The Framework of Three Learning Activity Levels for Enhancing Usability and Feasibility of Wireless Learning Environment

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Abstract

With advances in information technology, wireless communication and mobile devices most recently applied to education. The wireless technology enhanced classroom (WiTEC) integrates wireless local area network, mobile learning devices, and client-server architecture to support instruction and learning activities. This paper introduces a framework that involves three learning activity levels, namely learning function, learning episode, and learning flow, as a basis on which to design an integrated system that supports various types of learning activities in WiTEC. A teacher can use this system to generate new learning flows before class and to implement them during class. A two-stage evaluation was conducted in three elementary classes to investigate the usability and feasibility of the proposed system. The participating teachers indicated that the use of three learning activity levels eases the burden of preparing, implementing and reviewing instruction and learning activities.

1. Introduction

In the last decades, many technological innovations have been applied in the classroom, such as radio, television, film, video, and the computers. Besides computers, most media technologies that support one-way communication, have had only isolated, marginal influences on how and what children learn in school, despite the early championing of their revolutionary educational potential (Roschelle, Pea, Hoadley, Gording & Means, 2000). Even the computer has not yet fundamentally affected classrooms since they are heavy, have messy wires, and are operated via a keyboard and mouse. It is important to understand where it is going before jumping into the specifics of the educational changes that technology will cause (Tinker, 2001). New devices and technologies bring opportunities and challenges for researchers to develop new

forms of learning. Most applications of wireless and mobile devices in learning use devices with small displays, such as personal digital assistants (Chang, Sheu & Chan, 2003; Chen, Kao & Sheu 2003; Hsi, 2003) and portable computers (Bannasch, 2001), to support outdoor or mobile learning. Ubiquitous educational technologies can greatly expand the range of activities that students can undertake (Tinker, 2001).

Our previous work focused on the development of the Wireless Technology Enhanced Classroom (WiTEC) that integrates a wireless LAN, mobile learning devices (MLD), an electronic whiteboard, a resource and class management server and an interactive classroom server, to support everyday activities unobtrusively and seamlessly in the classroom. Among these devices, the interactive learning center, which is installed on an MLD, as the student's client program, supports a learner's interactions with peers and the instructor, as well as interactions within content-rich contexts without barriers. The interactive instruction center, which is operated through an electronic whiteboard, as teacher's client program, assists teacher to play the role of mediator, supporter, facilitator or guider during everyday classes. The resource and class management server manages teaching and learning resources, the contents of activities, students' learning and teacher's teaching; and the interactive classroom server keeps track of individual operating processes as well as coordinates interactions between teacher-student and among students. In contrast to traditional classrooms, the WiTEC enhances productive teacher-students and peer-peer interactions (Liu, Wang, Liang, Chan & Yang, 2002), and enables the teacher and students to concentrate on teaching and learning itself rather than spending too much time and efforts on tedious tasks. It helps the teacher to monitor each student's learning status for further gudiance, to engage students in learning activities, to facilitate collaboration among students in a group, and to empower the teacher and students to apply technologies to a variety of traditional and innovative learning and teaching activtities (Liu, Wang, Liang, Chan, Ko & Yang, 2003). These features of WiTEC effectively support the teacher and students in performing numerous instructional and learning activities that are difficult to implement in ordinary classrooms, to which the Jigsaw model or project-based learning may apply (Liu *et al*, 2003; Liu *et al*, 2002).

Gay et al. (2001) noted that 'not every teaching activity or learning community can or should successfully integrate mobile computing applications' (p. 273). Tuckman asserted that 'The nature of the instructional model is the critical element in technology-enhanced instruction' (Tuckman, 2002). The WiTEC has been established and tested in real classroom settings, but some issues remain to be further explored. Different structures of classes, learning contents, and pedagogical models all influence the productivity of learning and instructional activities in WiTEC. Accordingly, whether other innovative learning approaches are suitable for the WiTEC must be determined. Besides, whether the WiTEC can

achieve its anticipated goals and facilitate students' learning effectively depends on how the teacher and students use it. Hence, guiding class members in appropriately using the device and integrating the relevant technologies into everyday teaching and learning activities are crucial (Ko & Liu, 2001). Compared to conventional classrooms and computer classrooms, most teachers and students still view the WiTEC as innovative technology. Developing appropriate tools for guiding effective implementation is key to the progress of the WiTEC from the research stage to practical use.

Gifford and Enyedy presented a theoretical framework for Computer Support for Collaborative Learning (CSCL), called the Activity Centered Design (ACD) model, to help course designers and teachers to design collaborative learning activities that could be implemented in the classroom (Gifford & Enyedy, 1999). ACD identifies and provides a unifying theoretical perspective on designing CSCL activities to help learners develop the ability to perform socially formulated, goal-directed activity by using mediating material and social structures. Adopting the ACD model, Brecht et al. (2002) proposed the ClassSync Modeling Language, which is a language for mapping the design of an activity onto its implementation of the activity in a wirelessly networked classroom in which all members use handheld computers (Brecht, Chung & Pea, 2002). CML allows authors and teachers to construct activities by creating assemblages of three components, which are performers of action, units of information, and an interaction network. Once the activity was created, the teacher can implement the activity at runtime in the ClassSync system. However, whether the CML can be effectively and efficiently used in practical instruction environments has not yet been determined.

This paper presents a framework that involves three learning activity levels, namely learning flow, learning episode and learning function, to support the design and implementation of instruction and learning activities in a wireless learning environment. An integrated system, which comprises an instruction-supporting subsystem, a learning-supporting subsystem and a collaboration mechanism supported by learning functions, was developed by adopting the framework to support teaching and learning activities in WiTEC. The system not only provides flexibility of design of activities, enabling the teacher to arrange and implement such activities, but also is extendible by the system developer, who can add new features to meet practical needs. A two-stage evaluation of three sixth grade classes, based on collaborative learning using the proposed system, was conducted to investigate the usability and feasibility of WiTEC.

2. Three Learning Activity Levels

Learning activities in a classroom can be designed, analyzed, and evaluated from three levels of different scale units: learning flow, learning episode, and learning function. The progress of a learning activity can be presented by a learning

flow, which is composed of several learning episodes supported by many learning functions. A learning function is a specialized mechanism for facilitating learning activities, such as content presentation and content transmission. A learning function is defined in terms of three elements: *action*, *content*, and *participants*. For an example, the content presentation function allows a teacher to present content to students. The action in this example is "to present" and the participants are the teacher and the students. A learning episode is the basic unit of a learning or instruction activity, such as lecturing, holding a group discussion and creating reports. Each episode is supported by a small set of learning functions. For an example, an episode of "teacher's lecturing" involves the presentation of content and the use of annotation functions using which the teacher presents content and annotates it. A function may support several learning episodes; for instance, the content presentation function supports presentation episode of both the teacher's lecturing and the students' group work presentation. A learning flow is a collection of learning episodes in a sequences to perform a completely set of learning activities. For example, a learning flow may be composed of four episodes: teacher's lecturing, students' group work co-construction, students' presentation of group work and students' peer voting. A learning flow may have branches to allow the skipping of or switching among some episodes, according to the each student's status. Different combinations and sequences of learning episodes can produce various learning flows to realize diverse instructional strategies or strategies for particular students. Figure 1 depicts the three learning activity levels.

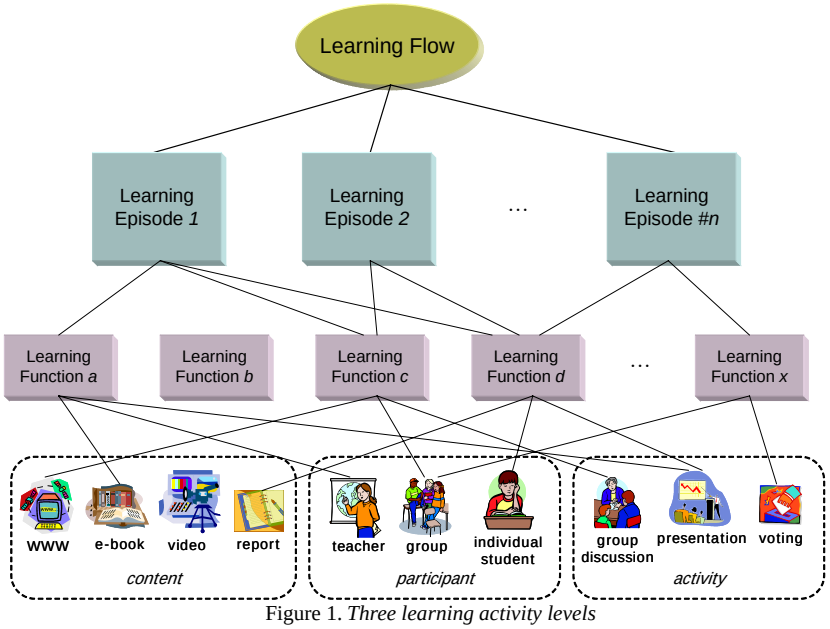

Figure 1. *Three learning activity levels*

The WiTEC strongly supports many learning functions, facilitates various learning episodes and learning flows as well as increases the efficiency or convenience of activity. Hence, the teacher can select learning functions to compose specific learning episodes and organize these episodes to create a learning flow that is suited to a particular learning method or instructional strategy. The learning functions required for collaborative learning in the WiTEC are listed and analyzed below. Although this list is of functions is not exhaustive, the analysis presents a rough picture of the main elements in collaborative learning activities in the classroom.

- **Content presentation & annotation:** whether the teacher is lecturing or students are presenting, a platform is required on which to display and explain content, and to annotate it. Traditionally, teachers use a blackboard, a slide projector and/or a wall chart. In WiTEC, teachers can present content using a video projector; the projector can be operated and the content annotated using an electronic whiteboard.
- **Content transmission & replaying annotations:** although students can buy textbooks, copy teacher's hand-outs, or download files from networks before or after class, while the teacher is lecturing, they are usually busy noting the teacher's annotations. In WiTEC, the teacher can transmit content and annotations to students' MLDs immediately, so students do not have to take notes, allowing them to concentrate on the teacher's lecture. The students can look at the content received by the MLD and even replay the teacher's annotations after class. Students can make and save their own annotations.
- **Student mapping and control:** during activities, understanding the status of students and controlling their behavior can help the teacher to manage the class. The teacher must be able to observe an individual student's status unobtrusively or to control each student's MLDs, such as by disabling some functions or locking the screen of the MLD to ensure that the students focus on the current activity.
- **Work construction & co-construction:** when students do or collaborate on work, they may use pencil and paper, the blackboard or other devices. MLDs enable students to search for relevant information from WWW; to present their thoughts, and to do their work using some software. Furthermore, each student can work on his/her MLD and then transmit the work to other students' MLDs to exchange ideas and merge work into a group project.
- **Voting & quiz:** during an activity, the teacher may take a vote or set a quiz to elicit students' responses or assess their understanding. Traditionally, teachers ask students to raise hands to answer questions or to write an evaluation. In WiTEC, the teacher can display questions on an electronic whiteboard and the students can use

their MLD to vote or answer questions. The students' answers are sent to a server and statistical results are immediately calculated and shown on an electronic whiteboard. Anonymous votes can also be taken.

By adopting the framework of three levels of learning activity in WiTEC, system developers can freely add new learning functions to the system, to meet practical needs and extend the applications of the system in the classroom. Well-arranged learning episodes can be used to implement specific instruction strategies, which can be shared with other teachers. Moreover, learning flows allow a teacher to think about instruction procedures before class, guides both instruction and learning in class as well as help the teacher to review students' learning portfolios after class.

3. System Description

WiTEC provides students and the teacher advantages of ubiquitous computing. This paper applies the framework of three learning activity levels to establish an integrated system to support instruction and learning in WiTEC. The integrated system includes an instruction-supporting subsystem for teachers, a learning-supporting subsystem for students, and a collaboration mechanism supported by learning functions. It provides tools for supporting not only in-class instruction and learning, but also preparation before-class and review after-class.

3.1 Instruction-Supporting Subsystem

In the WiTEC, the instruction-supporting subsystem combines an interactive instruction center with a resource and class management server to support teachers in preparing, implementing, and reviewing instruction. The teacher uses the interactive instruction center to control the pace of instruction, to monitor students' status and to conduct activities. Table 1 lists the learning functions of each subsystem; ISS is the abbreviation for Instruction-Supporting Subsystem and LSS is the abbreviation for Learning-Supporting Subsystem. Every learning function associates action, content, and participants. The "voting" function, for example, enables the entire class of students (participants) to vote (action) on a question (content). The teacher can set up the type of question and the number of allowed responses. A statistical graphic of responses can be generated and instantly displayed with numerical data together in the interactive instruction center.

The functions of the instruction-supporting subsystem support both teacher-oriented and student-oriented activities. For example, 'annotation' and 'content delivery' are teacher-oriented functions, which support a teacher in lecturing to an entire class on the electronic whiteboard and transmit related content, such as annotations made on an e-book, to students.

Student-oriented activities include ‘co-construction of report’ and ‘quiz’. Group members are automatically logged into the resource and class management server to edit their own group report. They can discuss details face-to-face; modify the content of pages; change the order of the pages and insert and/or delete pages.

Table 1. *Learning functions of the integrated system*

Function	Action	Content	Participants	Subsystem	
				ISS	LSS
annotation	annotations on e-book	e-book	teacher	✓	
	annotations on e-book	e-book	individual student		✓
content delivery	transmit content to student	e-book, URL link, presentation file, image	individual student, group, or whole class	✓	
	receive content from teacher	e-book, URL link, presentation file, image	individual student		✓
co-construction of quiz	compose items to form a quiz	quiz file	group member	✓	
	edit items of a quiz	quiz file	group member		✓
co-construction of report	compose pages to form a group report	report file	group member	✓	
	edit pages of a report	report file	group member		✓
quiz	whole class based simultaneous test	quiz file	whole class	✓	
	respond to items of a quiz	quiz file	individual student		✓
voting	collect individual response and display statistical results	question	whole class	✓	
	respond to question and transmit the response to the teacher	question	individual student		✓
group work presentation	retrieve and display presentation file	presentation file	group member	✓	
replay annotations	replay annotations	annotations	teacher	✓	
replay learning records	replay individual student’s annotations	learning records	individual student	✓	
student mapping & control	display students’ statuses/retrieve individual student’s learning records	statuses of interactive learning centers/ individual student’s learning records	whole class/individual student	✓	
notebook	free sketch on notebook	sketches	individual student		✓

A learning flow editing tool in the instruction-supporting subsystem enables teachers to arrange the learning flow before class. Figure 2 presents a snapshot of the editing of a learning flow. A teacher can generate a learning flow by firstly labeling its name and then adding new learning episodes into it. Once a learning episode has been generated, the teacher can select those learning functions s/he needs from the list of the functions and add them to the learning episode. Each learning function automatically incorporates related materials, so the teacher does not need to choose this content explicitly.

Additionally, the teacher can implement an available learning flow at any time.

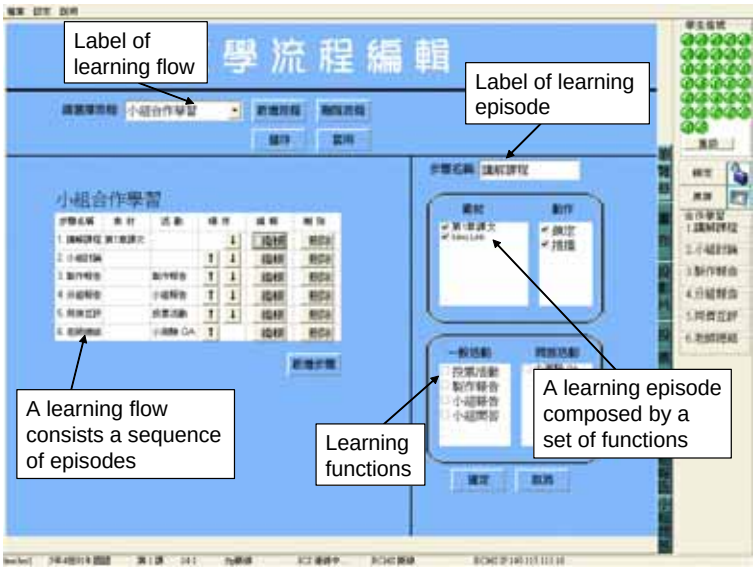

Figure 2. *The teacher uses the learning flow editing tool to arrange activities before class*

For example, the teacher can generate a learning flow, named “collaborative project-based learning”, which includes six learning episodes: these are 1. “introductory discussion”, 2. “group discussion and information gathering”, 3. “co-constructing group product”, 4. “group presentations”, 5. “peer-evaluations among groups”, and 6. “discussion and conclusion”. The “introductory discussion” episode may include two learning functions, “annotation” and “content delivery”. The “co-constructing group product” episode may include two learning functions, “co-construction of report” and “co-construction of quiz”.

Figure 3 shows a frame of implementing the learning episode “introductory discussion” in the classroom. The teacher firstly clicks the learning function labeled “annotation” in the learning flow area and the associated e-book file is automatically displayed on the content area of the frame. The teacher can use annotation tools on the e-book. After the teacher has completed the annotations, s/he clicks the learning function labeled “content delivery” and the current display of e-book, including the annotations, is thus transmitted to the MLDs of the entire class of students. The learning flow is listed on the right hand side of the frame. When the teacher clicks on one of the episodes of the learning flow, the list of functions associated with the episode will be extended as a menu. Furthermore, all students’ MLDs statuses are displayed in the upper right corner, enabling the teacher continuously to monitor the progress of the students as they perform an activity. This area, furthermore, is also the interface for retrieving individual student’s learning records while implementing

the learning function, “replay learning records”.

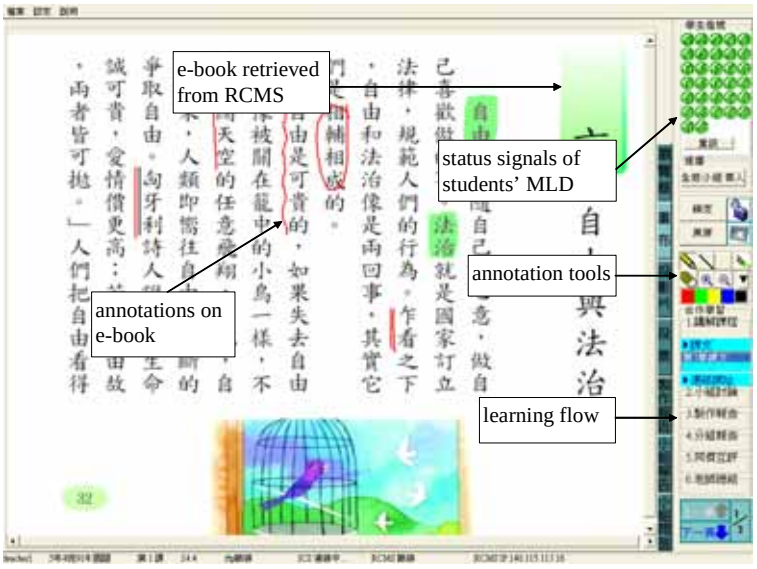

Figure 3. *A snapshot of the implementation of the learning function, “annotation”*

WiTEC, which adopts client-server architecture, provides the flexibility to add, delete and organize learning functions for instruction. Before class, the teacher arranges the learning flow in the interactive instruction center; the flow is stored in the resource and class management server. In class, the teacher retrieves the well-arranged learning flow from the resource and class management server and then performs each learning function in the interactive instruction center. After class, the teacher and students can retrieve instruction and learning records from the resource and class management server.

3.2 Learning-Supporting Subsystem

Table 1 lists several functions in instruction-supporting subsystem for students, which correspond to functions in the instruction-supporting subsystem. For example, once the teacher performs the learning function, “voting”, every student’s interactive learning center automatically activates the corresponding “voting” function at the command of the instruction-supporting subsystem. A number pad pops up on the frame of each student’s MLD, and waits for a response. After the student clicks one of the number buttons, the response is sent to the interactive instruction center and statistical results are instantly shown on the interactive instruction center. Besides the functions that correspond to the instruction-supporting subsystem, the learning-supporting subsystem includes isolated-execution functions, such as ‘notebook’ and ‘annotation’.

The learning-supporting subsystem combines an interactive learning center and a resource and class management server. The resource and class management server stores learning materials, student profiles and group setting. Once an MLD is booted up, it is automatically logged into the resource and class management server as one of the group to which it belongs. The memory of the MLD only stores temporary data. After a learning function is implemented, the content temporarily stored in the MLD is stored in the appropriate area of the resource and class management server. Additionally, group produced products, associated with a collaborative learning function are stored in the group area of the resource and class management server. Figure 4 shows the frame after the learning function "quiz" is completed: the statistical results are stored in the resource and class management server and displayed on the interactive learning center.

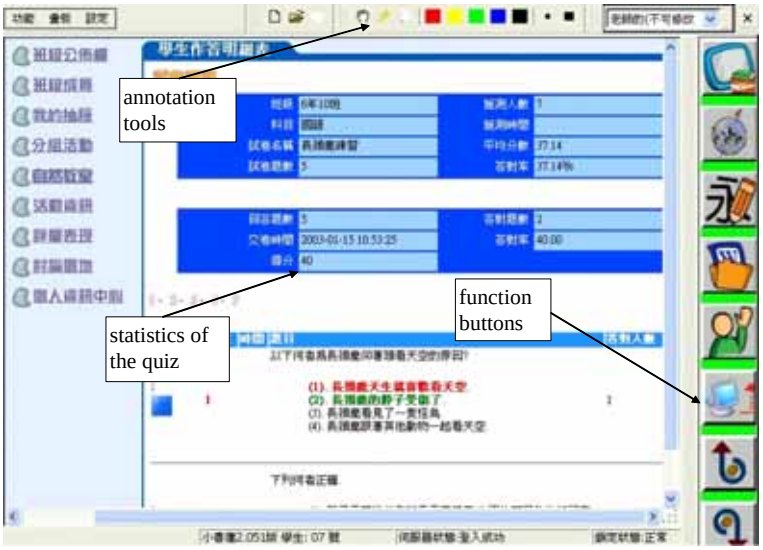

Figure 4. *Statistical results after the interactive learning center has completing the learning function "quiz"*

3.3 Collaboration Mechanism Supported by Learning Functions

Most collaborative learning activities require learners to create material related to the courses and make it accessible to other learners (Ferraris, Brunier & Martel, 2002). Such collaborative activities allow students to share each other's sentences, pictures, notes or other constructed materials, generally via a web-based interface (Hoppe, Lingnau, Machado, Paiva, Prada & Tewissen, 2000). Pupils are loosely coupled during learning. However, there still are many kinds of instruction and learning activities, especially simultaneous group-based activities, can not be implemented in this manner.

Besides collaborative learning, many instruction and learning activities also use collaborative mechanisms. The collaborative mechanism supported by learning functions is based on the resource and class management server and the

interactive classroom server. The resource and class management server is basically a web-based collaborative activity center which provides a shared working area for peers within a group while they are co-constructing group products. Additionally, the interactive classroom server coordinates not only the actions but also the content of learning functions. For example, the teacher transmits a project guideline to the designated group by implementing the “content transmission” function. The interactive instruction center firstly retrieves group setting information from the resource and class management server and then transmits the guideline to all members of the group via the interactive classroom server. Accordingly, the interactive classroom server is a synchronous collaborative activity coordinator that supports activities that must be processed or responded to in real-time.

Figure 5 illustrates the mechanism that between the interactive instruction center, the interactive learning center and the interactive classroom server. The interactive classroom server includes three blocks of a total seven modules. The daemon block comprises the daemon and protocol-parsing module. The connection management block comprises the connection management and authentication modules. The activity control block comprises the message delivery, the response control, and the broadcast control modules. The daemon block receives, transmits and parses highly interactive protocols. The connection management block authenticates logins from the interactive learning center and the interactive instruction center; handles the connection of all interactive learning centers in the classroom using wireless communication; detects the connection status of each interactive learning center, and recovers a disconnected one. The activity control block processes both synchronous and asynchronous activity protocols. All of the synchronous activity protocols are processed by the broadcast control module and response control module while asynchronous activity protocols are processed by the message delivery module.

For example, once the interactive instruction center has performed the “voting” function, it sends the corresponding highly interactive protocol to the daemon of the interactive classroom server. The protocol-parsing module parses the received protocol and then passes it to the response control module. After the protocol is processed, the response is generated and sent to all interactive learning centers through the daemon to activate the “voting” function of the interactive learning center. On the side of the interactive learning center; the activated “voting” function waits for each student’s response. Then the responded data is encapsulated as a protocol and sent back to the interactive classroom server via the daemon, before being parsed by the protocol parsing module. The response control module then sends the response to the interactive instruction center. The final result of the “voting” function is displayed on interactive instruction center, by collecting all responses from the interactive learning centers.

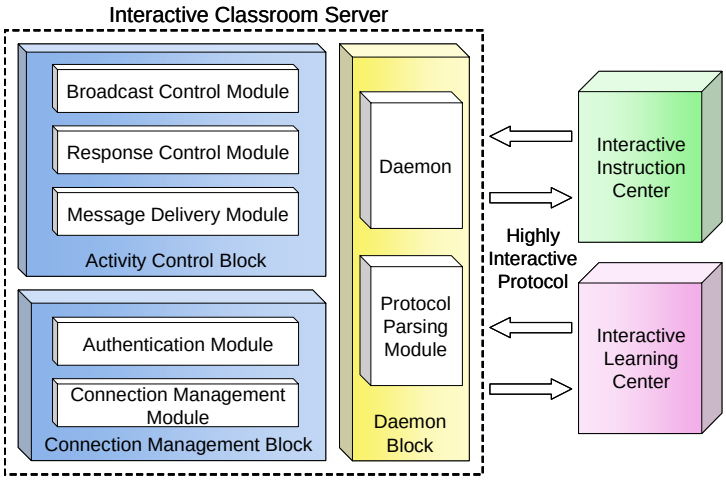

Figure 5. *Seven modules in the interactive classroom server that support collaboration in WiTEC*

The interactive classroom server also coordinates asynchronous activities. Once an interactive learning center has been activated for an asynchronous activity, such as “co-construction of report”, it communicates with the interactive classroom server, is authenticated, and is automatically logged into the area of resource and the class management server that belongs to its group. Subsequent operations would be directly processed between the interactive learning center and the resource and class management server, without coordination of the interactive classroom server.

4. Evaluation

A two-stage evaluation of the usability of the integrated system and the feasibility of the learning flow was conducted. The first-stage evaluation focuses on the teachers’ opinions about using the learning functions or instructional functions that are not integrated by the instructor as the learning flow in the class. The second-stage evaluation focuses on the teachers’ opinions of applying the learning flow in the class and whether WiTEC affects the instruction through the learning flow. The subjects of the two evaluations are the three teachers in Nan-Hu Elementary School, Taipei, Taiwan who had participated in the experimental project. Each student uses a webpad, equipped with a 10.4 inches TFT-LCD and a touch panel. The system ran Windows CE Traditional Chinese version OS and the learning-supporting subsystem. The teachers used 72 inches electronic whiteboards, connected to a PC and running Windows 98 Traditional Chinese OS as well as the instruction-supporting subsystem.

4.1 Stage 1 Evaluation

From May 2002 to January 2003, three participating classes used the first version of the integrated system. In this version, the learning flow was not developed and only some learning functions were available. The three participating teachers were interviewed in January 2003. The results of the interviews with the three teachers (whose first names are abbreviated as C, H, J) are summarized as follows:

Complexity of WiTEC:

- The system interface seems to be user-friendly – only two or three hours are required to become familiar the operation of the entire system. (C, J)
- Less frequently used functions still need to be reviewed before formal usage – not because the functions are unclearly described, but because the large number and complexity of the functions make their use difficult to memorize. (H)

Frequently-used functions of the integrated system:

- **Content transmission & annotation:** these functions help to present and broadcast quickly the prepared digital materials to the students. When text materials were used in the class before, many students often could not find the material keep up with the teacher. This function greatly improved this situation. (J,H)
- **Voting & quiz:** these functions enable teachers and students to see the results immediately, saving much time. (C, H)
- **Co-construction of report:** this function is also used frequently. 'If I am planning to ask the students to conduct a group discussion and write a report, I will arrange the assignment and questions before class, and broadcast them to each group during the class.' (H)

Favorite functions:

- 'I select the function that is appropriate to the current part of the course and have no specific preference.' (J)
- The **replay learning records** function is useful for sharing the learning results with the whole class and enables the teacher to see immediately the students' learning status. (C)
- **Co-construction of report:** In-group members can use this function to co-create, share or revise group reports. (H)

Functions that should be added

- The functions of the system are plentiful and useful, thus the teachers often need to consider what to do for next steps and which functions they should use, which explicitly increases their burden. Some functions are suggested to

add in order to facilitate the teacher in applying various functions to the preparation before class or in-class instruction. (C, H, J)

- A calculator function should be added or a blank space provided for calculations. (C)

In summary, the teachers had positive attitudes toward the system, but saw room for improvement in the usability and convenience of the system. All of the teachers felt that various functions of the integrated system were very useful. They also considered that some of the functions of the system increased the burden of using it. These shortcomings are yet to be overcome.

4.2 Stage 2 Evaluation

From January 2003 to May 2003, the three participating classes adopted the second version of the integrated system, which included basic functions similar to those of the first version, but further add the integrity functionality to the learning flow. The teachers first applied the learning flow in a four-week collaborative learning class. They were then interviewed, and the interview results were analyzed.

4.2.1 Applying learning flow to collaborative learning

Preparation Phase

The teacher uses the students' score management function in the resource and class management server in class computer to set the fundamental score of each student, and then divides students into heterogeneous groups according to their past learning performances. Additionally, the teacher uses the functions of the resource and class management server to design different project-based learning for every group and to search for required information.

Execution Phase (Implementing Learning Flow)

1. **Introductory discussion.** In the beginning of the class, the teacher introduces project-based learning and broadcasts relevant resources and guidance to individual students or each group through the interactive learning center upon the electronic whiteboard.
2. **Group discussion and information gathering.** Group members discuss the assigned project face to face. If necessary, they may search for relevant resources online.
3. **Co-constructing group product.** Through the process of exploration, discussion, communication, debates, clarification, and collaboration, group members accomplish their project. Meanwhile, the learning portfolio can be

saved and reserved respectively in each individual MLD. According to the division of labor, group members do their own part of the group report. Finally, they exchange and combine individual reports to complete the group project.

4. **Presentations.** Each group selects one or several representatives to present group reports on the electronic whiteboard with the support of the interactive learning center. If the group wants, group members can design items in advance and broadcast them to other groups for further assessment. The results of the assessment can be saved in the resource and class management server.
5. **Peer evaluations among groups.** When a group presents its project, the members of other groups can evaluate their peers by synchronous group interaction. The teacher may display and share the results of peer evaluation with the whole class on the electronic whiteboard. The resource and class management server stores the score and the entire whole learning portfolios of each group.
6. **Discussion and conclusion.** When displaying each group project on the electronic whiteboard, the teacher can conduct discussions with the students and summarize the results of the project-based learning.

Follow-up Phase (Using the Products of the Learning Flow)

1. **Recognition.** According to the self-evaluation and the peer evaluation, the system can calculate improvements in individual performance and group achievement. The teacher may then display the score of each group on the electronic whiteboard and conduct recognition activities.
2. **Revising, sharing, and grading.** Each group revises their own project based on other students' suggestions. After the projects have been revised, the groups record the completed project as a specific file in the resource and class management server for further reference. The teacher can retrieve the projects and each student's learning portfolio from the resource and class management server, and then grade them on the interactive instruction center.

4.2.2 Results of interviews

Preparation Phase

- **Comprehensive instruction and ease of operation:** the learning flow mechanism enables teachers to use WiTEC more structurally and systematically. The teachers need only to follow the instructional objectives and the contents of the activity step by step to arrange the instructional materials that corresponds to the system functions. Teachers H and J felt that the learning flow enabled them to follow easy and clear procedures to prepare instructional activities.

- **Thinking about instruction procedures in advance:** when the teachers are mapping the learning flow, they are also clarifying the steps and contents involved in an instruction activity. They almost go over the entire instruction process. For example, teacher C felt that “using the learning flow to draw up instructional materials and activities helps teachers to think over the instruction process.”

Execution Phase

- **Guiding both learning and instruction:** In using the learning flow in class, the digital instruction materials and system functions required by every instruction procedure can be shown in order, so the learning flow can guide the teacher’s instruction. For example, teacher H felt that “sometimes I forget what to do for the next step during the class. When I use this system, I know exactly what the next instruction activity is.” Teacher C remarked, “when I employ unfamiliar instruction procedures, I usually preview the lesson by myself but then inevitably forget something during the class. The system helps the teacher to know where we are, and helps the students to know what they must do next.”
- **Saving time and reducing cognitive loading:** when the teachers apply the learning flow to in-class instruction, what they need to do is to click on certain procedure at proper time. This procedure both saves the teachers’ time and reduces their cognitive loading while searching for and presenting the materials. Teacher J indicated, “when I use information technology to teach, I worry that I cannot make sure when to use which function or which digital instruction materials I should present. Pre-editing the instruction procedures prevents me from going through the class in a disorderly way, so I save time and can concentrate on the students’ learning.”

Follow-up Phase

- **Integrating students’ learning and instruction activities:** even though the first version of the system can also record students’ learning process, it is often difficult to judge which portfolio is implemented and accomplished from which activity because there are too many portfolios. Therefore, more efforts are needed to be made for after class. This version of the system can organize and sort the students’ learning portfolios according to the sequence of the learning flow, which helps the teacher review the contexts of the students’ portfolios clearly. Teacher H noted that “reviewing and evaluating students’ in-class works according to the sequence of the learning flow enables me to review the students’ in-class works while thinking about the instruction activities in which they are doing in-class works. This allows me to evaluate the students’ works more deeply on the one hand, and reflect my instruction process on the other hand.”

- **Facilitating the teachers' revising and utilizing once again:** As teacher C noted, "when I used information technology in teaching before, students' portfolios were often dispersed in different files and so reviewing and correcting them required much time. The learning flow enables me to review the entire instruction sequence in order. If a student's portfolio requires correcting, I can go to the editing part to do some correction immediately." Teacher J remarked, "when using information technology in teaching before, I found that managing portfolios was not easy. When I repeated a class in the following year, I didn't know where the portfolios were or what the entire process was. Using the learning flow solved this problem."

4.3 Discussion of the two-stage evaluation results

According to the two-stage evaluation results, before the learning flow was applied, although the three participating teachers regarded the various functions in the WiTEC as helpful in teaching, the large number and complexity of the system's functions increased the burden on the teachers of using the system. After applying the learning flow, the teachers thought that the integrated learning flow mechanism enabled them easily to design WiTEC-based instruction activities by following detailed guidelines before class. This process helped them to think in advance about the instruction procedures. During the instruction, the learning flow not only guided both the teachers and the students, but also saved time and reduced cognitive loadings of the teachers. After the instruction activities were ended, the learning flow provided a context in which the teachers could review the students' learning portfolios, with reference to corresponding instruction activities, facilitating the teachers' revising of the instruction procedures and contents. In summary, the learning flow solves the earlier problems associate with the WiTEC before, and allows teachers to use the various functions of the WiTEC anytime during instruction with less effort.

5. Conclusions

This paper presents a framework that involves three learning activity levels, including learning function, learning episode, and learning flow, to provide an effective and efficient method for arranging learning activities and thus to solve the problem of the complexity of instruction and learning practices in WiTEC. Learning flow is a series of learning episodes that are composed of learning functions. The learning episode is the basic unit of an instruction and learning activity. Learning functions can be added as required to form new learning episodes. When a teacher wants to perform a

specific learning activity, s/he can compose appropriate learning episodes to form and then implement the needed learning flow. That is, a learning function can be added to different learning episodes and a learning episode can be arranged in different learning flows. A system developer can add new learning functions to the system to support the teacher and students in new forms of instruction and learning. Teachers can exchange their learning activity designs in the form of learning episode. By adopting the framework of three learning activity levels, this study developed an integrated system, including an instruction-supporting subsystem for teachers, a learning-supporting subsystem for students, and a collaboration mechanism supported by learning functions, which could be used in WiTEC.

The WiTEC and the integrated system were installed in three elementary classrooms in Taipei City to conduct a two-stage evaluation. Interviews with the three participated teachers revealed that they felt that the learning flow mechanism made them think in advance about instruction procedures and ensure that it was comprehensive. The learning flow in class not only guides both learning and instruction, but also saves time and reduces cognitive loading. Moreover, the learning flow helps teachers to integrate students' learning processes with the instruction activities, and helps them to revise the activity after class and utilize it again. In summary, the framework of three learning activity levels enhances the usability and feasibility of the WiTEC. However, the two-stage evaluation was of the application of the integrated system to project-based collaborative learning. It should be further tested for different kinds of instruction and learning models.

The framework of the three learning activity levels in a wireless learning environment can be improved in many ways - 1) by developing more learning functions to support a wide range of instruction and learning practices, including indoor/outdoor learning, collaborative/individual learning, and others; 2) by creating a mechanism for exchanging learning episodes to help teachers to share knowledge about designing learning activities, and 3) providing templates for learning flow, to reduce the time required to prepare courses.

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