher #2: "It was necessary to retrieve the information that was needed for the class sessions as there were some sites, which were not accessible or disappeared. It was also necessary to edit the information to meet the comprehension level of the students."*

Learning activity sheet

At each CPS stage, the learning activity sheets were used effectively when applying the social studies knowledge in the CPS to encourage the students to have divergent and logical & critical thinking. In addition, the learning activity sheets were used well during the instructions by the teachers.

> *Teacher #3: "It was good to have the learning activity sheets, which can be used to organize and understand the problem contexts through the observations. This process of finding the core issues will help the students understand the subject matters."*
> *Teacher #1: "The thinking activities, which were listed in the learning activity sheets, were helpful in generating the students' thought provoking prompts."*

However, there were difficulties in preparing and submitting the individual learning activity sheets as there was only one computer per group.

> *Teacher #3: "The students had difficulties in separating the individual and group activities as they had only one computer to use in each group."*

Multimedia Thinking Tools

The multimedia thinking tools such as, Mind Map, Post It, and Six Thinking Hats promoted the students' learning activities during their CPS processes.

> *Teacher #3: "The students easily recognized the problem context as they drew and defined the mind maps."*
> *Student #3-22: "It was possible to exchange the ideas with many people through the use of Mind Map, Post It, and Six Thinking Hats."*

However, the students and the teachers suggested a few improvements on the input method, category selection, storing and deletion functionalities of the Post It tool.

> *Teacher #2: "The Post It thinking tool did not allow the students to enter the idea without the category assignment. However, there were cases when the ideas did not need any category*

assignment."
Student #2-14: "It could have been better if storing and deletion was easy to do when using the thinking tools."

The teachers emphasized the functionality improvements of the thinking tools so the tools can be used freely in all learning activities in addition to the CPS processes within each chapter.

Teacher #2: "It is necessary to improve the functionalities of the thinking tools such as, Six Thinking Hats and Post It so that the tools are usable by the teachers while conducting teaching and learning activities for all chapters. The teachers want the tools, which can be used independently by the learners whenever they want in addition to the CPS stages."

Teacher Instructions and Feedbacks

We found that it is difficult for the teachers to find spare time for checking and also providing feedback about the students submitted learning activity sheets by using the teachers' computers during the class sessions.

Teacher #1: "It is not possible to find any time to check and to give feedback regarding the learning activity sheets during the class sessions."

Especially, we found that the students' activities had to be halted while the teachers move from the problem solving helper screen to the learning activity monitoring screen on their computers as the teachers had to go through many steps to accomplish the transition.

Teacher #4: "It is difficult to provide learning guides and also to check learning activities during the class sessions. The students' activities had to be stopped while the teachers transit to the learning guides screen and/or the learning activity monitoring screen."

This led to a realization that we need to improve the navigation to and from the learning activity monitoring screen.

CONCLUSIONS

Based on the field tests, we found that most of the menu items and the functionalities of the web-based support tool satisfied the intended goals specified in the design strategies. However, we also concluded that we need to improve and refine the web-based support tool of the following aspects to effectively and efficiently support the curriculum-based CPS based on the CPS models.

Firstly, it will be necessary to improve some of the web-based support tool functionalities to be more user-friendly from the six-stage CPS activities support point of view. Both teachers and the students will be able to use the web-based support tool more easily by adding the function of replaying only the needed parts of the multimedia contents, which are viewable under the 'Problem Context' menu. In addition, the problem solving helper is currently operating independently as a part of each CPS stage. However, the problem solving helper should be linked across the CPS stages as the six-stages of CPS are interrelated. By improving the web-based support tool for the above outlined two aspects, it will be possible to better support the related nature of the CPS stages, provide an environment for the teachers to remove or integrate certain stages of the CPS according to the specific lesson subjects, and thus support flexible instructions. Furthermore, there should be an improvement of a functionality to select the appropriate exposure level based on the capabilities of the students then present the metacognitive, procedural and strategic guidelines for the CPS.

Secondly, it will be possible for the students to learn the subject knowledge and also conduct the CPS based on the acquired knowledge if the learners can select and utilize the appropriate multimedia learning

resources. To accomplish this, the resources should have been provided in the 'information confirmation' sub-menu of the problem solving helper by the respective students' capabilities levels. In addition, the teachers will be able to easily create the learning activity worksheets for various CPS classes if the teachers were provided with the appropriate learning activity worksheets authoring tools, which can take into account the characteristics and goals of diverse curriculums. The current web-based support tool was designed and developed for the classrooms with one personal computer for each team. However, it is difficult to conduct the individual learning activities in such a team-based learning environment. Fundamentally, it will be better to have an individual web-based support tool for each student. However, we should apply the strategy of utilizing the support tool only for the team-based learning and using printed materials and workbooks for the individual learning if it is not possible to have a classroom with one personal computer per student.

Thirdly, it will be desirable to provide the thinking tools, which will be suitable for promoting the divergent thinking and logical-critical thinking, in the problem solving helper. At the same time, it will be essential for the students to use the thinking tools freely during the CPS processes. This means that the web-based support tool should allow the multimedia thinking tools usages to be independent of the CPS model stages.

Fourthly, it will be necessary to improve the menu structure to allow the teachers to access the 'learning activity monitoring' menu from all other menu items in the web-based support tool from the teachers' guidance and the feedback points of view. The learning activity monitoring enables the teachers to monitor the students' online learning activities.

The teachers and the students alike expressed positive reactions to the design strategy, provided functionalities, and menu items of the web-based support tool when the tools were used in the subject-based CPS classes. The systematic, relative long-term, and many applications of the web-based support tool in the practical settings revealed the above outlined items and functionalities to improve. The execution of the improvements will enable the revised web-based support tool to satisfy both the teachers and students more than before. The improvements will also make the tools more appropriate for the practical settings and provide flexible and rich grounds for the CPS classes.

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