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Design-Based Research for Developing Wiki-Based Inquiry Support Tools*

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The purpose of this study was to design an inquiry supporting tool on wiki based collaborative learning and to investigate the effect of the inquiry supporting tool. Eight design principles were selected and more specified design strategies were made from the literatures. The first system with the first-round design principles was developed and implemented in an actual classroom. After the first field study, researcher found a few drawbacks of the system. The second system was implemented in the classroom again. Finally developed wiki-based inquiry supporting tool system is unique in that it allows instructors to design their own CSCL inquiry activities, and it has intuitive menu tabs showing inquiry learning processes.

Keywords : wiki, CSCL, inquiry Supporting tool, Collaborative Learning, design-based research

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Introduction

Collaborative inquiry is the process that participants share concepts of given research projects through widening understanding each other on research projects (Dillenboug & Traum, 2006). In other words, in collaborative inquiry, it is more important to evolve various views from participants into shared knowledge through explanation and debate than to just widen individuals' knowledge. To do this, learners need to define their common research projects, makes plans to do the projects, observe process and find out and save the information they need. Thus, several efforts have been made to support this collaborative inquiry.

Preceding research have suggested various systems to support the collaborative learning and reveals the effects of the systems(Bell & Linn. 2000; Bell, 2002; de Vries, Lund, & Baker, 2002; Scardamalia & Bereiter, 1994). These systems are made to build common data base, open all the information to all participants, and give opportunities to seek various thoughts of learners.

Existing systems ,however, use thread mode boards. In the boards, to upload their opinions on postings, learners should use the function of reply. To read postings, learners should endure the nuisance to click every posting, which leads to passive attitudes towards collaborative learning activities. In addition, Baek, Lee and Kim(2003) point out that existing boards have difficulties in collecting common opinions by learners' uploading of their opinions.

To reduce these difficulties, some universities and businesses have recently used various collaboration support systems(wiki, blogs) to replace existing web boards in web-based environment. Especially, as wiki pursues document boards rather than thread mode boards used in existing web-based collaborative learning, it is valued as one of the alternatives to minimize impediments of web-based collaborative learning including difficulties in observing contents, time-consuming debates, passive attitudes, the tendency that important issues or themes are forgotten over time. Let's take a look at some research to prove the educational usefulness of wiki

in collaborative activities(Richardson, 2009). When big tidal waves took place in 2004, 76 words related to the waves in Wikipedia only in 9 hours. Twenty four hours after the waves, 3,000 words were edited through more than 400 times of modification, and pictures, features and graphs related to the waves were attached. Twenty four hours after this (48 hours after the waves) 6,500 words were edited through more than 1,200 times of modification and a large amount of video clips were attached. Six months after, more than 7,000 times of editing took place and 7,200 words were registered in total. This proves that it is possible to make more data through cooperative work than that made by just one expert and knowledge was built by collaboration. Moreover, it revealed that though strangers come together to build knowledge, it is possible to produce common knowledge, not centered to one person, through spontaneous participation. This result is in line with studies by Arina, Alastair & Janet(2008), Lipponen(2002), de Pedro(2006). Therefore, wiki will be able to give positive effects in computer-based collaborative inquiries.

In this regard, this study tries to develop collaborative inquiry tool based on strengths of wiki and inquiry method would be design-based method. Under these circumstances, the author produced design principles and principles to carry out the design principles.

Theoretical Background

Wiki, its properties and usage as tools for collaborative inquiry.

Anyone who has access to wiki can modify and add the existing postings uploaded by the administrator or other participants. In other words, this means open editing; whoever, wherever, whatever and whenever.

It is possible because there are differences between writing in exsiting web-based boards and wiki-based boards. There are thread mode and document mode in web boards. In the former, users replies to other's postings. In the latter, anyone could modify, add and delete existing postings and it is strongly encouraged. In this mode, users don't reply or leave their names unlike the thread mode and greatly pursue the development of the document itself. Though users can use both modes in wiki-based mode, document mode is encouraged. This is because document mode wiki diminishes boundaries of somebody's writing or thoughts to reduce the limit about postings, and users can have shared attention to the quality and contents of substances in the website they participate. This trait makes it possible for users and learners to have direct access and feedback(Abawi, 2006). Accepting wiki in an aggressive way, learners can enjoy seeing themselves whose thoughts, not the existing standardized ones, evolve inside collaborative inquiry. Additionally, witnessing the increasing contents and modifying process in this process, learners is able to secure self-fulfillment, increasing feedback and spontaneousness in their own knowledge refining process.

As all the participants are producers of knowledge, learners can take part in collaborative inquiry learning in an aggressive way when given inquiry themes. However, there are two conditions to have successful collaborative inquiry. First, individuals' achievement and groups' achievement should be interdependent. Wiki makes it possible for learners to acquire successful collaborative inquiry for the group's achievement by making them participate in an equal way. Second, there should be personal responsibility. Wiki helps members of groups assign different roles and the amount of work, and helps evaluate each learner's qualitative and quantitative contributions. This encourages learners to have personal responsibilities by promoting spontaneous participation in collaborative learning. This is because as wiki saves all the activities of each learner in history, it can evaluate learner's activities in a proper way(Irina, Alastair, & Janet, 2008). In addition, since wiki can improve interaction between peer learners, knowledge sharing, sharing of

expertise(Lipponen, 2002) and cooperative abilities(Pedro, 2006), it is the appropriate environment in collaborative inquiries.

Nevertheless, according to preceding inquiry concerning wiki(Engstrom & Jewett, 2005; Notari, 2006: Prensky, 2001; Raman, 2005), there are three weaknesses in wiki. First, as anybody can be an editor, personal writings, emotional ones, mischievous ones or simply other's postings are possibly deleted to make learners passive participants. Second, wiki's editing style can make users unfamiliar with it psychologically shrink and feel difficulties to fail to achieve its educational purposes. Last, but not least, for learners who is familiar with multimedia, text-based wiki lacks of interests and motivation to curb learning effects without additional ways to stimulate their interests. In a nutshell, existing functions of wiki are not enough for active knowledge building and sharing in wiki-based collaborative inquiry. Therefore, wiki needs improved supporting tools to weaken these weaknesses and support collaborative inquiry.

Definition and process of collaborative inquiry

Collaborative inquiries can be said to be the process where learners understand different opinions of peers on a certain assignment through interaction and negotiation of meaning. In this process, they reorganize individual level knowledge and share knowledge about assignment.

This study is to take a look at PI(Progressive Inquiry, PI) model and Platten (1991)'s inquiry training model to draw stages of collaborative inquiry proper to this study. Learning process of PI model consists of the circle of creating context, setting up inquiry question, constructing working theory, critical evaluation, searching deepening knowledge, generating subordinate question, and constructing new working theory. Let's take a closer look at Platten(1991)'s model. In the first stage, instructors give explanations about inquiry process to learners through ‘confrontation of situations in question’ and present inquiry problems -

contradictory situations causing cognitive conflicts or unusual conditions. In the second stage, learners collect data and information to resolve inquiry problems through 'collection of data and examination. In the third stage, learners deepen their inquiry process by building and proving their hypotheses through 'collection of data and verification.' In the fourth stage of 'organization, making and explanation,' which is the stage where explanations about inquiry problems represented in the first stage try to be made, instructors guide learners to organize collected and verified data and draw rules or explanation. This is the stage where resolutions of problems are developed. In the last fifth stage, however, through reviewing of inquiry process, learners analyze strategies or questions to discern effective ones from ineffective ones and take a look at if activities in this inquiry process can be applied to other situations.

In this regard, collaborative inquiries have the characteristics that in collaborative inquiries learners identify inquiry problems by themselves and carry out their activities by collecting data and information for resolving the problems. One of the important things in their process is that learners, other participants and instructors build up common knowledge through interaction.

Preceding research on tools for collaborative inquiry

Examination of tools for collaborative inquiry

Tools for collaborative inquiry include 'CSILE(Computer-Supported Intentional Learning Environments)', 'CoVis', 'FLE', 'Explanation Constructor.' Let's take a look at characteristics of each tool.

First, 'CSILE' is the network-based learning environment where learners are provided common communities to support collaborative activities. 'CSILE' has personal space and collaborative space and individual learner use text type note or link and node type using built-in graphic functions. Learners, based on this note, make common notes, contending with peer l earners. This tool makes it possible

for learners to coordinate shared thoughts or conflicts with peer learners. Therefore, in CSILE, learners can openly express their different thoughts and it provides tags to make it possible for learners to view various thoughts of peer learners about this representation activities. Specifically, they can figure out who writes what and when through the tags. This helps individual learners arrange their own opinions and show ways when sharing notes with peer learners.

Second, 'CoVis' aimed to make network to connect experts as project partners in collaborative inquiries, and build up learning community for science learning using scientific visual tools. Tools for CoVis include Collaboratory Notebook and Scientific Visualization Tools. Learners write down their own inquiries such as their hypotheses, experimental process, observation and result in collaboratory notebook. The notebook provides representation activities using metaphor as interface, and support learners' debate activities by encouraging learners to write their opinions in the notebook with the provision of icons which compare learners' type of thoughts. Scientific visual tools are demonstration tools to show principles and results of certain arguments and that supporting explanation for the arguments are visualized in the form of graphic images or animation.

'FLE' is computer-based collaborative inquiry program to support the PI. One of the features of FLE is that learners lead their knowledge construction process in an active way. Learners figure out problems through communication with peer learners and plan and carry out problem-solving process. And this is where learners try to think in a voluntary and active way and learn how to aggressively participate in the process. Taking a look at components of 'FLE,' individual learners have their own learning space, 'WebTop' where they store various data and 'Knowledge Building' to support debates inside groups. In addition, 'Jamming' is the tool to structure digital data through collaborative activities within the group and learners can easily recognize debate themes and simplified contents related to them.

Fourth, 'Explanation Constructor' aims to support knowledge construction and evaluation by effectively expressing explanations and views on learners' inquiries

(Sandoval & Resier, 2004). Consequently, learners experience the process of constant writing and explaining their findings, in this process, learners have helps to clearly express cause and effect of natural phenomena and present accurate proof for learners' explanation. Elements of Explanation Constructor include 'questions/explanations' where learners write down inquiry questions, 'explanation' to provide assignment-dependent scaffolding and 'proof representation.'

Inquiry supporting tools have their focus on learners' knowledge building or internalization of complicated inquiry functions to make sure that learners can acquire scientific knowledge systematically. Thus, there are four areas to support inquiry support tools; Sense Making area to make hypotheses, plan research, collect and analyze data and draw results; Process Management area to manage the whole process of inquiry and acquire supervising functions(Quintana et al., 2004; Quintana & Fishman, 2006); Articulation and Reflection area to verify the correctness(Quintana et al., 2004); area to support collaboration between learners to reduce cognitive pressure. Let's take a closer look at these areas.

First, sense making area aims to support establishing detailed knowledge through activities such as building hypotheses, collecting data, ayalizing them and interpretating results. This is why existing inquiry support tools provide different types of nodes and links and separate storages to write inquiries and individual problem-solving process. 'Explanation Constructor,' to help select inquiry problems, has screen display to refer inquiry problems with separate space to write down the problems(Sandoval & Reiser, 2004). Participants can sort out and store various data in FLE and it helps knowledge building through webtop where they can have access to others' webtop.

Second, process management area aims to make sure that learners perform their roles needed in each inquiry process and evaluate role assignment and management of schedule. In this matter, 'Explanation Constructor' can be said as instructors' direct scaffolding strategies to exhibit separate guiding writings in the window of 'explanation guiding' for learners to identify important activities they have to carry

out in each inquiry process(Sandoval & Reiser, 2004).

Third, Articulation and Reflection area helps evaluate if scientific concepts are properly built by clarifying the concepts in visual and linguistic forms and places its focus on reflection on if inquiry and collecting activities are properly performed according to inquiry problems. To do this, existing inquiry support tools provide visualization of inquiry results or tools to reflect participants' results related to inquiry problems and their hypotheses. 'Covis' offers visualized tools for learners to present their own argument built in the inquiry process and its clear supporting arguments. Specifically, in 'CoVis,' the relationship between hypotheses and data is shown; 'for' is used to explain relationship between data when data explain hypotheses; 'against' is used when the two hypotheses are contradictory and they hypotheses and data are inconsistent; 'and' is used when explaining relation between data more clearly. In the meantime, 'Explanation Constructor' support clarification and reflection process by connecting participants' hypotheses and linked supporting ideas through science and webzines(Quintana et al., 2004).

Last, the area to support collaboration supports interactive communication between learners as a way to reduce their cognitive burden when individual's efforts are not enough to finish complicated inquiry process. Thus, 'CSILE' uses tags, discourse support notes(Scardamalia, 2004). In the meantime, CoVis provides collaborative notes for building hypotheses, collecting data and recording results(Quintana & Fishman, 2006) and FLE supports building digital data through collaboration within groups with 'jamming.'

Research Method

Design-based research

This study selects design-based research method. The method designs teaching

methods more effective and efficient in educational fields having various factors. Design-based research starts in the reflection that existing educational research failed to improve educational situations compared to ways to prove effectiveness as experiment-centered research. One of the features design-based research is that it improves educational situations and give helping hands to research subjects in a practical way by reflecting opinions and view in the field while carrying out designing and development based on theories. For this matter, all the persons concerned including instructors, participants as well as researchers take part in the designing process. This is because circumstantial contexts and cultural factors in the educational field should be reflected in the designing process to generate right improvement effects in the field(Jang & Hyu, 2006).

Richey and Klein(2007) said that design-based research methods have no limited boundaries and depend on the purposes of each research. In other words, when research puts its focus on designing and development of each stage in the research of developing outputs and tools, there are research methods frequently used include case study, analysis of contents, experts review, observation of fields, in-depth interviews and questionnaires. When research focuses on development of models, ways such as case study, Delphi, in-depth interviews, reference research, questionnaires and Think-Aloud(Kim, 2008). Therefore, this study carries out design-based research by using various research methods according to the focus of research, specific methods would be mentioned in each stage of research.

Procedure for research

This study used procedures and methods of design-based research to develops tools for wiki-based research activities. Design-based research was performed according to the <Table 1> below.

Table 1. Design-based Research Procedure

	Contents	Date
Theoretical Research	- Identify collaborative inquiry stages - Analyze designing principles for inquiry support tools	2008. 1.
1st System Development	- Draw the 1st system designing principles based on theoretical research - 1st system development	2008. 2. 1 .- 2. 28.
1st System Evaluation	- Apply 1st system in the field and collect data - Analyze the application	2008. 3. 1. - 3. 30
2nd System Development	- Draw 2nd system designing principles - 2nd system development	2008. 4. 1. - 4. 30.
2nd System Evaluation	- Apply 2nd system in the field and collect data - Analyze the application	2008. 5. 1. - 5. 31.
3rd System Development	- Draw 3rd system designing principles - 3rd system development	2008. 6. 1. - 6. 30.
Final System Evaluation	Correct errors and wrap up	2008. 7. 10.

In theoretical research, the author drew stages of collaborative inquiry and analyzed designing principles for inquiry support tools, and developed the first system. Afterwards, the author applied the fist system in the field and analyzed the results of the application to come up with ways to modify and improve problems. Based on this process, the second system designing principles were drawn and developed and lead to the application. The author analyzed the results of the second application and arranged the 3rd system designing principles at the same time, and developed the 3rd system based on the 3rd principles. At last, the final system was developed after correcting the errors and bugs of the developed systems.

Development and Application of Wiki-Based Inquiry Support Tool

Stages of collaborative inquiry through theoretical research

The author analyzed process of collaborative inquiries and inquiry training models in the theoretical research. Stages of collaborative inquiry can be classified as <Table 2> below.

Table 2. Stages of Collaborative Inquiry

Stages	Contents
Identifying Problems	Presenting inquiry situations. Debating to identify inquiry problems
Making Hypotheses	Collecting data, asking questions and making new hypotheses for problem-solving
Inquiry	Verifying collected data. Supplementing hypotheses
Analyzing Results	Drawing rules and explanations about collected data
Reflecting	Analyzing coordination and effectiveness of used research methods and questions. Drawing follow-up research directions

Collaborative inquiry stages include identifying problems, making hypotheses, inquiry, analyzing results and reflecting. In the first stage of identifying problems, instructors present to learners inquiry situations such as contradictory situations possibly causing cognitive conflicts and learners interpret the situations and discuss what are the problems they have to dig in. The second stage of making hypotheses is the stage where learners collect data to solve problems and ask questions to instructors to make new hypotheses. In the third stage of inquiry, learners collect data to prove if their hypotheses are right and verify the data. Specifically, in this stage, learners can correct and supplement their hypotheses made in the second stage. In the fourth stage of analyzing results, learners draw rules and explanations by organizing collected and verified information. In the last stage of reflecting,

learners analyze used research methods, effectiveness of questions, coordination activities by reflecting inquiry, and reflect the possibility if these activities can be applied to other situations.

Drawing design principles of wiki-based inquiry support tools through theoretical research

In theoretical research, the author analyzed characteristics of wiki and collaborative inquiry support tools. The result showed four areas of collaborative inquiry support tools. Thus, this study came up with design principles of each area and they are shown in <Table 3> below. Each principle were applied to developing wiki-based inquiry tools. The four areas include 'sense-making,' 'process management,' 'articulation and reflection,' 'collaborative activities support.'

Principles for sense-making area provides various types of loads and link, scaffolds and editing depending on levels of inquiry. Principles of process management area provides scheduling, role assignment and history. Those of articulation and reflection area provides visualization of research results and reflection of the results. Principles of the last area provides interaction and individual responsibilities.

Table 3. Design Principles through Theoretical Research

Areas	Design Principles
Sense-making	Scaffolds depending on levels of research activities
	Editing depending on levels of research activities
Process Management	Scheduling and role assignment
	History
Articulation and Reflection	Visualization of research results
	Reflection of the results
collaborative Activities Support	Interaction
	Individual Responsibilities

First system development

The first system of this study was developed according to design principles in theoretical research and was shown <Table 4> below. The first principle for sense-making is provision of scaffolds depending on levels of research activities. Learners participating in online learning sometimes are dropped out as they don't have clear picture about how and what to act in wiki-based environment for inquiry support tools. Specifically, there could be high cognitive overload for beginners who don't have clear scripts about how and what to do in each research stage. Therefore, the study tried to enhance the effectiveness of the activities with minimizing the overload by making instructors watch learners and provide instant scripts need for accurate research activities. In addition, instructors provide schema of how experts recognize problems, what and why strategies they use and what the results are. With this provision of schema, instructors help beginners make their own schema needed for problem-solving, and ultimately help diminish much cognitive burdens to build knowledge. The second principle is editing depending on levels of research activities. It is designed to promote building shared knowledge by giving all the participants this editing function - one of the basic properties of wiki - in an equal way.

The principles of process management include scheduling, role assignment and history function. The first principle is scheduling and role assignment. With this principle, groups building shared knowledge communicate in an effective way, level of understanding assignment presented become similar between participants, and participants can anticipate and expect more clearly their future assignments or activities and demands. Therefore, it is designed to help scheduling and role management through effective management of research assignment, resources and participants. The second principle is history function. This function makes it possible for participants to track down the editing process of all the writings and its proceeding directions and history for process management.

Principles of articulation and reflection are visualization of research results and reflection of the results. The first design principle is visualization of research results. If a writing becomes long, learners should scroll down to grasp the context of the writing. With the scroll bar down, learners are not able to see the previous parts of the writing, which leads to cognitive overload to learners to reduce the effectiveness of research activities. The function that learners can see the whole writing at each research stage are provided to get rid of these inconveniences. The second design principle is reflection of research results. When learners carry out their activities without deep reflection of their activities and the results in the research, they amount to failing to organize significant knowledge with depth they intended to produce in the first place and result in acquiring superficial knowledge. In this regard, this support tool offers reflection.

Principles for collaborative activities support provide interaction and individual responsibilities. The first principle is interaction. Existing wiki functions such as editing, history and recently modified writing have quite an importance in document development. This means the functions lack social interaction in terms of building shared knowledge. Therefore, this tool offers asynchronous communication to enhance interaction between learners and between learners and instructors. With these interactions, learners can utilize spaces to coordinate each other's opinions including simple ideas and future process. The second principle is to give responsibilities in an individual level. Although wiki provides individual responsibilities with functions like history and editing, learners can be personal and emotional writings and postings of other learners as anybody can be an editor. In this reason, the principle holds learners responsibilities to replenish this weakness with log-in function.

Table 4. Design Principles and Strategies through Theoretical Research

Areas	Design Principles	Design Strategies
Sense-making	Scaffolds depending on levels of research activities	- Script - Successful examples
	Editing depending on levels of research	- Equal authority to edit the whole pages
Process Management	Scheduling and role assignment	- Tools for scheduling and role assignment
	History	- Lists of each stages
Articulation and Reflection	Visualization of research results	- Output lists of each stages
	Reflection of research results	- Critique between learners of outputs
Cooperative Activities Support	Interaction	- Communication space to share each other's views
	Individual responsibilities	- Individual responsibilities and log-in function for contents protection.

Results of the Application of the First System Development

Application subjects

The first application subject was 48 5th graders in P elementary school located in Kyunkido, near Seoul. Instructors were 3 teachers including the class teachers of learners and scientific genius class in the school. This study made participants carry out 2 preceding training sessions related to collaborative learning in the wiki system to exclude subjects inexperience on wiki system and their novelty effect. Training details are as follows in <Table 5>;

Table 5. Previous Training Sessions to Use wiki-based inquiry support Tools

	!st	2nd
Training Details	Checking characteristics of wiki system, Registration and introducing research schedule	Practicing writing, according researcher's feedback
Required Time	30 minutes	30 minutes

The author investigated subjects' level of wiki usage after the preceding training sessions. The results said that although the levels' of each subjects showed differences, there would be no difficulties in using the system as there were no difficulties in writing documents and wiki usage.

Questions of research

There are two questions in the first application; Do wiki-based inquiry support tools give practical help to learning?; What are the inconveniences, if any, learners and instructors feel in wiki-based inquiry support tool system and what are the ways to be correct and complement?

Learning context and research process

The role of the instructors was to select appropriate research assignment for 5th graders and support learner's research activities. Learners had to resolve the assignment. In this process, collaborative inquiry process are supposed to be reviewed and remodified through wiki-based research activities support tool system. This took place for 2 weeks(14 days) and specific schedule is shown in <Table 6> below. The author made public research themes in the system and instructors selected learners into groups in a random way in the first week. Learners of each groups started role assignment and scheduling through the system in the same week.

In the second week, learners started the collaborative inquiry in the system and was made to upload the results of the inquiry.

Table 6. Activities of Research Subjects

	Instructors	Learners
1st week	- Creating and making public research themes - Organizing groups - Making script and successful examples	- Introducing each other - Identify research themes - Scheduling and role assignment
2nd week	- Making public scripts and successful examples - Answering 'Questions to Teachers' - Evaluating results	- Starting Inquiry - Uploading the results

Collecting and analyzing data

Data was collected by using questionnaires of learners and instructors. The questionnaires was given to all the learners and instructors after they finished their activities in the class. The first frame was analyzed through quality comparison of learners' research results. The author asked learners and instructors to come up with ways to improve the system. The questionnaire was used and consisted of open-ended questions to get overall various views of learners and instructors on wiki-based inquiry support tool system. Let's take some examples of the questions. Does the system help your research activities? If so, specify it. What are the strengths and weaknesses of the system and why? What can you suggest to improve the inconveniences?

Results of the first application

The application results was ordered with the first research frame. First, the author figured out with research results (draft and final assignment) if wiki-based inquiry support system was useful to learning. The result was that there was an average of 1.9 scores increase in quality (perfect score of 30) when it was interpreted in scores.

The author analyzed questionnaires of learners and instructors for the second research frame.

Learners showed positive evaluation of wiki-based inquiry support tools. However they offered some ideas for improvement. For example, as they can express their opinions only in the form of text, learners who are not confident of writing can possibly have a step back in activities.

Learner A : "Learning community is organized to be useful for collaborative learning."

Learner B : "I've never seen this kind of site in science class before. I had fun with this new attempt."

Learner C : "It helped me figure out what I have to study." "It was good to carry out planning and making hypotheses." "I felt like I have stronger sense of collaboration."

Learner D : "I wish I knew how to ask questions to teachers in the system."

Instructors said that as it was inconvenient to make groups with several stages, it would be more convenient to provide functions to make several groups for one theme. In addition, they suggested that since menu names for scripts are not easy to understand, it's better to change menu names into ones easy to understand.

One instructor said that it was inconvenient to give feedback on if students perform according to the schedule and who has to do what activities. The instructor said the reason was there was no feedback menu for scheduling. In this matter, the instructor suggested that they have to provide feedback for scheduling in the form of scores to give individual learners responsibilities.

The instructor also pointed out the inconveniences that instructors should explanations to each menu of the site when learners start their activities and they should give explanations several times. In addition, with wiki, there are already many preceding explanations, moreover explaining the menus made learners and instructors spend more time in preparation. Under these circumstances, it would be easier to have explanations on each menu in advance.

Table 7. Result of the First Application

Inconveniences	Suggestions
Systems Aspects	
System management and insufficient DB capacity	Hiring web-hosting company for enough storage and system operation
Insufficient manager functions	Introducing mileage system to record the number of log-in, writings, wiki modification and writings and its replies)
Interface Aspects	
Difficulties in using sub-menus	Change into mouse over to go to sub-menus with only one mouse click
Insufficient explanations on each menu	Offering simple explanations on each menu to reduce preparation time
Difficulties in understanding menu names	Change menu name of scripts into easier menu name for instructors to understand
Inquiry Aspects	
Text-centered expression	Giving two choices of expression -text and graphi- to learners
Lack of interaction with instructors	Adding the menu of 'Ask Instructors' for learners to ask questions anytime
Insufficient feedback functions of activity scheduling	Adding menus for instructors to give feedback of each learner's activities according to scheduling

There also were opinions about systematic aspects; "As the site provides home screen, spaces for each stage and history, users need more DB, hard disk storage and daily traffic capacity with the increases in the number of learners and writings."; "The site lacks functions to manage and analyze learning activities because it only provides simple functions such as registration, personal information change and aggregate access." Additionally, when it comes to interface, there said to be inconveniences that users have to click main menus to use respective sub-menus and have to click sub-menus if they want to see what the menus are for.

Several inconveniences and according suggestions of the fist development system are summed up in <Table 7>.

Drawing design principles of the second system and developing system

The author came up with design principles of the second system based on suggestions made from the results of the first system application. <Table 8> shows the added design strategies.

Table 8. Added Second System Design Strategies

Areas	Design Principles	Design Principles
Sense Making	Editing function in each stage	Provision of both text-based wiki and graphic based wiki
Process Management	Scheduling and role assignment	Enhancing instructors' feedback on activity scheduling

In the second version, the author added graphic-based wiki by accepting opinions of the limit of text-based wiki. As with too complex graphic expression there are no differences from text expression(Suthers & Hundhausen, 2003), the author designed the graphic-based wiki for learners to use in an simple and easy way. The frame of graphic expression is the form to provide templates designed in

advance and is designed for learners to express their knowledge and ideas in their constructional traits.

With the opinion that there are no feedback of learners' activities according to the schedule, the author added feedback function for instructors to give feedback. In addition, scores were designed to be summed up automatically.

Results of the Second Application

Subjects and period

The subjects were the same with the first application. It took one week to come up with design strategies and design principles to improve the system after the first application and three weeks to build new system based on suggested ideas. In total, it took 4 weeks to reveal the second system to learners and instructors after the first application.

Questions of research

There are two questions in the second application; Are the design principles suggested by the results of the second application effective to learners and instructors?; What are the possible design principles additionally needed?

Learning context and research procedure

The second learning context and research procedure were the same with the first ones. Learners were given different research themes from the first application and different groups from the first one.

Collecting and analyzing data

The methods to collect and analyze data were the same with the first application. The only difference was the questions in the questionnaire. The questions include; What are the improvements and inconveniences of the second system compared to the first one and why?; Was the second system helpful to your learning?

Results of the second application

The results of the second application can be summarized in terms of the two questions as follows. First, The response was positive to the question if the design principles suggested from the second application were effective to learners. The majority of answers was that it was fun to express opinions in the graphic form, and the stable system on the whole was useful to learning. Especially, respondents showed satisfaction with the improvement made from their suggestions on the first system.

Second, the author analyzed the answers of the questionnaire to figure out additionally needed design principles.

Let's take a look at learners' opinions. Learners said that instructors' feedback of group activities were good attempt. Specifically, witnessing their activities changed into scores stimulated their interests and hold responsibilities for their roles. In terms of the function of 'Ask Instructors,' learners said that it was good to see questions asked by other learners to avoid the same questions and it was easier to use with the interface menu. Specifically, compared to the first system, there were a reducing number of students who raised their hands asking questions with loud voices.

Let's turn to the instructors' views. First, they said that it is more natural to change script provision name into 'Questions/Modify.' Second, instructors said that while many learners have more interests and fun with the graphic wiki, some

learners can have difficulties in understanding graphics other learners made. Third, it was convenient to give objective feedback such as mileage and the progress of research. Fourth, they need to have statistics function to evaluate learners. With the function, it would be easier for instructors to manage individual learner's research progress.

Drawing design principles of the third system and developing system

The third design principles were drawn based on improvements suggested from the results of the second application. <Table 9> shows design principles added after design principles of the first and second application.

Table 9. Third System Design Principles

Areas	Design Principle	Application
Sense making	Negotiation of meaning	- Providing reply function in graphic wiki - Providing the function to ask and answer questions - Providing function of reply completion

In the tool where learners express their opinions in the graphic form, they can ask other learners questions about their graphic expression and learners can have the function to let them know that replies to the questions are uploaded.

Major Characteristics of the Final Wiki-Based Inquiry Support Tools

All the previous process amounts to the final system. Here, the author explanations, among various functions of the final system, focus on the differences from existing other research support tools as a learning system.

Designing of the whole system

This wiki-based inquiry support tool developed based on LINUX. MUSQL was used as database and PHP was used as server script language to link web server to database. PHOTOSHOP was used to edit images and EDIPLUS for HTML. The domain of wbil.net was provided for learners to have access to the site in an easy way. For stable learning system and constant use of the system, the study was given web server hosting with 1500MB storage hard disk, 2000MB of daily traffic and 150MB storage database.

Designing of the whole system for developed wiki-based collaborative inquiry support tools consists of 'group activities,' 'research activities,' 'knowledge repository,' 'personal space' as shown in <Figure 1> below.

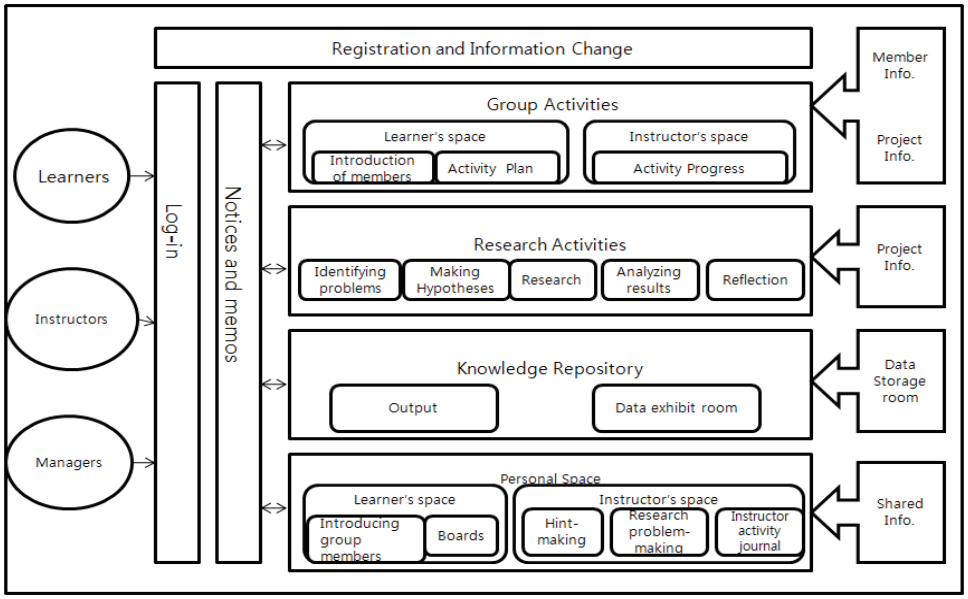

Figure 1. The Whole System Construction of Wiki-based Collaborative Inquiry Support Tools

Group activities

Group activities were developed as a space to plan and change research activities.

First, learners, instructors and managers should register the site and log in after the registration. The log-in function is to give learners responsibility and protect contents. With 'Notice' and 'New Memo,' learners can check memos, which helps promote asynchronous interaction.

Sub-menus of group activities include 'Notice,' 'Introduction of members' and 'Activity Plan.' In 'Introduction of members,' the author tries to give learners social presence by providing functions to check their group members' information(names, IDs, email addresses, nicknames and self-introductions).

In 'Activity Plan,' a new window pops up to input information related to the activities and the information is shown automatically in the calendar as a title and a person in charge of managing the activity plan is made to assign roles. The 'Activity Plan' space is the space to manage research process and manage scheduling and role assignment in an effective way.

Research activities

'Research Activities' is the space where real collaborative inquiry projects are carried out and is composed of five stages in learning process; identifying problems, making hypotheses, research, analyzing results and reflection. Participants were supposed to submit final output through these 5 stages.

This space is the space to help sense-making and articulation and reflection, and uses document-type boards and give all the participants of the project editing authority to help build common knowledge.

Participants can track down changes in writings through 'history' function as in and when they double click the list, they can go back to the previous version. Participants also can check 'history' in each research stage. In addition, they can

check up history except the research activity boards in ‘recently modified writings’ and when they click the list, they can go back to the previous version.

Instructors should provide clear scripts of certain activities in each five stage. The author also made sure that instructors should offer scripts by sub-stages in each stage depending on learners' level. When providing scripts, they should give their guidance in the title of scripts of what and how to do.

Participants can see the whole writing in 'The Whole Page View.' This can prevent lack of understanding of the previous part of a writing when they fail to understand the logic of the writing, it becomes longer to read it using the scroll bar. 'Hint' has three advantages; providing experts' schema by their provision of problem-solving process and results; helping forming schema which beginners need for problem-solving; ultimately maximizing cognitive space for knowledge building by minimizing cognitive overload.

For learners who feel uncomfortable to show their opinions in the form of text, the study provided the function to do in the form of graphic. The author designed graphic function for learners to use relatively easily and understand related knowledge construction in an easy way. To do this, the author provided templates designed in advance and how learners can express their own knowledge and ideas according to constructional traits. When learners select one template, the selected template is enlarged below the template. When they double click, they can write down their thoughts and all the participants have the authority to modify. If anyone has any questions on contents uploaded in the graphic form, he or she ask questions using reply function positioned in the bottom part of the graphic tool. In addition, if he or she isn't sure what to ask, they can write replies using question tags. When questions are not answered completely, they are shown as ‘modifying,’ and when completed they are shown as ‘completed,’ making it easy for participants to clearly figure out the process.

Knowledge repository

Knowledge repository is the place where intermediate and final output is shown in the form of image and data needed in research activities can be uploaded. It consists of 'output,' 'data exhibit room.'

In 'output,' learners can criticize research results of other learners and store the results. The results and the final output are stored in 'related stage(1),' 'related stage(2),' and when participants have to modify while examining files, if they double click the title they can go back to the page and modify. 'Data exhibit room' is the place where participants can store useful data and site addresses, and encourage critiques on images by uploading replies on stored data. When clicking lists of data, participants can reply promoting critical activities on the data.

Personal space

Personal space was developed dividing it into two spaces of learner's space and instructor's space.

In learner's space for cooperative activities support, learners can interact each other sharing opinions of simple ideas and future progress. Clicking the space, participants can see the names of groups members and clicking names, they can send memos. Writings are classified as 'open' and 'locked'. Thus, if learners don't want others to read their writings, they can classify them in 'locked' and they also can classify their writings in 'open' to have asynchronous communication with other members of the group.

In instructor's space, instructors can make research problems, hints and scripts, and manage mileage. In making research problems, when participants click the registered problems after instructors make public the problems, a window for registration pops up. In the registration, groups are offered their own problems. Learners can check hints and make scripts in each stage when necessary.

Conclusion and Discussion

This study aims to design and develop wiki-based inquiry support tools with design-based research procedure. Specifically, the author tries to provide design principles for wiki-based inquiry support tools which can practically be used in the real educational fields and knowledge of situational context to make research activities more effective.

One thing you shouldn't wink at in this study is that wiki-based inquiry support tools are not the tools developed from the previous studies. The difference is that the tools in this study were drawn not only by the author alone but by learners and instructors - core participants of the inquiry. This implicates that research teams doing research for a long period should consist of not only the author and instructors but also learners to improve and refine future tools and all of them should understand design principles in an in-depth manner.

There are two suggestions for future research.

First, when designing wiki-based inquiry support tools, authors can hire ways to easily add and reduce menus and functions to make interface easier to use. Even though the author designs and develops after analyzing a large number of previous studies and based on various theories, if learners and instructors - core participants - feel pressure to go through extra learning of complicated and multi-functional tools this would provide stumbling blocks for effective support tools. Therefore, to discard this weakness, the author should let participants use menus and functions offered by research support tools according to research themes and learners' characteristics.

Second, after developing wiki-based inquiry support tools with design-based research, future research should let not only learners and instructors but also the author express their aggressive and developmental views. That's because learners can feel uncomfortable using the function even if various functions come up with by authors, learners and instructors can or can't be materialized by lack of

developer's personal incapacity or lack of understanding. The author suggests that to prevent this from happening, the developer, as a researcher of design-based research playing a practical role, should exchange feedback constantly and take part in refining process of support tools.

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