Design of an Introductory Statistics Education Model: Understanding of Student, Interaction, and Activity-Based Learning

By

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Presented in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy
in Graduate School of Chonbuk National University

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2006

博 士 學 位 論 文

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2006年 2月 22日

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효과적인 기초통계 교수학습 모형 설계:
학습자 이해, 상호작용, 그리고 참여적 학습을 중심으로

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본 연구에서는 정보기술이 교수학습에 기여할 수 있는 유형과 효과적인 교수학습을 위한 명강의들의 원리 및 특성을 살펴보고, 이를 통해 교육의 대부분을 이루고 있는 교실수업을 위한 새로운 형태의 교수학습 모형을 설계하는데 그 목적을 두었다. 특히, 본 연구에서는 교실수업에서 발생하는 다음과 같은 문제들에 대한 해결 방안을 모색해 보았다.

- 학습자의 이해정도를 교수자가 실시간으로 파악하고 즉각적인 피드백을 제시할 수 있는 방안은 무엇인가?
- 모든 학습자들과 적시성 있는 상호작용을 할 수 있는 방안은 무엇인가?
- 모든 학습자들이 활동에 기반한 경험적 학습을 동시에 할 수 있도록 하는 방안은 무엇인가?

본 연구에서는 첫째, 정보기술의 발달에 따른 교육환경의 변화와 효과적인 교수학습을 위한 명강의들의 원리 및 특성을 살펴보았다. 둘째, 이러한 연구를 바탕으로 새로운 교수학습 환경과 발전하고 있는 정보기술의 유용한 기능들, 그리고 다음과 같은 명강의들의 공통적인 속성을 고려한 교수학습 모형(UIA model)을 제안하였다.

- 교수자의 학습자에 대한 실시간 이해와 즉각적인 피드백 제시(Real-Time Understanding of Students' Comprehension)
- 적시성 있는 상호작용(Timely Interaction)
- 모든 학습자들의 경험적 학습(Simultaneous Activity-Based Learning)

셋째, 효과적인 기초통계 교육을 위해 통계교육의 주요 특성들을 반영한 모형(UIA-SE model)을 제시하였다. 넷째, 본 연구에서 제안된 교수학습 방법을 교실수업에 실제로 적용하기 위해서 실시간 기초통계 교육시스템(RT-SES)과 이를 기반으로 하는 교수학습 컨텐츠를 설계하고 구현하였다. 마지막으로, 실제 교실수업에 적용하고 학습자들의 반응을 통해 그 유용성을 조사하였다.

실제 수업에 적용한 결과, 기존의 교수학습 방법으로는 구현할 수 없었던 모든 학생들과의 실시간 상호작용과 동시적 참여를 통한 교수학습이 가능하였다. 또한 학습자들이 교수자와의 상호작용이나 동료 학습자들과의 활발한 상호작용을 하는 모습을 볼 수 있었다. 학습자들은 약간의 긴장감과 참여를 통한 수업이 흥미가 있다고 하였고, 다른 학습자들의 활동결과를 공유하고 서로 비교해 볼 수 있어서 흥미롭고 학습에 도움이 되었다고 하였다. 결과적으로, 본 연구는 새로운 교수학습 환경에 걸맞는 교수학습법에 관한 새로운 모형을 제시한 데에 의의가 있다고 하겠다.

1. Introduction

1.1 Background and Need for the Study

According to the rapid advance in information and communication technology (ICT), research studies of teaching and learning have shown a shift from teacher-centered lectures to student-centered learning (Moore, 1997; Symanzik, 1998). The use of ICT in the beginning has usually been used as Computer Added Instruction (CAI) that focused effective transfer of knowledge. In recent years, research that focused on the use of the Internet and Web has suggested additional learning and sharing take place outside the class (Leon & Parr, 2000; Malone & Bilder, 2001).

In respect of instructional methods, most research emphasizes enhancement of interaction and the use of active learning methods. Cooperative learning methods were also proposed to aid in the effective teaching and learning process. Most of the research also noted that students may learn more by working together than they would independently (Garfield, 1993; Garfield & Gal, 1999; Kvam, 2000; Scheaffer et al., 2004). Scheaffer et al. (2004) pointed out that the students appeared to understand and enjoy concepts far better through active learning than from attending lectures. Love and Hildebrand (2002) emphasized that all students should have hands-on experience with data collection, analysis, and presenting results. They noted that the courses should be problem-oriented, not oriented towards particular statistical tools.

The use of ICT in introductory statistics courses has been strongly proposed to intensify the learning process (Velleman & Moore, 1996; Moore, 1997; Schwarz, 1997;

West & Ogden, 1998; Anderson-Cook & Dorai-Raj, 2001; Blejec, 2003; Symanzik & Vukasinovic, 2003). Advanced ICT and its interaction with social, political, and economic factors will force change upon us. Therefore, change is not an option in the future (Symanzik, 1998; Straf, 2003). West et al. (1998) pointed out that the Web offers a tremendous opportunity for the fields of statistics education and research. Leon and Parr (2000) suggested the use of a Web-based course homepage in the statistics instruction. Malone and Bilder (2001) suggested using a course Web site for the purpose of varying interactions. Mittag (2000) emphasized that the use of multimedia resources and Web-based learning environments are crucial issues in the teaching and learning.

Although, most research has emphasized interaction and active learning of the student, it almost does not apply in the classroom. That is, the students do not have a chance to actively participate in their class. Therefore, we may not expect to see a positive change in teaching and learning effectiveness. In addition, most of the research focused on on-line distance education, such as cyber learning and e-learning. Hence, there is little research about classroom instruction. Most of the previous research is just traditional teaching and learning materials transferred to electronic materials. Usually, these research studies do not consider the use of ICT.

In these situations, introductory statistics courses still have some problems as follows:

- It is difficult to understand how each student comprehends the topic.
- It is not easy to achieve timely interaction with all students and the teacher.
- There is not enough time for the activity-based learning of all students.

However, there have been various studies in statistics education, most of the research does not solve these problems. But, we will solve these problems if we use ICT such as computers, database management systems, and the Internet. Furthermore, it supports simultaneous communication which can be appropriately applied in the class. Hence, the teacher can understand all students' comprehension, and lead the activity-based learning of all students together. It also makes timely interaction with every student possible.

In order to achieve effective instruction, we need new teaching and learning methods which are suitable to a changing educational environment. The instructional methods and textbooks must reform the new educational method which adapts to the new educational environment. It should also consider the principles of excellent teaching and the advancement of ICT (Rossini & Rosenberger, 1996; Yilmaz, 1996; West & Ogden, 1998; Woo, 2000).

In this study, we examine the methods of using ICT in the classroom and the characteristics of excellent teaching for effective teaching and learning. Through the results of this study, we first propose a new teaching and learning model for general education. Secondly, we propose a model which is expanded to include effective introductory statistics education.

1.2 Purpose of the Study

The purpose of this study is to propose an effective teaching and learning model in introductory statistics classroom education. This study also presents the components of the model and frameworks to construct the statistics education system. In this study, we examine the changes of the educational environment with ICT and

classify the important principles of excellent teaching for effective instruction.

In particular, this study focuses on the real-time understanding of each student's comprehension, timely interaction, and simultaneous activity-based learning. To achieve effective teaching and learning, the following questions were considered:

- How can the teacher understand all the students' background knowledge and comprehension in the class?
- How can the teacher make timely interaction with each student?
- How can the teacher make activity-based learning with every student in the class simultaneous?

Figure 1.1 represents the general concept and method for achieving this goal.

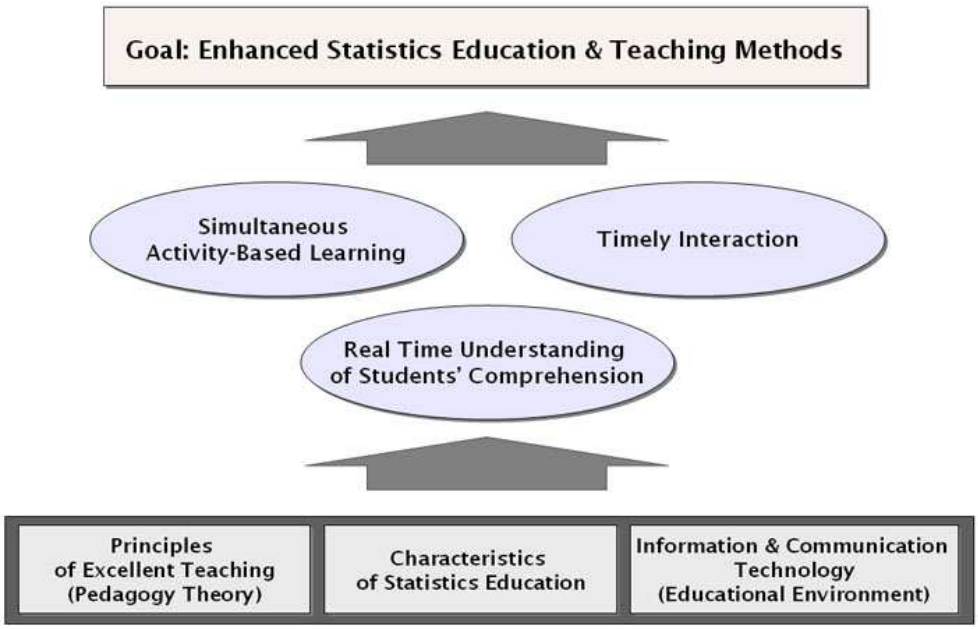


Figure 1.1: General concept of the study

1.3 Procedure of the Study

In order to make an effective teaching and learning model, the procedures of this study are as follows:

First, we examine the change of the educational environment from the influence of advanced information technology. The Internet and Web has strongly influenced educational fields. It allows for more interaction and communication channels.

Secondly, we look at the characteristics and principles of excellent teaching methods that support effective teaching and learning. This may help students deepen their initial knowledge.

Third, we suggest a new teaching and learning model which is based on the previous research studies. In this model, we present a method for real-time understanding. We consider the use of ICT to initiate timely interaction and simultaneous activity-based learning.

Fourth, we suggest a new model of statistics education which is based on the previous general model. We consider the characteristics of statistics education.

Fifth, we present some design and flowcharts that make real time teaching and learning support system and contents.

Finally, we show a demonstration of the system. The system is based on previous proposals and design concepts. We also examine the performance of the suggested method and implemented system.

1.4 Significance of the Study

In this study, we explore a new instructional model which supports real-time understanding of students' comprehension, timely interaction, and simultaneous activity-based learning. Therefore, it is possible for the teacher to interact with all students and give appropriate feedback immediately. It also allows students to take part in the class simultaneously.

The proposed model can be thought of as the solution to the problems of traditional instruction methods. These methods required much more time and labor for interaction and active learning to take place. Consequently, the use of the proposed model will be able to improve the effect of statistics education which emphasizes active participation and hands-on experience of all students.

1.5 Structure of the Thesis

This study is presented in seven chapters. Chapter 1 introduces the study and describes the need and purpose of the study. It gives an overview of the research problems and contributions.

Chapter 2 reviews the related research. This review consists of three approaches: the learning-by-doing approach, ICT-based approach, and the pedagogical approach.

In Chapter 3, we examine the changes of the educational environment in the classroom. We also examine the characteristics and principles of excellent teaching. This chapter is based on the model which is proposed in this study.

In Chapter 4, we present a new teaching and learning model that is based on the principles of excellent teaching and the tools of ICT. We call this model the 'UIA

model'.

In Chapter 5, we present the 'UIA-SE model', which supports introductory statistics education. It is an expanded UIA model and applies introductory statistics education.

Chapter 6 includes the design and implementation of the real-time statistics education system which is based on the UIA-SE model in Chapter 5. We also introduce some frameworks for effective classroom education. They include a developmental environment and contents of the system. In addition, it presents the implemented system for understanding and the results of adaptation in the classroom.

Finally, Chapter 7 offers the summary and conclusions of this study.

2. Review of Related Research

2.1 Overview

Most introductory statistics courses are dependent on a textbook and blackboard, and these are mainly carried out in the classroom. They are usually conducted in traditional lecture format, and are focused on calculation and theory (Magel, 1998; Gelman & Nolan, 2002). According to a survey conducted by Gelman and Nolan (2002), most students who studied introductory statistics gave negative responses. Bradstreet (1996) also indicated that most students often said "Statistics was my worst subject!" and "It's too abstract! What do X's and Y's have to do with the real world anyway?".

In order to overcome these difficulties and enhance student's interest, many instructors have studied and applied instructional methods. These methods focused on student's experience and participation, such as learning-by-doing and hands-on experiences. In addition, they have reported that these methods were effective. Furthermore, for the purpose of sharing effective teaching ideas, some conferences have been held (e.g., International Conference on Teaching Statistics (ICOTS) and United States Conference on Teaching Statistics (USCOTS)). Various research studies also have been published in journals, such as the Journal of Statistics Education, Teaching Statistics, and The American Statistician. In addition, this research has been published in books, such as *Workshop Statistics* (Rossman, et al., 2001), *Teaching Statistics a bag of trick* (Gelman & Nolan, 2002), and *Activity-Based Statistics* (Scheaffer, et al., 2004).

In this chapter, we review the research studies for introductory statistics education in three parts as follows:

1) **Learning-by-doing approaches**: research focused on student's experience and participation (see, Section 2.2).

2) **ICT-based approaches**: research using advanced Information and Communication Technology (ICT) (see, Section 2.3).

3) **Pedagogical approaches**: research using teaching and learning theories such as constructivism (see, Section 2.4).

2.2 Learning-by-Doing Approaches

In order to increase the effect of introductory statistics courses, Cobb (1991) argued "Students learn what they practice doing; they learn better if they have experience applying ideas in new situations." Hence, one of the most effective instructional methods which makes more students remember, easily understand, and enhance interest, may be the activity-based learning methods by students themselves (Scheaffer et al., 1996; Gelman & Nolan, 2002). In respect to these methods, the learning-by-doing style is a representative method.

In the case of statistics education, many researchers have studied these learning-by-doing methods. Most of the research has emphasized similar conditions such as 'Using real world data' and 'Hands-on experience/experiments'.

Use of Real Data

George Cobb (1992) emphasized "Statistical concepts are best learned in the context of a real data set." Moore and Roberts (1989) also stated "We believe that data should be at the heart of all statistics education and that students should be introduced to statistics through data-centered courses." Ballman (2000) advised that real data can emphasize the problem-solving nature of statistics. In particular, using real data dispels the misconception that doing statistics is doing calculations and taking exams.

Fortunately, using computers and software to automate calculations and produce graphics makes it possible to work with real data (Cobb, 1992). That is, it can help students experience the analysis of large and real world data (Woo, 2000). This instruction method is more adapted to recent research that emphasizes more data, concepts and statistical thinking.

The research of using real data can be divided into following three categories: (1) Students collect data by themselves, (2) Data archive on the Web, and (3) Consulting data. Various research which relates to these three fields exist as follows.

(1) Students collect data by themselves

There is some research which emphasizes the experience of data collection by student themselves. With respect to this type of research, Magel (1996) argued that having students collect data by themselves turned out to be a very good idea, and it made the class more relevant to students. Magel (1998) also suggested that class activities be used with hypothesis testing. One such test had students collecting data to test for differences in the mean number of chocolate chips per cookie be-

tween two brands. Diamond and Sztendur (2002) emphasized that when students produce their own data, they gain experience in both the design and analysis aspects of statistics, usually have a lot of fun and interact more with their classmates and learn more in depth than in a traditional lecture. Johnson (1995) presented that students were encouraged to fit the regression model which they build using food data that they collect.

(2) Data archive on the Web

In spite of the importance of using real data, it is not easy to use it in the class, due to the lack of students' familiarity with authentic data. To overcome these problems, some researchers suggested the use of data-rich Web sites as follows (Ballman, 2000; Lock, 2000):

- Journal of Statistics Education Dataset Archive
  - http://www.amstat.org/publications/jse/jse_data_archive.html
- The Data and Story Library (DASL) at the Statlib at Carnegie Mellon University (see Figure 2.1)
  - http://lib.stat.cmu.edu/DASL
- Government Data Sources at Governments' Web Sites

(3) Consulting data

Another way to use real data to teach statistics is through simplifying consulting problems. Diamond and Sztendur (2002) indicated that generating data is

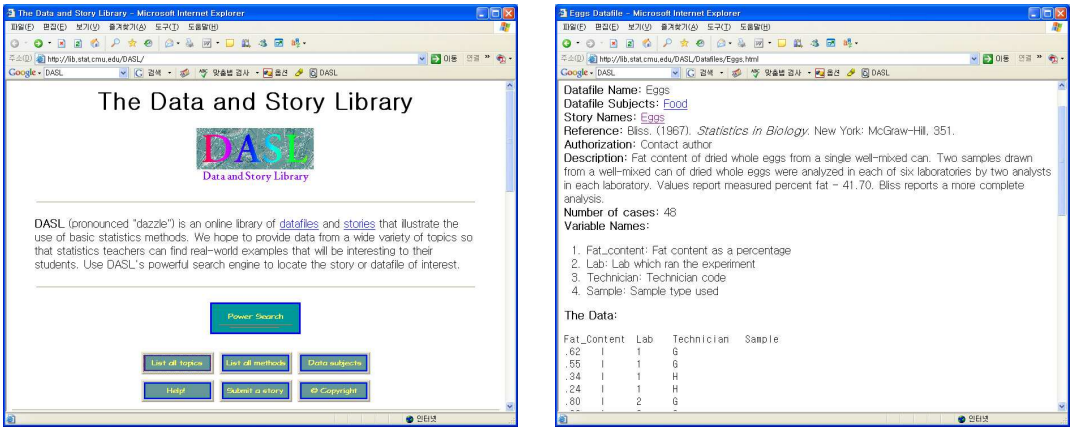


Figure 2.1: Data and Story Library (DASL) at the Statlib at Carnegie Mellon University

time consuming so it should not be done all the time. Therefore, another source of interesting data sets and problems can come from the instructor's own consulting.

Hands-on Experience/Experiment

With regards to the importance of student's activity, Garfield (1995) suggested, " Statistics teaching can be more effective if teachers determine what it is they really want students to know and do as a result of their course, and then provide activities designed to develop the performance they desire." Most research also showed that students appeared to understand some concepts far better through active learning than just listening in the class (Kvam, 2000; Gelman & Nolan, 2001; Rossman et al., 2001).

The followings are distinguished books which enhanced hands-on experience and student's activity.

- *Activity-Based Statistics* by Scheaffer et al. (1996)
- *Workshop Statistics: Discovery with Data* by Rossman et al. (2001)
- *Teaching Statistics a bag of trick* by Gelman and Nolan (2002)

These books are commonly designed for courses that employ an interactive learning environment by replacing lectures with students' hands-on activities. In addition, they emphasize conceptual understanding, genuine data, and the use of technology. The essential point of these books is that every student is actively engaged in learning the material through reading, thinking, discussing, interpreting, and so on. In this manner, students construct their own knowledge of statistical ideas as they work through the activities (Rossman, 1996; Scheaffer et al., 1996; Gelman & Nolan, 2002).

The activities in these books also have a collaborative learning style. Hence, students can work together through the activities, helping each other think through the material (Rossman, 1996).

In the case of research literatures, there are also many research studies for activity-based instructional methods. Anderson-Cook (1998) suggested a method that was suitable for an introductory experimental design course. The purpose of this experiment was to explore the important factors which influence the melting rate of ice cubes. Stone (1998) presented the method that aimed to provide the teacher with a student activity to help reinforce learning about variation, bias, stability, and other statistical quality control concepts with blind paper cutting experiments.

Now, we can summarize the above research as the follows. These are commonly emphasized factors for effective elementary statistics education in the aspect of learning-by-doing:

- Minimize the use of complex formulas and mathematical notation
- Focus on the visualization and Solving real problems
- Use of real world data and more graphics
- Intuitive data-centered approach
- Student-centered instruction
- Collaborative and interactive work with peers

2.3 ICT-Based Approaches

The process of learning-by-doing requires manual work, which takes more time and effort to apply in the actual class. In order to solve this problem, various researchers have considered the usage of ICT.

ICT has been used in several ways to aid in introductory statistics education (Moore, 1997). In particular, using computers to automate calculations and graphics make it possible to concentrate on more statistical concepts. Moore (1997) suggested that technology should be used to automate graphics and calculation. This allows students to focus on visualization and problem solving. He pointed out the use of multimedia as a mean of providing the opportunity for active learning, and the use of simulation will let students focus on the concepts involved.

The research of using ICT in introductory statistics course may be divided into two categories: (1) Computer Aided Instruction (CAI)/Computer-Based Training (CBT), and (2) Web-Based Instruction (WBI).

Computer Aided Instruction/Computer-Based Training

Moore (1997) insisted that the use of multimedia as a mean of providing an opportunity for active learning will let students focus on the concepts involved. Mills (2002) pointed out that the use of computers allowed students to accomplish computational tasks more quickly and efficiently, thereby freeing them to focus more on statistics concepts. Blejec (2003) also suggested that computer aided statistical simulations can be used for more obvious demonstrations of statistical phenomena.

The research of these CAI/CBT can be divided into two parts: (1) electronic textbooks and (2) simulation materials.

(1) Electronic Textbooks

The CAI programs are usually used both as classroom demonstration tools by instructors and as self-paced exercises by individual students or small groups. In order to improve the student's understanding of concepts, these programs have focused on visualization and easy calculations.

Many researchers have presented interactive multimedia packages, such as *An Electronic Companion to Statistics*, *Visual Statistics*, and *StatConcepts*, to complement a traditional statistics textbook (Peck, 2000). These programs make it possible to focus on concepts and interpretations rather than computations.

One of the most famous CAI programs for statistics education is *STEPS (Statistical Education through Problem Solving)*. It was developed by the STEPS consortium that consists of nine departments in seven universities throughout the United Kingdom. The STEPS program includes various problem-based modules to support the teaching of statistics in Biology, Business, Geography and Psychology. The modules

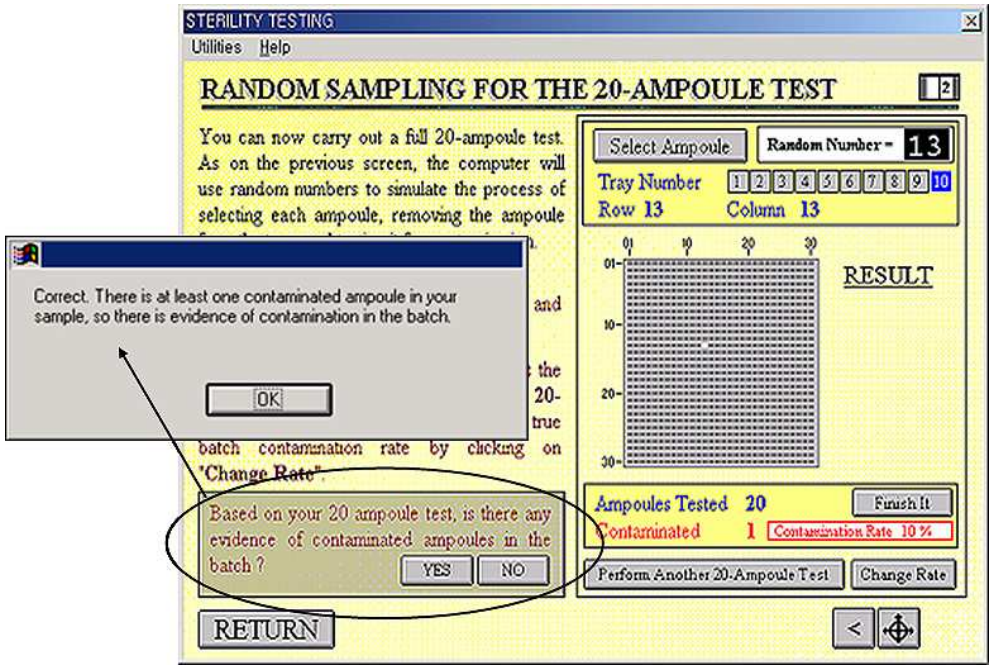


Figure 2.2: STEPS: Individual Student's Activity in Sampling Step, Simple Quiz and Feedback about the Answer

were intended to be used as problem-based lab material in the class. In addition, all modules progress step-by-step. Figure 2.2 is a screen shot in a Sterility Testing Module in the STEPS to show STEPS features.

In another research study, Brooks and Raffle (2005) presented the *FISH (Friendly Introductory Statistics Help)* program which was intended to conceptualize introductory statistical ideas. The FISH program supports a function of pseudo random number generation for classroom demonstrations. In addition to being useful for classroom demonstration by instructors, the step-by-step process also allows students to use the FISH program for independent study of statistical concepts (see, more detail at http://oak.cats.ohiou.edu/∼brooksg/fish.htm).

(2) Simulation Materials

To enhance student understanding of concepts, researchers have suggested the use of simulation methods. Mills (2002) argued that the use of computer simulation is able to enhance student understanding of difficult statistics concepts and help more empirical learning. Iversen and Marasinghe (2001) also insisted that using lessons and exercises based on simulation and dynamic graphics will not only improve student understanding of statistical methodology but also enhance their intellectual curiosity and interest.

West and Ogden (1998) presented Java applet examples which allow students to interact with the graphic display. Anderson-Cook and Dorai-Raj (2003) presented a number of Java applets which were intended to help students understand the role of power in hypothesis testing. In addition, they reported that students reacted very positively to the applets. Most of these simulation programs commonly allow students to manipulate parameters during the experiment.

Web-Based Instructions

Kemery (2000) pointed out, "Recent computer technology now makes it possible to import vast amounts of resources into the classroom, take students on world tours, and even bring in guest lectures at the click of a mouse." In particular, Internet and Web technology has led these changes in education. In the case of statistics education, the use of Web-based instructional materials have also become a popular method.

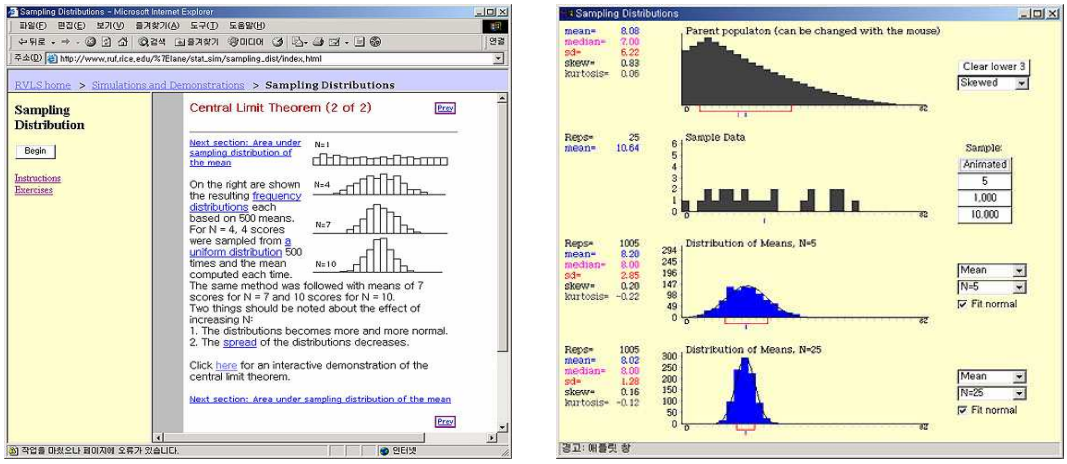


Figure 2.3: HyperStat: Hypertext-Based Content and Java Applet for Simulation

(1) Web-based textbooks and materials

The On-line Multimedia Textbook in Statistics (OMTS) which evolved from the Rice Virtual Lab in Statistics (RVLS) is a very famous Web-based teaching and learning material. The RVLS contains an introductory statistics textbook (HyperStat), simulations/demonstrations, case studies, and a basic statistical analysis program ('Analysis Lab'). It has many Java applets that demonstrate various statistical concepts. Figure 2.3 presents the hypertext-based content and Java applet for simulation learning.

Han et al. (1998) presented an example of an on-line textbook for Web-based introductory statistics. The textbook, *CyberStat*, can support statistics context and simulation at the same time. It can also be used interactively in teaching statistical basic concepts by using 14-faces dice. Han et al. (2003) suggested using Web-based interactive material that focused on real-time interaction with Java applets, self-directed learning, and using real data.

Symanzik and Vukasinovic (2003) pointed out that Statistics and the Web have become much more interwoven these days. They presented an overview of their 'Web-Based Statistics Course' and their experiences gained through teaching the course. Leon and Parr (2000) suggested how a Web-based course homepage can be used to support classroom teaching statistics. They presented a demonstration and showed how it is used. Malone and Bilder (2001) pointed out that student-to-teacher and student-to-student interactions outside of the classroom are very important in the learning process. In order to help assist such interactions, they suggested using a course Web site, and provide a guideline for instructors to develop their own statistics course Web site (including chat room and message board).

Mittag (2000) noted that multimedia represents an ideal platform for visualizing statistical concepts and for discovering basic statistical principles by self-driven experiments. In addition, he presented a Web-based multimedia software prototype on descriptive statistics and exploratory data analysis.

(2) Educational Resources on the Web

Many excellent resources for teaching and learning statistics are freely and globally available on the Web. There are several types of Web resources shown below (Lock, 2000):

- On-line Course Materials (e.g., course syllabus, assignment, and homework)
- On-line Textbooks
- Java Applets
- Electronic Journals

- Discussion Lists and Newsgroups
- Dataset Archive Web Sites

Lock (2000) presented these useful sites, which have been found to be the most helpful (see more detail at http://it.stlawu.edu/∼rlock/maa51/www.html).

2.4 Pedagogical Approaches

Effective teaching and learning is very difficult because learning is more complex than merely remembering what has been read or told. Therefore, it is important to think about how students learn in general before new teaching and learning methods can provide some insight (Mills, 2003). In addition, the theory of learning serves as a basis for theories of instruction that draw conclusions about how the instructions should be carried out (Garfield, 1995b). In order to understand how students learn, various pedagogical theories such as constructivism, behaviorism, and cognitivism have been studied and suggested. Therefore, the use of learning theories can be applied to effective teaching and learning in statistics education.

A recent theory of learning which has been widely accepted in education communities is '*Constructivism*' (Garfield, 1995b). Constructivism is a framework for thinking about how students can learn in given situations and how others can mediate in the process of learning (Mvududu, 2005).

Constructivist viewed students actively and individually construct their own knowledge, rather than copying knowledge 'transmitted', 'delivered', or 'conveyed' to them (Garfield, 1995b). They also insisted that individuals construct new knowledge internally by transforming, organizing and reorganizing previous knowledge.

They can also construct knowledge externally, through environmental and social factors that are influenced by culture, language and interactions with others (Mills, 2003).

Constructivism suggests that new knowledge is not passively received by student through textbooks and lectures, or by simply asking students to memorize facts; instead, meaning is acquired through a significant interaction with new knowledge (Mills, 2003). In addition, She pointed out that regardless of how clearly a teacher explains a concept, students will understand the material only after they have constructed their own meaning for the new concept. This may require restructuring and reorganizing the new knowledge and linking it to previous knowledge.

Garfield (1995b) emphasized that "Concepts are constructs, and learning is building" in her paper 'How Students Learn Statistics'. She also developed the ten principles of learning statistics for effective statistics instruction as follows:

1. Students learn by constructing knowledge.
2. Students learn by active involvement in learning activities.
3. Students learn to do well only what they practice doing.
4. Teacher should not underestimate the difficulty students have in understanding basic concepts of probability and statistics.
5. Teachers often overestimate how well their students understand basic concepts.
6. Learning is enhanced by having students become aware of and confront their misconceptions.
7. Calculators and computers should be used to help students visualize and explore data, not just follow algorithms to predetermined ends.

8. Students learn better if they receive consistent and helpful feedback on their performance.

9. Students learn to value what they know will be assessed.

10. Use of the suggested methods of teaching will not ensure that all students will learn the material.

Mills (2003) suggested that the application of learning statistics using computer simulation methods, grounded in the theory of constructivism, may benefit students by empowering them to develop their own understanding of statistics concepts. She also presented two examples where topics are central limit theorem (CLT) and confidence intervals.

Mvududu (2005) suggested the following ways to move from the theory of constructivism to the practice of it:

- Applied statistics should be taught in the context of real world problems.

- If the students have varied backgrounds, they might actually give a broader scientific approach to statistical problems than providing students only with familiar examples.

- The statistics course should be focused on statistical computations, even students with low mathematical ability can learn statistics.

In addition, there have been a number of studies on instructional strategies in statistics education. Although the word 'constructivism' may not have been used explicitly, researchers have advocated the following elements of constructivism (Mvududu, 2005):

- building communities
- active learning
- scaffolding children's learning
- sharing power with students to help them solve problems and take responsibility for themselves and others
- assessing students' learning in multiple ways
- authentic ways

The pedagogical recommendations provided by the ASA (American Statistical Association) and MAA (Mathematical Association of America) initiated a movement to reform the teaching of statistics, particularly at the introductory level. The reform efforts calls for researchers and teachers to focus on what Moore (1997) described as a synergy between content, pedagogy, and technology. Students should be active participants assigned with non mathematical structured activities focused on statistical concepts and ideas. Content and pedagogy should be strongly influenced by ICT.

3. Educational Environment and Principles of Excellent Teaching

Before looking at the research of effective teaching statistics, it is important to know about excellent teaching methods in general, because these are the basis of effective teaching and learning (Garfield, 1995b; West et al., 1998; Mills, 2003). Because instructional methods are found in the educational environment, it is also important to understand the recent changes.

In this chapter, we examine the recent educational environment and excellent teaching methods to deduce a new instructional method. In section 3.1, we look at the recent changes in the educational environment. In section 3.2, we examine the common principles of excellent teaching which were already proposed in related researches.

3.1 Recent Changes of Educational Environment

Using ICT in the class has changed teaching and learning methods. Change also continues as computer technology improves (Duckworth & Stephenson, 2002). Therefore, most of the recent research in effective instruction has focused on the effective use of ICT in the class. With the influence of ICT, research studies of instructional methods have focused more on student-centered learning rather than teacher-centered lecture.

Nowadays, because ICT provides various communication channels (e.g., email,

electronic board, instant messenger, chat room, and Web pages), it is possible to increase the student's experience through enhanced interaction and active learning. The Web has influenced the changes of instructional methods and materials, such as electronic textbook, cyber education, Web-based instruction, and e-learning. Most instructions in the class use both physical space and cyber space which does not depend on the time and place (Figure 3.1).

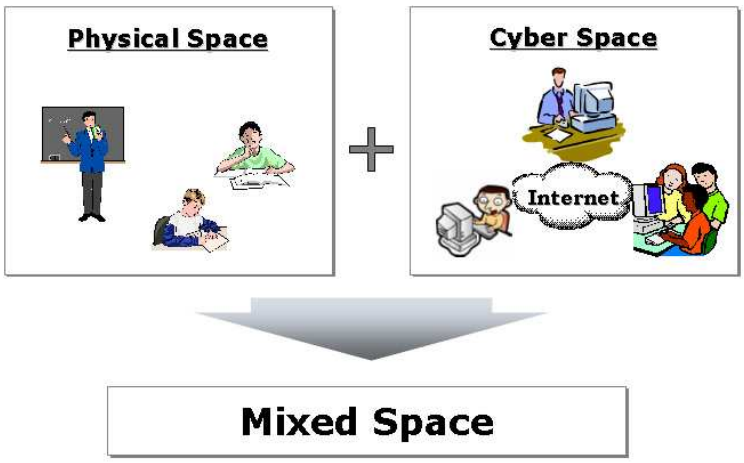


Figure 3.1: Change of educational environment with ICT

Use of Web-Based Instruction

Using the Internet and Web, computers all over the world can share information. It is also possible to have various interactions with different communication tools. Web-Based Instruction (WBI) gives us the following advantages (Han et al., 2003; Ahn et al., 2005):

- Independent of time and space

- Expend interaction (supports interactive communication and collaborative learning with colleagues)
- Student-centered educational environment
- Integrated educational environment
- Personalized learning
- Support of self-directed learning
- Stimulates recall of prerequisite learning
- Provides feedback about performance correctness

Therefore, a number of resources on the Web help teachers to access more good instructional materials. Furthermore, using these materials allow students to have more experiences in the class.

e-Learning and Blended-Learning

Table 3.1 represents the changes in the educational environment which are influenced by the Internet and Web. The CAI/CBT does not usually consider the interaction with teacher or other students.

As the Internet and Web expand, various types of on-line cyber education through the Web have appeared. In general, on-line cyber education has been called e-learning. The e-learning methods have been accepted as the effective method in which to solve the problem of time and distance restrictions in traditional distance education.

Table 3.1: Changes of educational form with advanced ICT

Type	Characteristics
CAI, CBT	- effective transmission of knowledge - individual activity based learning - isolated simulation
e-Learning (On-line, Cyber)	- any where any time - support out of class - various interaction and feed back
Blended-Learning	- mixed with on-line and off-line learning - use IT based materials in the classroom

However, e-learning has some problems. Lack of interaction and feedback are two examples, because e-learning does not have face to face instruction. To solve the problems of recent e-learning, the blended-learning method was usually proposed. It allows for more student interaction with the teacher and other students. It gives the student more chance to experience active learning. Nowadays, blended-learning has been expended to the mixed style of instruction which consists of on-line and off-line instruction. In the case of classroom instruction, many instructors have been using the Web, Internet and other information technologies more often.

One of the reasons why blended-learning has been emphasized is because interaction is the most important factor for effective teaching and learning.

Researches for the Future Educational Environment

As ICT continues to improve, the educational environment also continues to change. Therefore, we continually research and develop new instructional methods to fit the new educational environment.

In recent years, various instructional materials, such as Tablet PC, projection TV, e-book, and electronic board, have been developed. Hence, the changes of the educational environment are more rapidly visible.

Through the recent trends of educational research in advanced nations, we may estimate the future direction of education where ICT is applied in the class. In the case of Maine USA, as a kind of education reform to prepare for a future information society, the state gave a laptop to the state's 17,000 seventh graders. The classes were in progressed with electronic materials. They said that an education experiment took favorable criticism ('Maine users in a laptop revolution in the schools', *Christian Science Monitor*, 16 June. 2003). In the case of universities in the USA, actual circumstances that apply the e-book or on-line educational materials have been gradually enlarged.

Summary

Advanced ICT provides various communication methods. Therefore, the practical use of ICT makes it possible to expand the opportunity of interaction to the class. In addition, the recent educational environment includes cyber space in the classroom. The cyber community has a lot of educational materials, electronic libraries, Web repositories, e-mail, and so on. In these situations, we need a new instructional method which is suitable to a changed educational environment. We also should reconstruct or reform how to teach using ICT.

3.2 Principles of Excellent Teaching

The goal of education is to raise the ability of a student to solve problems (Miller, 2000). There is much research for effective teaching and learning methods that increase the comprehension of students, long-term memory, and make self-study possible after the class. These methods are called excellent teaching statistics.

The majority of research noted that the teacher must have subject matter knowledge, learn the pedagogical knowledge to make an excellent class, and apply it into his/her class to achieve the basic necessary condition of excellent teaching (Gearhart & Saxe, 2004).

In this section, we first examine the definition of excellent teaching. We also examine the principles of excellent teaching through the suggestions of previous research. Finally, we present the common principles to implement excellent teaching.

Definition of excellent teaching

We must first examine the definition of teaching before defining excellent teaching. Teaching is an activity causing or facilitating students to learn something. It is also defined as the interaction of a student and a teacher over a subject (Mohanan, 2005). Therefore, the teacher has to focus on the student's activities for excellent teaching.

Lublin and Prosser (1994) pointed out that good teaching is a teaching which helps students learn, and encourages high quality learning. They also described that good teaching encourages the learner to participate, motivates them to learn, understand, persevere, become independent, a gain a respect for the truth, and a desire to pursue learning (qtd. in Gibbs & Habeshaw, 2002).

Cho (2000) pointed out that the teacher who lectures during all class is not an excellent teacher. Therefore, an excellent teacher is one who knows how to lead students' active participation. He pointed out that excellent teaching may be possible, when the teacher uses the methods of excellent teaching.

With regards to the common characteristics of excellent teachers, Shulman (1987) noted that excellent teachers are concerned with knowing what students understand and how they learn, so they can help students integrate new ideas and transform prior conceptions.

Through these definitions and characteristics, we can summarize excellent teaching as follow:

Excellent teaching is having a teacher that understands the student's comprehension, and is able to reconstruct students background knowledge with new knowledge through various interactions and the active participation of the student.

(Goldstein et al., 2004)

Important Principles of Excellent Teaching

Now, we examine the importance and common principles of excellent teaching as they apply to the classroom. We try to find a common effective teaching and learning method through this.

There is some research for the principles of excellent teaching. Chickering and Gamson (1987) developed '*The Seven Principles of Excellent Learning*'. Goldstein, et al.(2004) suggested '*The Description of Excellent Teaching at the University of Ottawa*' which is included in the white paper for the Vision 2010 of Ottawa university. Bain(2004) developed a book, '*The Seven unifying Principles of Best College*

Teachers' which were the common characteristics of 60∼70 excellent professors in the USA.

These principles of excellent teaching are as follows:

- **The Seven Principles of Excellent Learning (Chickering & Gamson, 1987)**

  1) Encourages student-faculty contact
  2) Encourages cooperation among students (sharing backgrounds, use of study groups, peer tutoring)
  3) Encourages active learning (students may summarize to the class, use role playing or simulations, use field trips or internships)
  4) Gives prompt feedback (prompt, detailed evaluations on performance)
  5) Emphasizes time on task (clarify class preparation expectations, emphasize the need for studying)
  6) Communicates high expectations
  7) Respects different learning styles and talents.

- **The Description of Excellent Teaching at the University of Ottawa (Goldstein, et.al., 2004)**

  1) stimulates students to think critically
  2) produces independent learners
  3) enables students to develop skills for independent problem solving
  4) supports students in understanding important concepts and ideas

5) prompts questions, debate and other active learning activities

6) presents material with enthusiasm and motivates students to learn

7) transmits knowledge from teacher to student.

- **The Seven unifying Principles of Best College Teachers: Teaching Methods (Bain, 2004)**

1) Create a natural critical learning environment

2) Get their attention and keep it

3) Start with students rather than the discipline

4) Seek commitments

5) Help students learn outside of class

6) Engage students in disciplinary thinking

7) Create diverse learning experiences.

We can summarize the common principles of excellent teaching which are based on the above principles as follows:

- **Correct understanding of a student's comprehension**

  The view of constructivism is that learners can actively construct and make sense of new knowledge internally by reorganizing their background knowledge. The correct understanding of the teacher is the beginning of the teaching.

- **Timely Interaction**

  A vital constituent of excellent teaching is timely interaction in the class. This

should be between the teachers and the students, and promote debate among students. Various and timely interactions can maintain the interest of the students. It also supports cooperative learning and collaborative learning.

- **Frequent and Immediate Feedback**

  Frequent and immediate feedback is the most important factor in the student's satisfaction. Prompt feedback makes it possible for continuous growth in the student's thought process.

- **Active participation and hands-on experience**

  Nowadays, ICT gives more opportunity for teaching and learning in the class. Computer-based learning and various hands-on experiences such as simulation-based learning are very useful.

- **Continuous Concentration**

  It is natural that the student can not concentrate on the whole course. Therefore, we need various educational materials such as simple quizzes (Cho, 2000).

Summary

It is important to know the principles and characteristics of excellent teaching as they relate to effective instruction. In this section, we examined the definition of teaching and excellent teaching. We also examined the principles of excellent teaching. Through these investigations, we summarized the common factors, such as correct understanding of student's comprehension, various interaction, frequent and immediate feedback, active participation and hands-on experience, and continuous concentration.

4. A Model of Effective Instruction

We examined the principles of excellent teaching and learning in the previous chapter. In this chapter, we suggest a new teaching and learning model. This model is based on both the principles of excellent teaching and the various tools of ICT. In order to design this model, we focus on three factors: real-time understanding of students' comprehension, timely interactions, and simultaneous activity-based learning of all students. We call this model the '*UIA model*'. The components of this model are as follows:

- **Real-Time *Understanding* of students' comprehension**: We introduce a factor that allows the teacher to understand students' comprehension correctly. It focuses on important aspects, such as real-time understanding, frequent evaluation, and prompt feedback (see, Section 4.1).

- **Timely *Interaction***: It provides Web-based timely interaction, instant and automatic reporting and sharing of all students' responses (see, Section 4.2)

- **Simultaneous *Activity-based learning***: This method supports all students to simultaneously participate in the course. It also includes the concepts of collaborative learning, simulation, and monitoring (see, Section 4.3)

4.1 Real-Time Understanding

Important factors for effective understanding of students

In order to realize effective teaching and learning, it is important to know what students already know. This helps the teacher instruct student's at appropriate levels (Cho, 2000). The real-time understanding of students' comprehension helps the teacher know if students are grasping the main points. The teacher can then reteach any concepts that students are failing to grasp.

The most important aspect of quality teaching and learning is the degree to which the teacher correctly understands the students' background knowledge. Therefore, the process of instruction should be based on the students' previous knowledge.

Many researchers stress the following factors for understanding of students' comprehension and background knowledge:

- Real-time understanding
- Frequent evaluation
- Prompt and appropriate feedback

Elements for real time understanding

In order to give a successful instructions, the teacher should give prompt feedback based on the understanding of each student's comprehension. Therefore, the teacher needs methods that show the understanding of all students' comprehension correctly and easily. However, there was almost no way to evaluate the students understanding effectively in traditional classroom instruction.

Fortunately, nowadays, ICT can enhance the teacher's understanding in the class. It allows frequent evaluations, because it can automatically mark and report the results. The use of automatic evaluation systems makes the teacher better understand the student's comprehension. Because of the ICT-based evaluation system, it makes frequent evaluations, such as pre-tests, post-tests, and one minute quizzes, more accessible.

The following functions should be included to improve the teacher's understanding of students' comprehension:

- Real-time evaluation
- Frequent assessment
- Simultaneous evaluation of all students
- Prompt feedback by instant evaluation reports
- Appropriate feedback via personalized evaluation report

Figure 4.1 represents the flow of classroom instruction which takes into account the above functions. According to this flow, teaching and learning in the class may be more effective, because the teacher can give appropriate instruction based on the students' understanding.

Comparison of traditional understanding

Table 4.1 represents the comparison between the understanding method of traditional classes and the proposed method. From the teacher's point of view, the

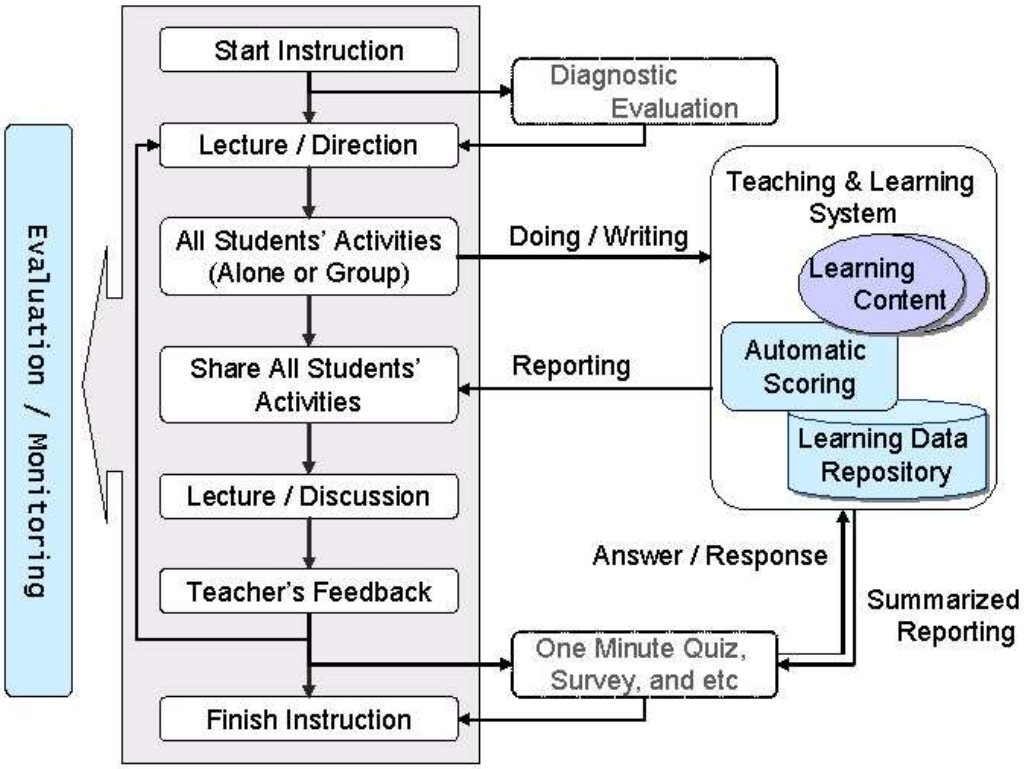


Figure 4.1: Flowchart for the real-time understanding of students' comprehension

proposed method makes it possible to instantly understand student's comprehension level. This is possible because it supports frequent and real-time evaluation. Therefore, the teacher can give the student more suitable instruction.

4.2 Timely Interaction

Important factors for effective interaction

Interaction is vital for effective teaching and learning. Timely and frequent interactions lead to the motivation of students, make it easier to measure student's

Table 4.1: Comparison of understanding of students' comprehension

Item	Traditional Method	Suggestion Method
Evaluation Purpose	Grading	Understanding
Evaluation Frequency	Limited	Frequent
Evaluation Method	Paper-Based	Student's Activities (behaviors)
Student's Activity	Passive, Limited, Sequential (Listening, Seeing)	Active, Totally, Simultaneous (Doing, Saying)

comprehension, guides the direction and accelerates the involvement of the debate (Chickering & Gamson, 1987; Choi, 1999a). Also, one of the most important factors for effective interaction is to supply more appropriate targets, time, and contents (Choi & Song, 2003).

Most research states the following common factors for effective interaction (Choi, 1999a; IM, 1999):

- Timely interaction to give immediate response
- Various interaction methods
- Frequent interaction
- Personalized interaction
- Related with student's learning activity
- Reflection of the evaluation to increase interaction involvement

Therefore, the following themes are more common factors.

(1) Timely and Continuous Interaction: For effective student learning, the student's thoughts must be evaluated continuously. Therefore, timely and continuous interaction is the most important factor (delMas et al., 1999).

(2) Simultaneous Interaction of All Students: One-to-one or face-to-face learning is the most effective instructional method. Therefore, interactions should take place at the same time so that every student feels that the full attention of the teacher is focused solely on them.

Problems of interaction in traditional classroom

Even though most teaching and learning is conducted in the classroom, recent research regarding interaction has not focused on classroom instruction. It has mainly focused on Web based interaction of on-line cyber education. Therefore, most classroom instructions have not followed the appropriate course of timely interaction.

Due to the lack of interaction in the classroom, instructors have used alternative ways to enhance interaction. Because of these reasons, the proposed interaction methods can not be applied to actual classes. Furthermore, the use of these interaction methods need much more time than traditional lectures. Therefore, we have to consider a new method which gives timely and appropriate interaction. In addition, the method should not truncate the flow of student learning activities and thinking in the class.

Elements of timely interaction

The lack of time is a problem that most classroom instructors face. Hence, it is usually impossible for effective interaction to take place. In addition, simultaneous

interaction with all students in the class has been impossible in traditional classroom instruction. Therefore, the teacher must appoint some students, and then they have sequence interaction. However, nowadays, we can support timely and simultaneous interaction when the instructor wants in the classroom. This is possible if we use the information technology which supports real-time communication.

In order to implement timely interaction, we must consider the activities of interaction more than the aspects of ICT. Therefore, it is better to use advanced ICT to improve active interaction in the classroom. Because of these reasons, we suggest the use of instruction support system and content which is based on the ICT.

The following functions should be considered to satisfy timely interaction.

- Interaction should be related with learning activity of each student
- Real-time gathering and summarizing of each student's learning activity
- Continually monitoring the comprehension of each student
- Easy evaluation for the interaction of every student's active participation
- Students take an impression like one-to-one personalized learning
- Share the results of all students' interaction to increase students interest in the class

Figure 4.2 shows the environment of timely interaction in the classroom which is based on ICT, such as the Internet, Web, database, and so on. This Figure describes the mixed interaction which consists of Human interaction and ICT-based interaction.

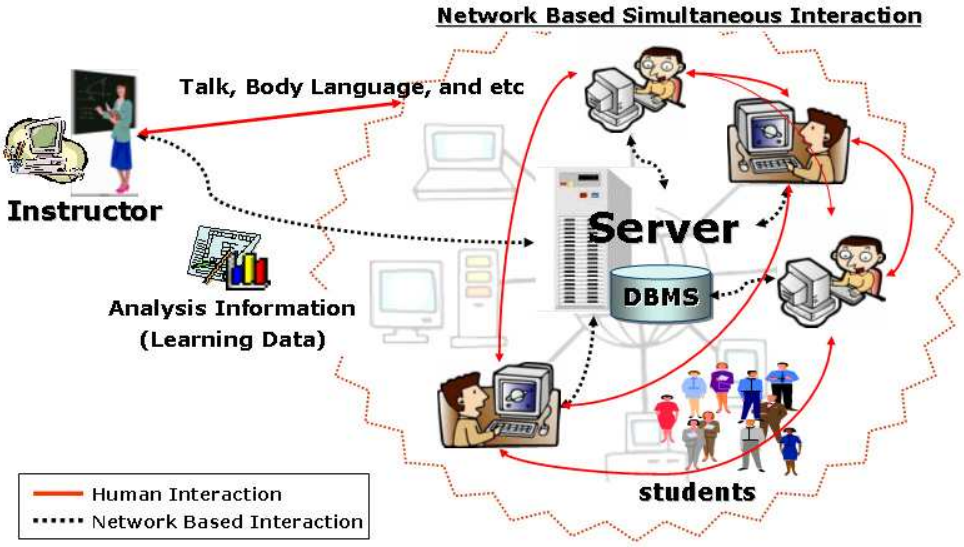


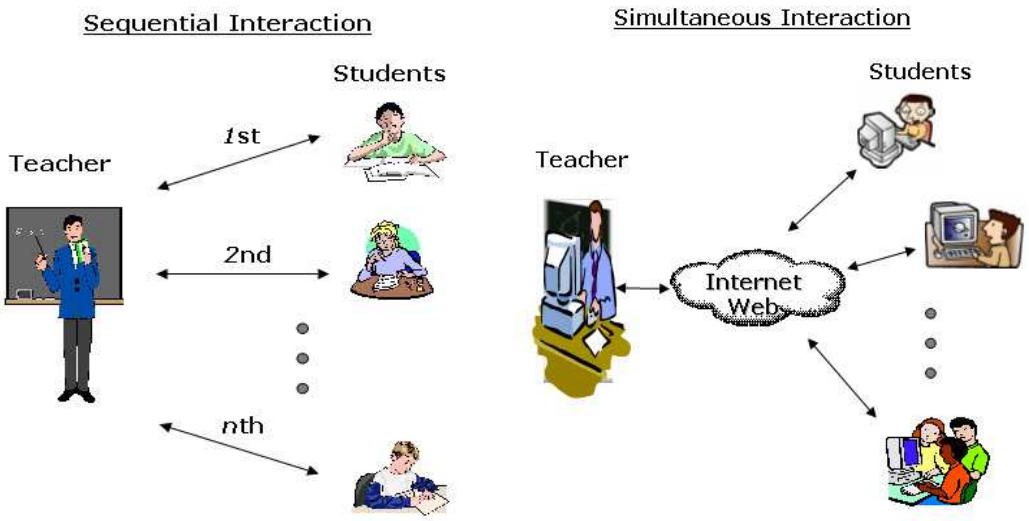
Figure 4.2: Two types of interaction in the classroom

The proposed interaction method has the characteristics of real-time and simultaneous interaction, while traditional education uses sequential interaction. Also, we consider that the teaching and learning content should contain the activities of every student and the teacher. Therefore, it is possible to achieve our intention.

- The teacher can make appropriate and timely interactions, because summarized reports will be supplied automatically.
- The teacher can monitor the learning activities of all students continuously.
- Students can share the results of the other students' activities.

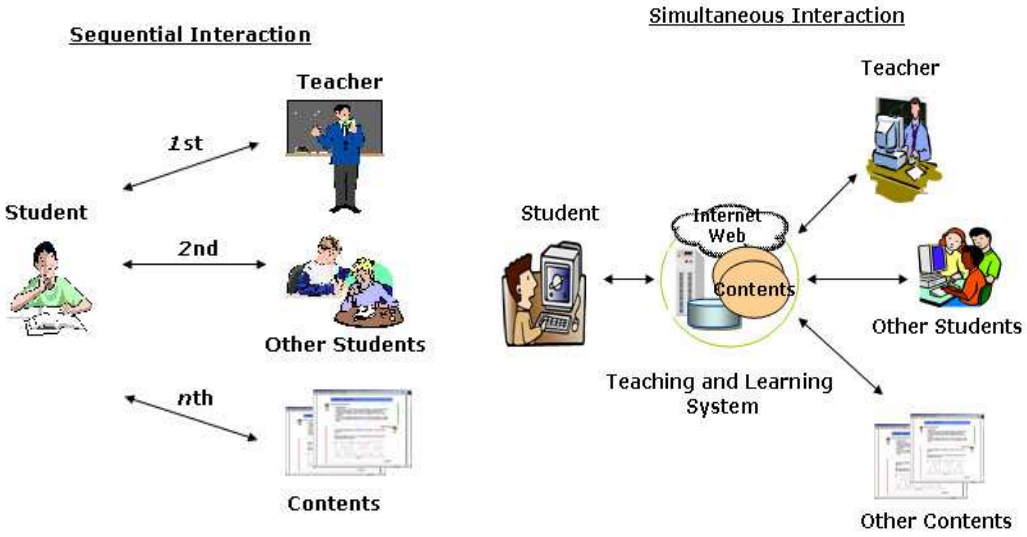
Comparison of traditional interaction

Figure 4.3 and Figure 4.4 represent the comparison with sequential interaction of traditional classroom instruction and the proposed interaction. It describes that all students in the classroom react or respond to the teacher's request at the same time. It shows that teacher can simultaneously interact with all students (Figure 4.3). Also, Figure 4.4 shows that the proposed method can lead every student to take part in the interactions actively. Therefore, we can conclude that the proposed method is helpful in order to overcome the conventional limitations of time and manpower.



(a) Conventional interaction (b) Proposed interaction

Figure 4.3: Comparison of teacher's viewpoint



(a) Conventional interaction (b) Proposed interaction

Figure 4.4: Comparison of student's viewpoint

4.3 Simultaneous Activity-Based Learning

Active Learning in the Classroom

For effective teaching and learning, research has emphasized active learning which was focused on the student's activity and hands-on experiences (Chickering & Gamson, 1987; Lee, 2001). Active learning is defined as instructional activities involving student's doing, thinking, saying, and writing. It emphasizes the instructional methods of learning-by-doing. It also appears as activities of conversation, debate, and writing (Chickering & Gamson, 1987; Bonwell & Eison, 1991).

Many researchers suggested that the learning achievement and retention level of active learning is higher than other instructional methods (Cho, 2000). With regards to learning-by-doing, An old Chinese proverb says: "I hear, I forget; I see, I remem-

ber; I do, I understand." Therefore, the best way to learn is to let the students run the simulation themselves and thereby gain understanding (Lee, 2001). In addition, regarding the psychology of memory, research highlights that active participation and learning-by-doing are the most important factors to enhance the retention level and achievement of students (Stice, 1987; Hyland, 2002).

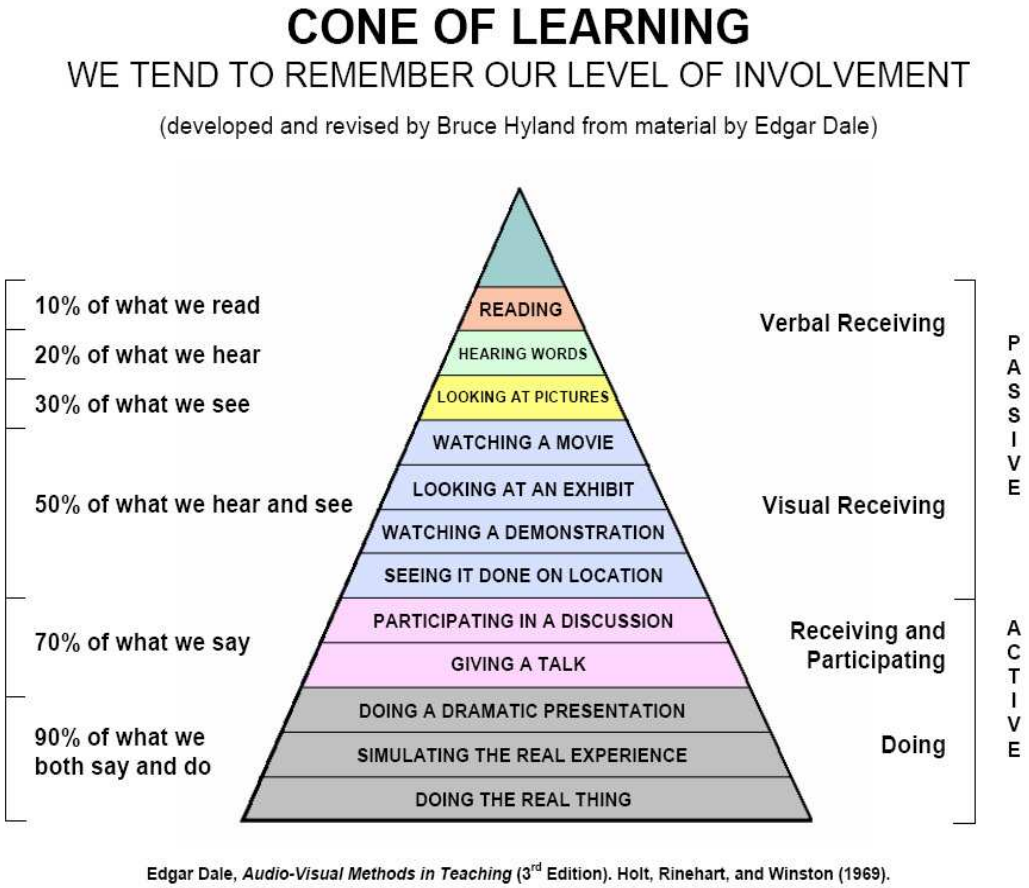


Figure 4.5: Cone of Learning from material by Edgar Dale (Hyland, 2002)

In this respect, Figure 4.5 represents the retention rate of Eager Dale according to the instructional methods (Hyland, 2002). In this figure, we find that the active learning method increases understanding far better than other passive learning methods.

In terms of the center of class, Berge (1997) presented the relative relation between instructional methods in Figure 4.6. He noted that the effectiveness was greater as the student-centered active learning increased.

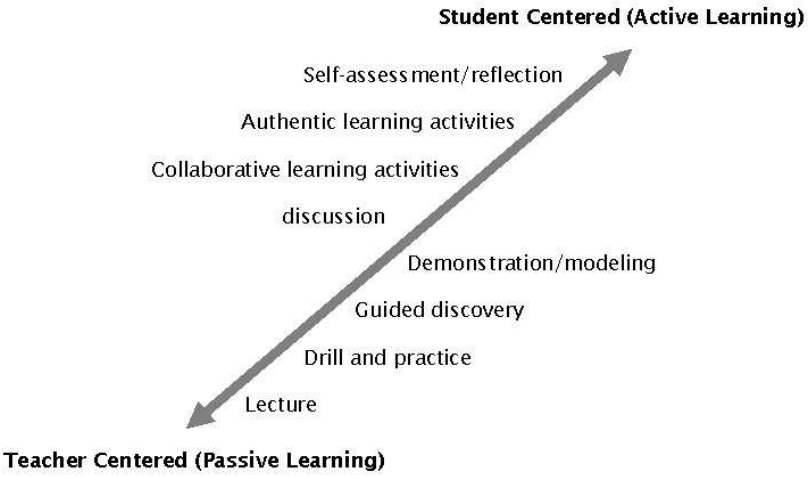


Figure 4.6: Spectrum of teaching methods focused on activity

As shown above, active learning is the most important factor for effective teaching and learning. It allows more interactive teaching and learning in the classroom. Also, it transforms students from passive listeners to active learners.

Types of Active Learning

There are many forms of active learning. This is due to the fact most research tries to find better ways of engaging students in the learning process. Fink (1999) noted that all learning activities involve some kind of experiences or dialogue, as seen in Table 4.2. For example, students write their own thoughts on a topic (dialogue with self) before they engage in a small group discussion (dialogue with others), therefore, the group discussion should be more interactive and meaningful.

Table 4.2: Types of active learning activities

Type	Kinds
Dialogue	Dialogue with Self or Others
Experience	Observing or Doing

Active learning methods involve small group work, presentations, debates, journalizing, role playing, learning games, field experiences, case studies, class discussions, simulations, and so on. We can say that these methods specifically apply examples of constructivism theory. Therefore, the fundamental goal of active learning involves more student-centered education.

Important factors for effective active learning

In order to improve comprehension and retention levels, students should actively participate in activities and express their thoughts (Chickering & Gamson, 1987).

The followings are the common important factors that enhance active learning:

- Student-centered teaching methods

- More hands-on experiences
- More say and write students' thoughts
- More activities in the class
- Cooperative and collaborative learning
- Constructivism
- Experience with various viewpoints

In this study, we propose a new instructional method to support simultaneous participation in classroom learning. This method takes into account the factors for effective active learning.

Elements of simultaneous activity-based learning

As ICT continuous to improve, instructional methods that encourage activities of students are being studied (Choi & Jun, 2000). However, limited class time is still one of the biggest obstacles to overcome, when we want to use activity-based learning methods in class (Bonwell & Eison, 1991).

In order to encourage student activity-based learning, the following things should be considered when the instructor designs teaching and learning contents.

- Instructional materials should be based on every student's activities
- The student has an impression of one-to-one personalized instruction
- The learning activities of all students should be shared during the class

- The responses and activities of students must be reported to the teacher instantaneously
- It allows the teacher to monitor the activities of each student immediately

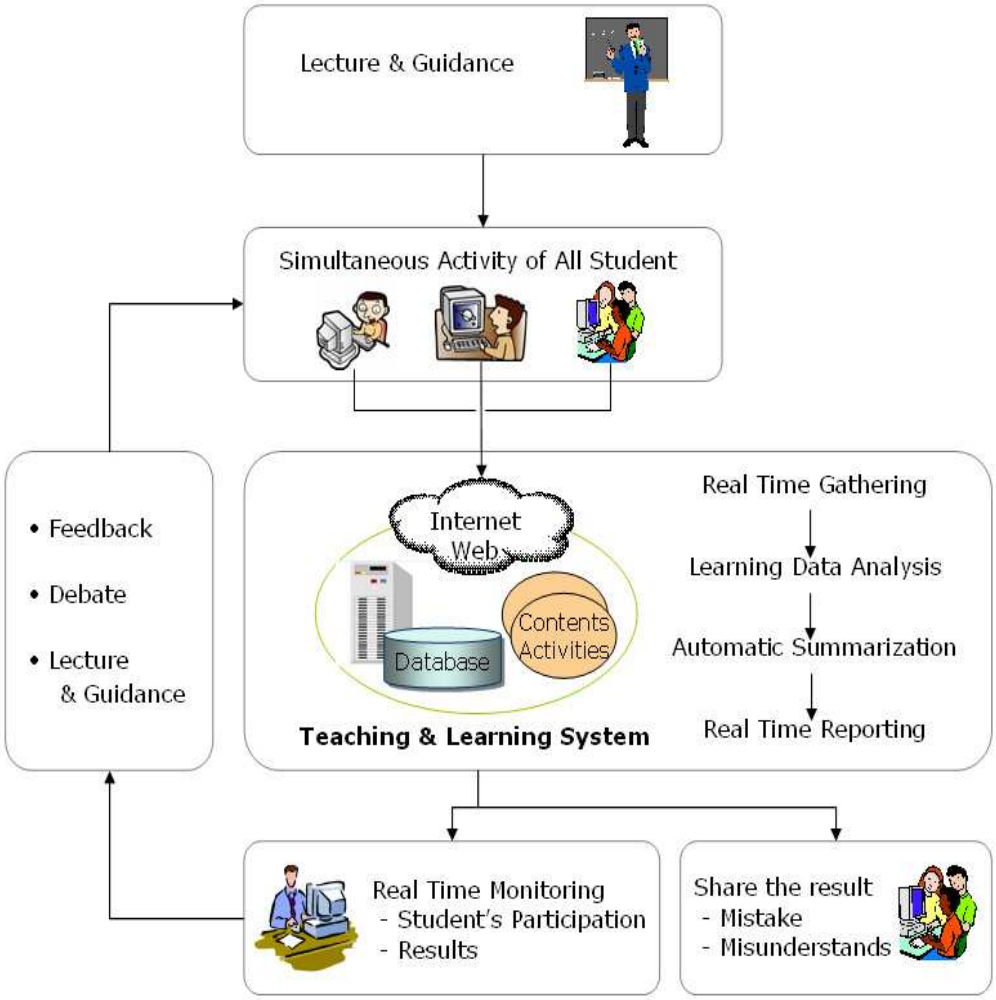
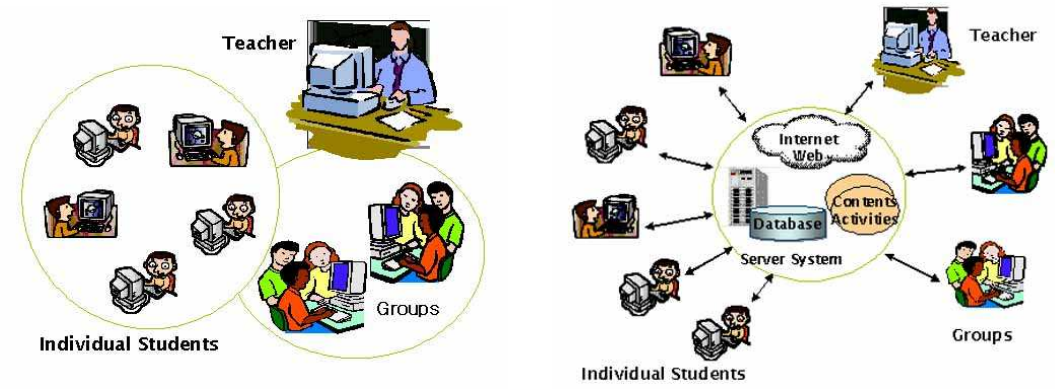


Figure 4.7: Flowchart of simultaneous activity-based learning

If teachers use the instructional content which is based on the above suggestions, every student can take part in the class course simultaneously. Also, teachers can present more appropriate feedback to the students, because they can monitor the result of each student. In addition, it gives students the opportunity to see the errors made by others. Thus ensuring they will not make the same mistakes. It also leads to more active participation in the class debate.

Figure 4.7 represents the use of teaching and learning contents for activity-based learning. The instruction with the proposed contents (e.g., lecture and guidance of the teacher, activity and response of every student, real-time data collection and analysis, and sharing of the results) should progress continuously.

Comparison of conventional active learning



(a) Isolated participation (b) Simultaneous participation and collaboration

Figure 4.8: Comparison of participation styles

Figure 4.8 represents the difference between the traditional active learning method and the proposed method. Students should participate throughout the whole class,

and they can share the results of all students' learning activities. Teachers must encourage every student's participation and activity-based learning, because they can monitor the results of all students' learning activities in the class. They also make students actively participate in the debate actively.

Table 4.3 represents the difference of traditional active learning methods and the proposed method.

Table 4.3: Comparison of the active learning

	Traditional Methods	Suggestion Method
Participation style	Individual Learning	Collaborative Learning
Share of activity	Isolation	Sharing & Opening
Fault & feedback	Not Share	Simultaneous Share

5. A Model of Effective Introductory Statistics Education

In this chapter, we present a new model for introductory statistics teaching and learning. The model is based on the UIA model presented in the previous chapter, and customized to introductory statistics education. Therefore, we call this model the 'UIA-SE model': It means Understanding, Interaction, Activity-based learning in Statistics Education.

In Session 5.1, we examine the characteristics of statistics education. Then, we present a UIA-SE model which considers these characteristics in Session 5.2. Lastly, we compare the UIA-SE model with the results of traditional teaching and learning styles.

5.1 Characteristics of Statistics Education

In order to accomplish effective statistics education, we should know the distinct characteristics of statistics. Firstly, statistics education should be more data-centered, because statistics in practice involves a dialogue between model and data. Hence, most researchers have emphasized, 'More Data and Concepts: Less Theory, Fewer Recipe' (Moore, 1997).

Secondly, it is very difficult and time-consuming to formulate problems and gather quality data that deals with the right questions. Hence, the experience of data production is the most important part of statistics, because if not done properly

all the subsequent analysis activities are not worth much (Cobb, 1992).

Lastly, understanding the concept of variability is the most important component in introductory statistics education. Variability is omnipresent in real world data. Therefore, it is the essence of statistics as a discipline. In order to better understand the concept, students should have hands-on experience because they understand more than in traditional lectures (Cobb, 1992).

Compared to other subjects, we can summarize the different factors of statistics as follows (Cobb, 1992; More, 1997):

- The need for data
- The importance of data production
- The ubiquity of variability

5.2 Barriers of Effective Statistics Education

In statistics education, research suggests that active learning has emphasized the student's experiences of data collection and analysis. Also, this research implies that Web-based interactions and simulation learning should be student-centered in the active learning process. Statistics education needs real-time understanding of students' comprehension, timely interactions with the teacher and students, and simultaneous students' learning activities.

However, in spite of most research, statistics education still has some problems as follows:

- **It is difficult to understand the student's comprehension at once:**

  There is no method for understanding the background knowledge of students

and comprehension when the teacher requires. Therefore, it is impossible to give appropriate and prompt feedback. Students satisfaction and educational effect may diminish as a result.

- **There are few methods to help timely interaction with all students:** There are few methods to interact with every student simultaneously in the class. Also, the teacher can not monitor every student's activity and responses. Therefore, the teacher can respond accordingly to each student.

- **There is not enough time for activity-based learning in the class:** In actual classes, it is very difficult for the teacher to collect and analyze student's learning data due to limited class time. Therefore, it may not improve educational effect because the flow of student's thought is often truncated in the class (Magel, 1996).

In order to solve these problems, much research has been studied, however, a positive solution was not found. We may solve these problems if we apply ICT, such as computers, Internet, and databases which support simultaneous communication, appropriately in the class. Therefore, the teacher can solely lead the activity-based learning of all students, and can monitor the real-time understanding of all students' comprehension. Also it makes timely interaction with all students possible.

5.3 A Model of Effective Statistics Education

Much research has been studied, but it is hard to find any evidence that the research results used actual teaching and learning in the class. This research may be therefore

ineffective. Furthermore, we could not find any good models for effective statistics education in classroom instruction. For this reason, it is difficult to believe the effectiveness of previous research results. Therefore, to achieve effective teaching and learning in statistics education, we need a systematic model which reflects the general effective pedagogical theories and the characteristics of statistics education.

In the case of statistics education, the concepts are best learned in the context of real data sets. Therefore, instructional models should focus on data and concepts. Fortunately, using computers to automate calculations and graphics make it possible to work with real data without becoming a slave to the mechanics (Cobb, 1992). Therefore, the UIA model presented in the Chapter 4 should be applied to effective statistics courses. In order to apply the model, it should consider the characteristics of statistics education. In this section, we present a UIA-SE model which considered these elements. The components of UIA-SE model are as follows:

- **Real-Time Understanding of Students' Comprehension:** To improve the understanding of students' comprehension, the UIA model has to include the following elements.
  - More questions to understand the level of students' comprehension
  - More monitoring of students' data analysis activities
  - In case of the quiz, more related data and concepts
- **Timely Interaction:** In order to enhance interaction in the course, the UIA model should take into account the following elements for timely interaction.
  - More debate about data collection and basic concepts
  - More questions and answers about data manipulations

  - More sharing of the results of each student's analysis activity

- **Simultaneous Activity-Based Learning:** To promote student activity-based learning in the class, the UIA model should consider the following criteria.

  - More hands-on experience of data collection
  - More learning by doing analysis activities with real data
  - More monitoring of each student's analysis activity

For example, we can consider the following teaching and learning process using the UIA-SE model in the general statistics course steps. The following process uses the abbreviations as follows:

- **U:** Real-time understanding of students' comprehension
- **I:** Timely interaction
- **A:** Simultaneous activity-based learning

1) Teacher: guides the direction of the class

2) Student: data collection and input activity [A, I]
Teacher: monitoring each student's activity [U]
- real-time data collection with software program: ICT
- simultaneously monitoring the process of data collection

3) Educational Material: automatic collection and reporting of students' activities

4) Teacher: guide students' next activity

5) Student: analysis activity [A, I]

Teacher: monitoring and interaction [U, I]

- the activity of analysis with the collected data
- using analysis software/packages
- hands-on experiences/learning-by-doing

6) Teacher: presents the collected results [U, I]

Student: sharing and debate with the results [I, A]

- sharing the results through the Web
- input each student's comments through the Web concurrently

7) Teacher: lead more learning activities [U, I]

- using the quiz system to understand students' comprehension
- deliver timely and appropriate feedback to the students

It is impossible for the course to use this type of teaching and learning process without the functions of advanced ICT. In educational fields, the ICT based instructional model like the UIA-SE model helps more real-time understanding of the student, makes timely interaction more frequent, and gives students more activity-based learning opportunities.

5.4 Comparison with Traditional Instruction Styles

In order to examine the effect of using the UIA-SE model, we compare the UIA-SE model with the following materials. These are the representative educational materials found in previous research.

(A) STEPS: This material is CBL (computer-based learning) software for teaching statistics in pyschology, biology, geography and business. Each module was made by a multimedia authoring tool
(see, more detail at http://www.stats.gla.ac.uk/steps).

(B) HyperStat Online: This is an introductory-level textbook in statistics operating on the Web. Each chapter has links to related texts, instructional demos, and free statistical analysis programs. It allows users to vary parameters and get feedback about the consequences. It also uses many simulation programs made by Java applet
(see, more detail at http://www.ruf.rice.edu/ lane/rvls.html).

(C) Cyber Education: Usually, on-line educational materials consist of video clips, Web pages, and documents (e.g., MS Word, PowerPoint, and PDF files). In particular, distance education institutes such as KNOU (Korea National Open University) use this style in their educational services.

Most of the previous teaching and learning materials have been dependent on multimedia such as video and flash movie, html pages, and document files. These also do not consider timely interaction and real-time monitoring by the teacher. Hence, the effectiveness of teaching and learning entirely depends on the student' attitude.

Table 5.1 presents the results of comparisons with three materials types.

Table 5.1: Comparison of the UIA-SE model with previous materials

Item	A type	B type	C type	UIA-SE type
Usable Students' Activity	X	X	O	O
Understanding				
- Real-Time	X	X	X	O
- Frequent Evaluation	X	X	△	O
- Prompt Feedback	X	X	X	O
Interaction				
- Instantaneous	O	X	X	O
- Simultaneous	X	X	O	O
- Frequent	X	X	X	O
- Personalized	△	△	△	O
Activity-Based Learning				
- All Students Participation	O	O	X	O
- Simultaneous Participation	O	O	X	O
- Monitoring the Activities	X	X	X	O
- Sharing the Results	X	X	X	O

6. Design and Implementation of the RT-SES

In chapter 5, we discussed the UIA-SE model which supports real-time understanding of students' comprehension, timely interaction, and simultaneous activity-based learning methods for effective introductory statistics education in the classroom. In this chapter, we examine the design concepts of the framework and how to apply it. Also, we implement the Real-Time Statistics Education System (RT-SES) and how its contents should be applied. We also examine the results of the application results and it's usefulness. We introduce this system divided by Real-Time Teaching Support System and Contents for the statistics topics.

In section 6.1, we explore the design of the RT-SES based on UIA-SE model. We examine the design of evaluation and data collection systems in section 6.2. In section 6.3, we look at the development environment and the tools of the system. In section 6.4, we represent the features of the contents and modules of the RT-SES. We present the comments of the students and the impression of the teacher.

6.1 Design of the RT-SES

For the implementation of the RT-SES, we need a design plan to consider the advantages of information and communication technology such as database management systems and internet technology. In this section, we examine the general framework of the RT-SES and the design of teaching and learning contents which are based on the components of UIA-SE model.

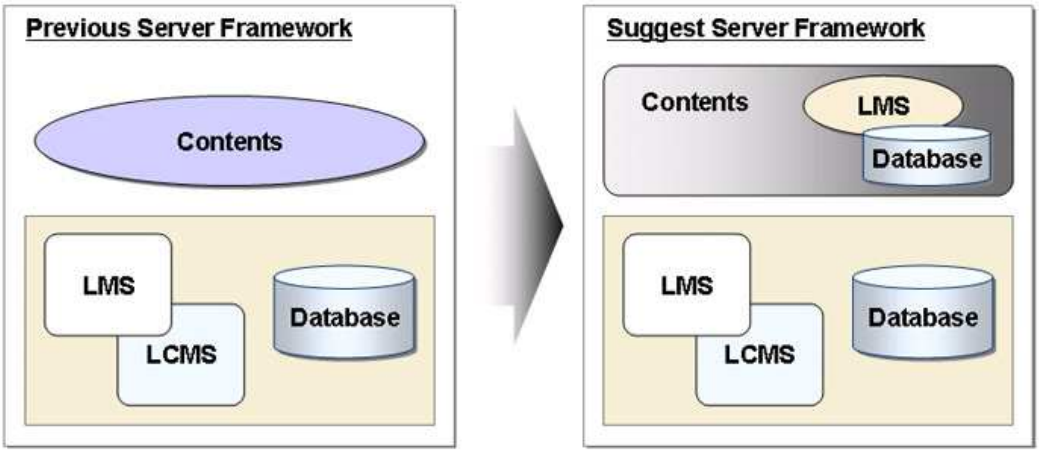


Figure 6.1: Comparison of contents frameworks

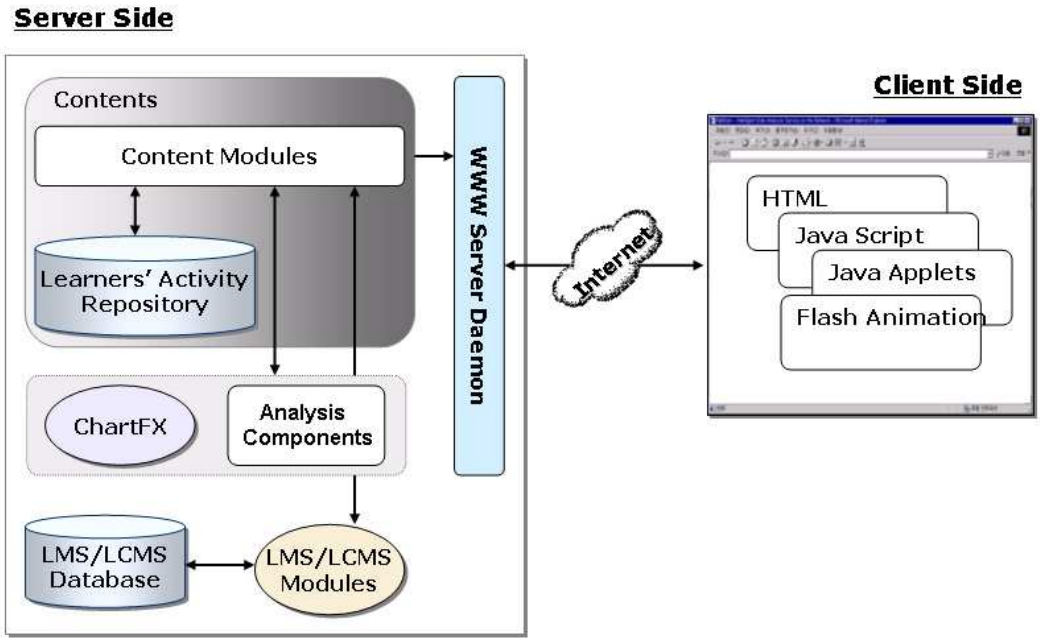


Figure 6.2: Framework of the RT-SES

Figure 6.1 compares the frameworks of traditional teaching and learning contents. When we design the content, it must contain the database which forms the student's activities and various interactions at the same time.

Traditionally, the database has had nothing to do with the teaching and learning contents. It has just been used for the learner management system (LMS). However, if we implement the teaching and learning content that is based on this research, the content should include it's database parts in the content's inner side. Therefore, we must include the LMS module and database that can deal the collection, store, and treat of student's learning activities.

Figure 6.2 represents the framework of a RT-SES. It shows the content that includes teaching and learning modules and a database repository to store student's learning activities. It is operated through the Web.

6.2 Design of Evaluation and Data Collecting System

We consider the practical use of the real-time evaluation system so that the teacher can understand the comprehension of every student at once. Figure 6.3 represents the flowchart of the real-time evaluation system. Before the class starts, the teacher inputs the evaluation questions in order to understand the student's comprehension or background knowledge through the Web. As the class progresses, students are evaluated through the Web. They submit their answers through the Web, and the evaluation system marks the responses automatically. It then proceeds to report the results to the teacher and the students.

In statistics education, most research has emphasized the empirical study of the student such as data generation, collection, and analysis. Figure 6.4 represents the

flowchart of the real-time collection system. It supports real-time data collection, simple analysis, and shares the collected data. Therefore, if we implement and use the system to follow the flowchart, we may solve the problems of lack of class time and substantial effort.

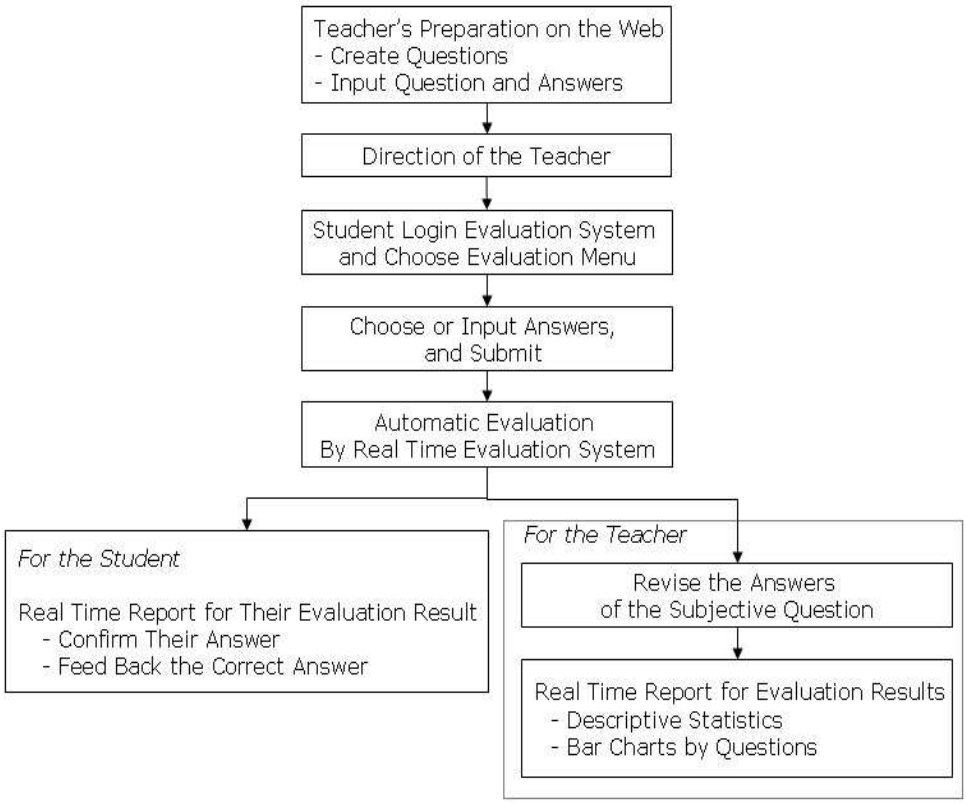


Figure 6.3: Flowchart of automatic evaluation system

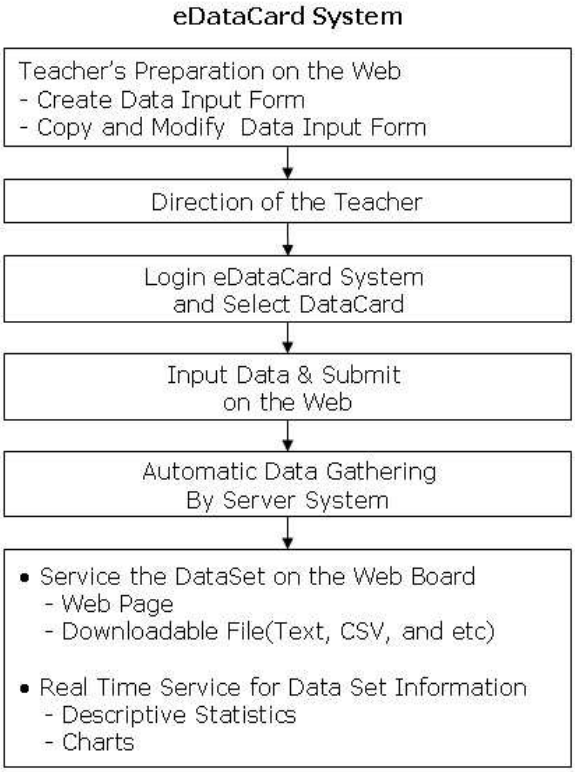


Figure 6.4: Flowchart of data collection, simple analysis, and sharing

6.3 Development Environment of the RT-SES

In this section, we introduce the development environment of RT-SES (see, Figure 6.5). The system consists of a MS Windows 2000 Server, MS SQL Server 2000, IIS (Internet Information Server), and other software. For student convenience, the RT-SES modules are based on the Web. Therefore, we use a Web browser such as Internet Explorer as the interface between the student and teacher.

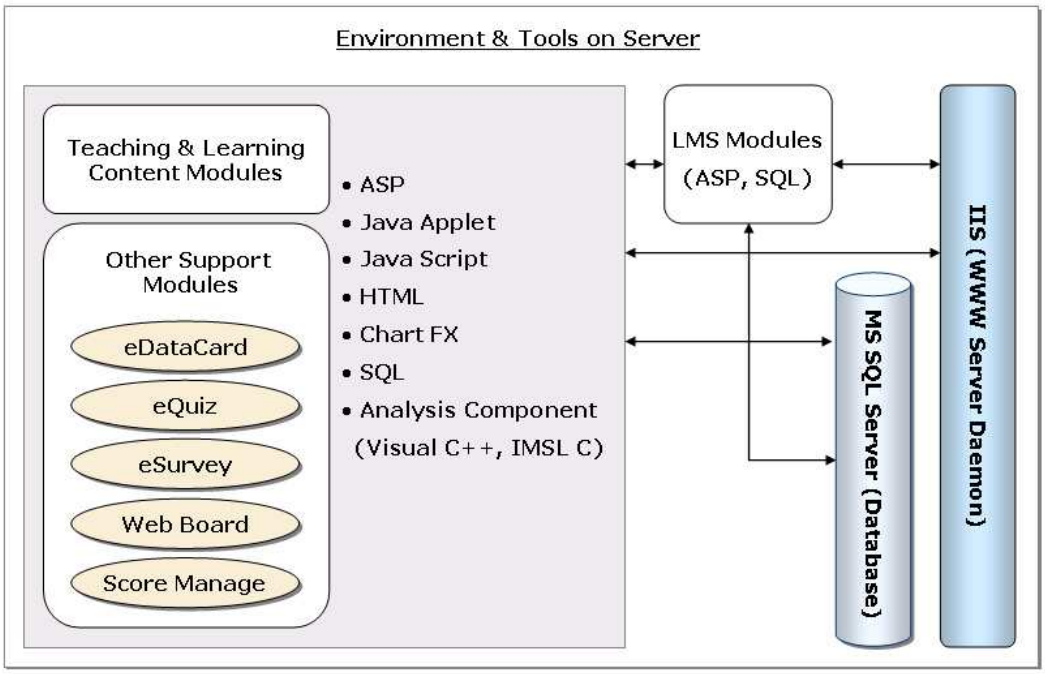


Figure 6.5: Development tools and environment of the RT-SES

Table 6.1 represents the development tools of RT-SES in this study. The use of database management systems (DBMS) make the collection and summarization of student's learning data available in real-time. Programming languages such as ASP (Active Server Pages), Dynamic HTML, and Java Script are used for dynamic Web pages. Java applet is used for graphs and mini applications of learning components, and ChartFX is used for making charts in the data collection system (eDataCard). The module for analysis of descriptive statistics in the system is manufactured by COM (Component Object Model) technology.

Table 6.1: Development environment and tools for the RT-SES

Item	Development Tools
Operating System	Server: MS Windows 2000 Server Client: MS Windows 2000, XP
Web Server	Internet Information Server 6.0
Web Page	HTML, ASP(Active Server Pages), Java Script
DBMS	MS SQL Server 2000
Graph & Chart	Java(Java Applet), ChartFX
Analysis Module	IMSL C
Component Object Model	MS Visual C++
Client Interface	Web Browser (Internet Explorer)

6.4 Features of the Contents and Modules

In this section, we examine the features of actual implemented contents and modules that are based on the elements of 'UIA-SE model'.

The implemented example is a form of *Simple Random Sampling (SRS)* taken in the classroom. Figure 6.6 represents a flowchart of teaching and learning content. It consists of real-time understanding of students' comprehension, timely interaction, active participation, and monitoring by the teacher.

According to the instructions of the teacher, every student should participate in each course step at the same time. They estimate an average value through their own subjective sample, and compare it with the result of SRS. The activities and interactions of every student are performed through RT-SES. The teacher can observe the activities of every student through the RT-SES. Therefore, the teacher can give immediate and appropriate feedback to all students.

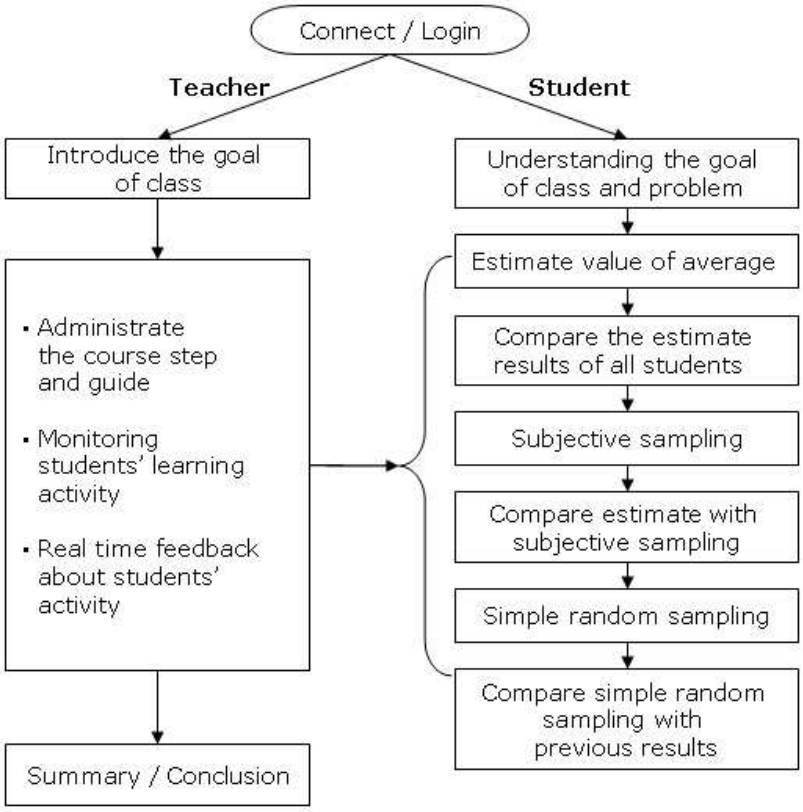


Figure 6.6: Instruction design of simple random sampling with the RT-SES

6.4.1 Understanding of Students' Comprehension

To understand each student's comprehension simultaneously, we can apply evaluation methods such as quizzes when we begin the class or during the class.

In this study, we included formative evaluation items in the teaching and learning content for real-time understanding of each student's comprehension (Figure 6.7). Every evaluation is marked or reported automatically. Therefore, the teacher can give prompt feedback to each student according to their response results. Also, this function may induce natural debate.

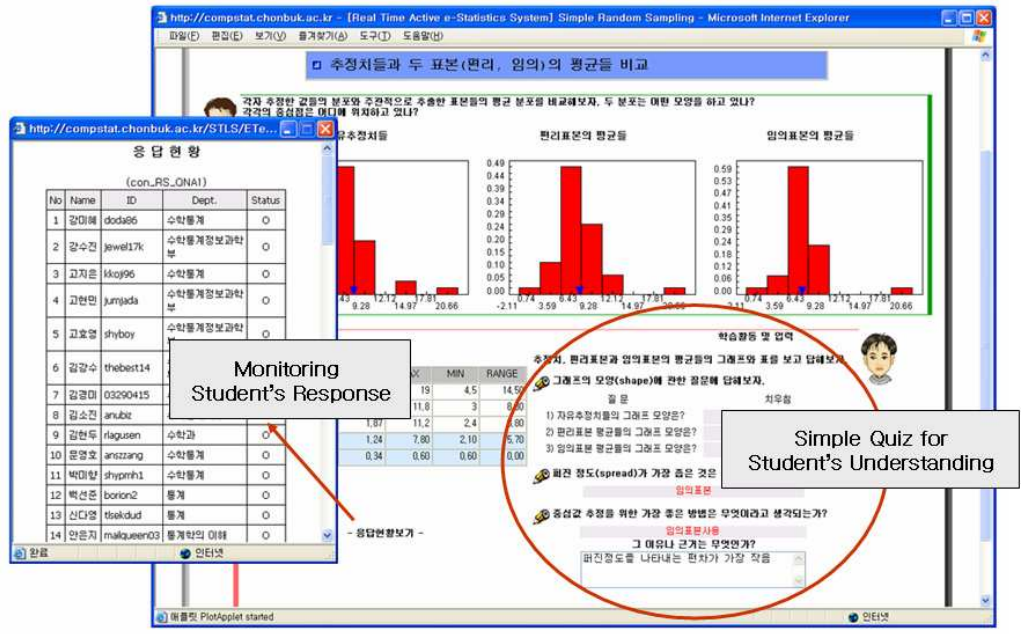


Figure 6.7: Timely interaction with simple quiz

For diagnostic evaluation, we use the real-time evaluation system, and we named it eQuiz system (Figure 6.8, 6.9, and 6.10). Figure 6.8 represents the teachers set of subjective or objective questions through the system. The response of each subjective question is marked automatically. Because this system only applies the correct answer, we implement a manual marking system with append (Figure 6.9). The evaluation system reports correct answer rates for each question according to the table or chart. It also reports the validity of each question from each student (Figure 6.10). Hence, the teacher may present appropriate feedback immediately.

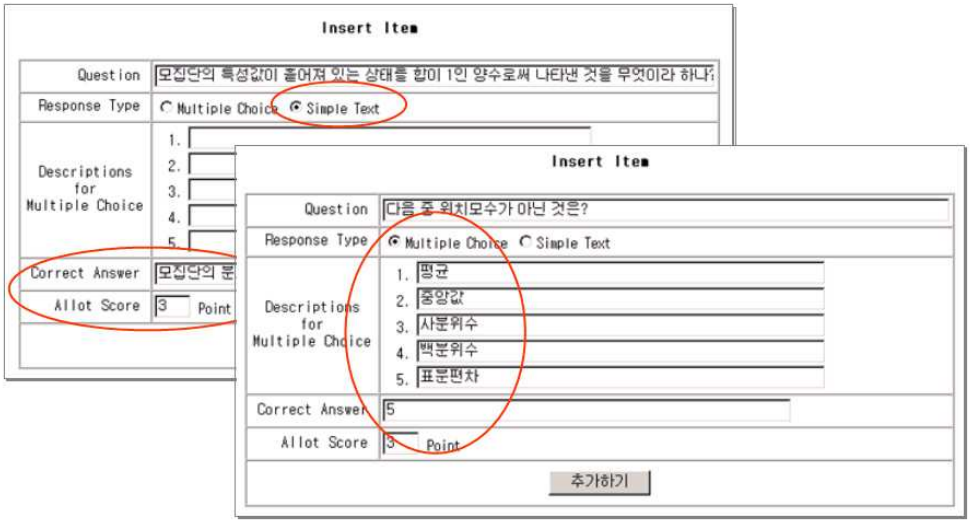


Figure 6.8: Insert questions into the evaluation system

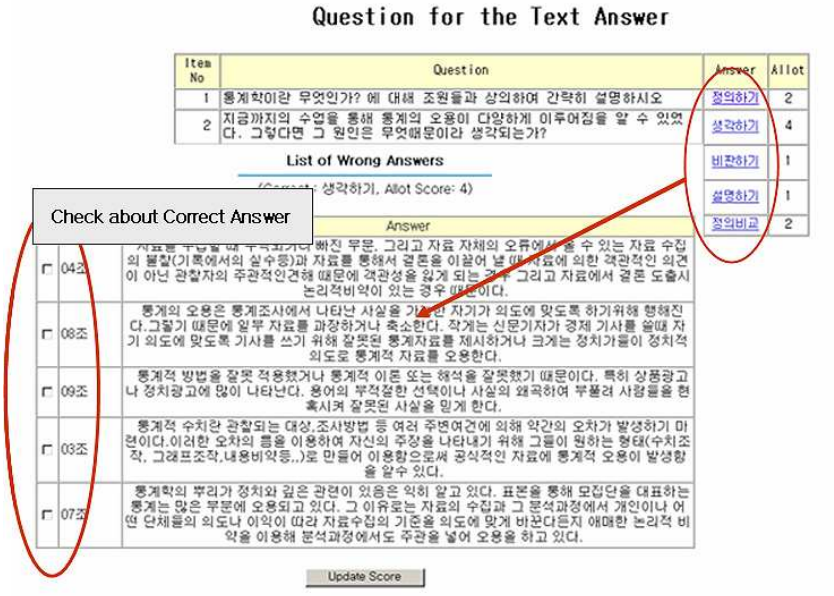


Figure 6.9: Check incorrect answers on subject questions

Quiz 평가 결과

(문항별 평균 점수 - 총 12 문항, 응시자 수: 27 명)

Quiz No	1	2	3	4	5	6	7	8	9	10	11	12	Total /Average
Correct(Corr/No)	23	19	26	24	25	27	22	27	26	20	25	17	281
Average(%)	85.19	70.37	96.3	88.89	92.59	100	81.48	100	96.3	74.07	92.59	62.96	86.73

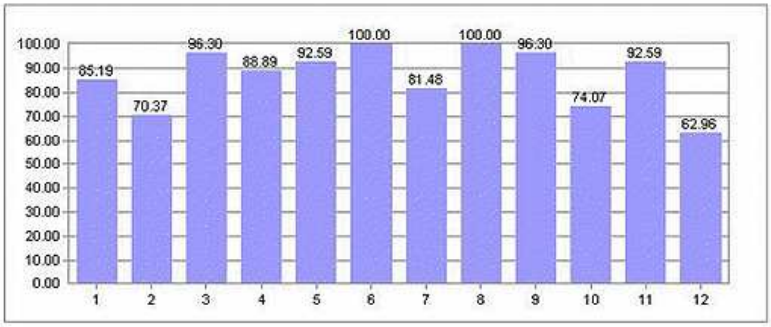


Figure 6.10: Automatic evaluation results and chart of achievement

6.4.2 Interaction and Activity-Based Learning

Figure 6.11 represents the timely and simultaneous interaction of every student's participation through using simple questions through the Web-based instructional material.

The teacher can monitor each student's activity and responses. Hence, these functions make sure that all students actively participate in the class. Because the system reports the results of every student without delay, it may enhance the instant and timely interaction with the teacher and other students.

Learning components based on the RT-SES include functions of summarizing and gathering responses and data of each student's learning activities. Therefore, the teacher can monitor and understand each student's comprehension and his/her sincere participation.

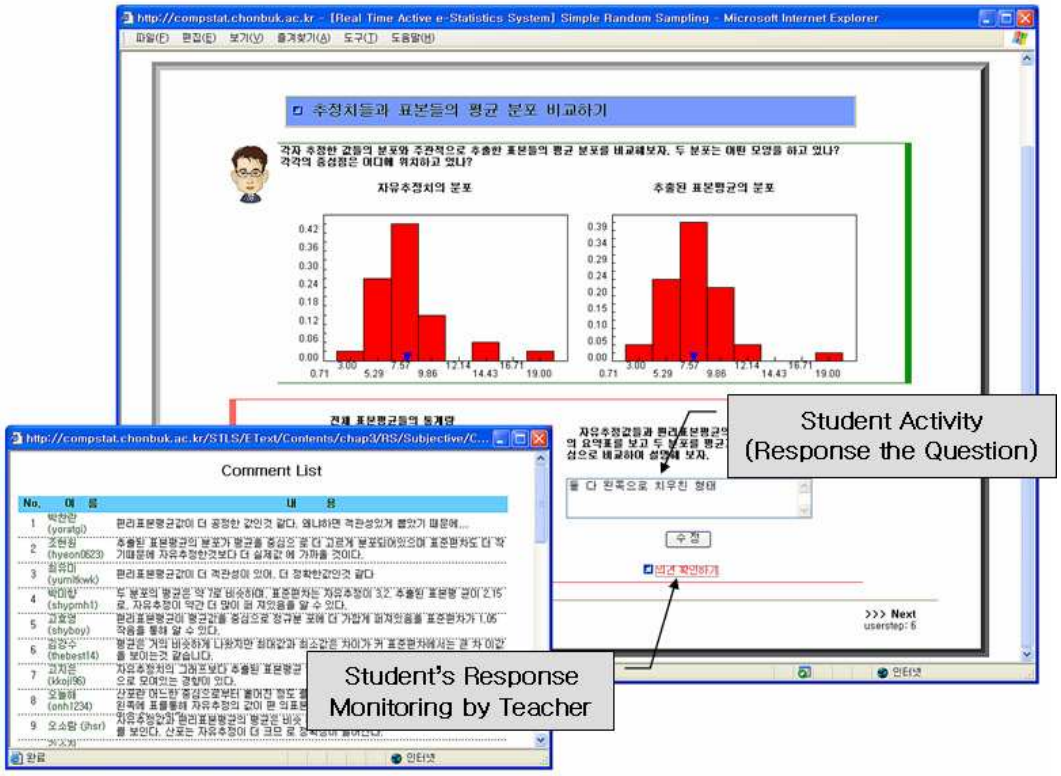


Figure 6.11: Simultaneous activities

Figure 6.12 represents the collected results of every student's activity. These results include the comments of comparing subjective and random sampling. The teacher can review each student's response and how the student works in each sampling step. Therefore, it can make the student participate more actively in the class. Students can compare their own result with other students, and it can increase the student's level of interest.

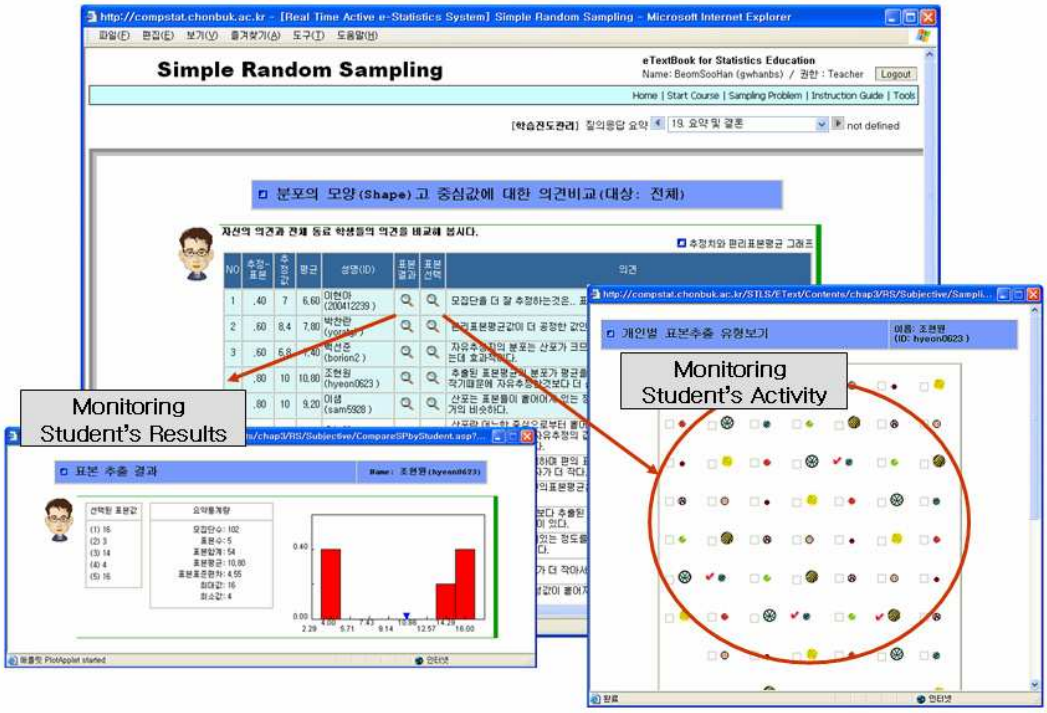


Figure 6.12: Real-time monitoring

6.4.3 Use of Real Data

The function of real-time data collection makes it possible for students to participate in learning activities when the teacher wants. Therefore, students have more opportunities to become involved in the empirical study of statistics education (Figure 6.13).

For the practical use of student friendly data, we implement the real-time data collection system, which is called the eDataCard system. This system requires students to input their own data directly (Figure 6.14). Because data is collected and summarized automatically, the teacher does not need to input any data. Figure 6.15 represents the functions of chart and descriptive statistics in the system.

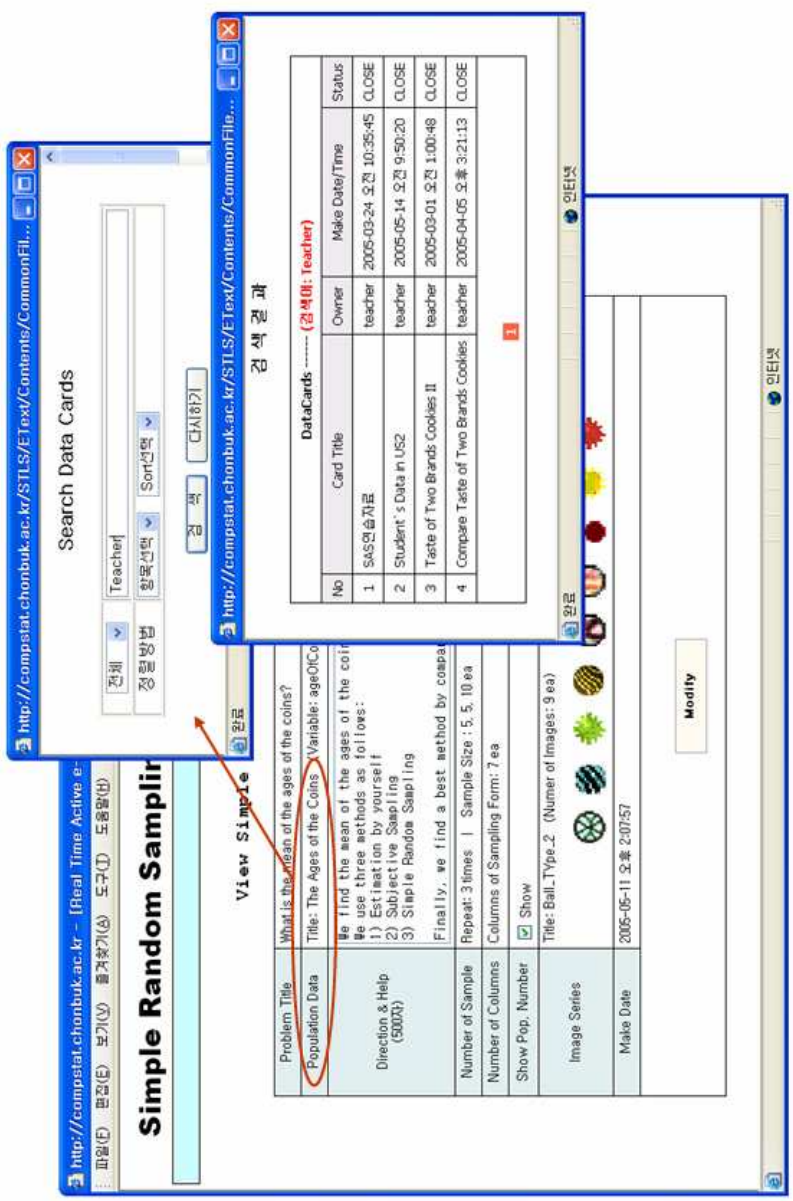


Figure 6.13: Connection with real-time data collection system

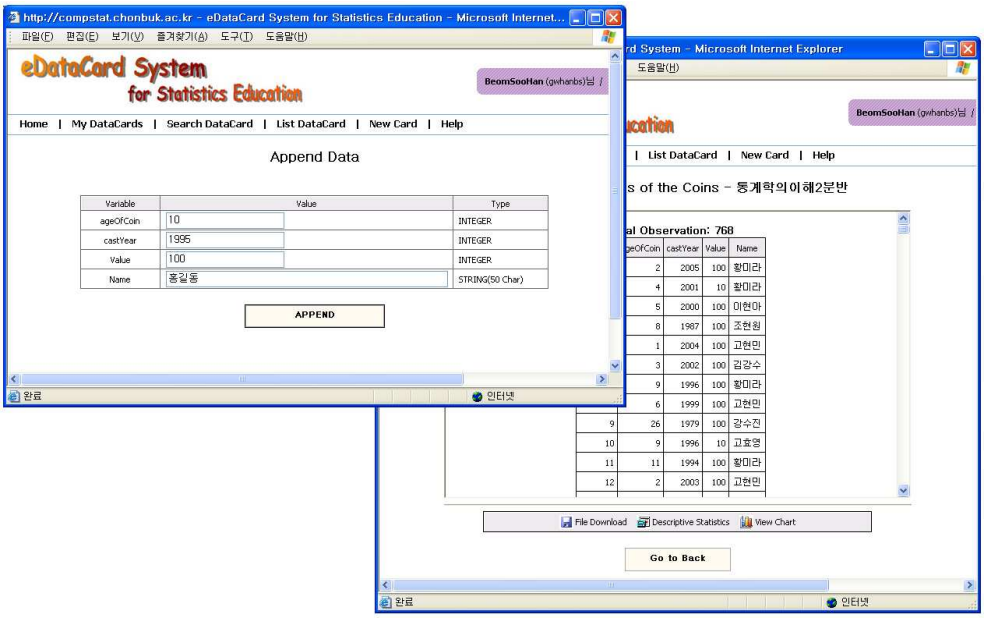


Figure 6.14: Real-time and simultaneous data collection

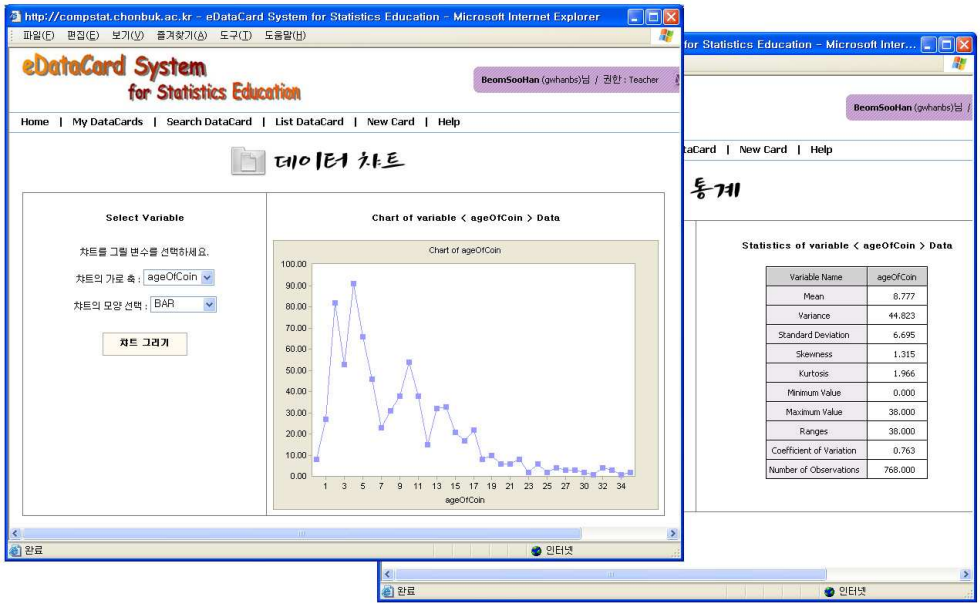


Figure 6.15: Simple analysis and charting

6.5 Comments and Discussion

For effective statistics education, we design and implement the RT-SES and teaching and learning content for simple random sampling. The system considers principles of excellent teaching and enhanced information technology in the classroom. Through the use of Web and DBMS, it supports real-time and simultaneous active participation and interaction of every student. It also enhances student's interest and concentration, because they can share other students' learning data. In addition, the teacher can monitor each student's learning activity. Hence, the content drives students to take part in their class more actively. Also, the teacher can grasp the student's misunderstanding and give them correct feedback immediately. To increase students' familiarity with real data, the real-time data collection system can be used.

In order to examine the efficiency of the proposed model, we applied the RT-SES and some contents to the authentic class in Chonbuk National University. To examine the students' responses and effectiveness, we conducted survey with open-ended questions after the class.

According to the results of survey, the 58% of the class students gave the positive responses. In particular, students answered that they could satisfy with participation in the class. They also replied that the proposed teaching and learning method made them more concentrate into the learning process. The 30% of the students replied that it is better and more interest, because they had the experiences of practical problem solving in the course.

The following comments were also collected from the students. They state the impressions of both students and teacher in actual classes.

Comments of Students

- "It was good and not boring, because we could participate together while the class was going on."
- "Because we practiced directly, we could take part in the class, and the class was not boring."
- "It was much easier than learning with only a textbook, and understanding is much better. Also, the practical use of theory can be grasped easily."
- "It was good because we could compare with other students' responses."
- "I'm interested because I could adopt theoretical statistics and apply them in actual problem solving."
- "It was a good, because I could gain experience that applies theory to an actual problem."
- "Through statistical analysis about practical questions, I felt that dimension about the practical use of statistics is big in everyday life."
- "It was good that the evaluation result was presented immediately after the evaluation."

Impressions of Teacher

- "Student's interest and convergence in the class were higher than traditional classes."
- "It became more active because students could do various activities and interact in the class."
- "There were few students who did unnecessary actions in the class."
- "It took very little time for data collection."
- "I could derive students' participation naturally, because I could monitor the status of students' input."
- "If the eDataCard system was used in the lecture, the results of previous research in statistics education could be utilized more easily."
- "Students might have more learning opportunity because of hands-on experience."
- "It could be used effectively in various level of statistics education."
- "Because there was no burden about marking, I could evaluate often."
- "Because the eQuiz system supports the grasp of student's understanding in real-time, it helped my understanding of the student's status."
- "Because we could share the evaluation result with students, we can present appropriate feedback to each student quickly and efficiently."

7. Summary and Conclusions

7.1 Summary of the Thesis

For effective introductory statistics education, many researchers indicated a necessity for new types of teaching and learning that adapt to the changing educational environment. In this study, we examined the advancement of information and communication technology and the principles of excellent teaching to encourage effective statistics education in the class. Throughout this study, we examined a new form of teaching and learning which occupies a major part of the education process. Finally, we presented the UIA model and the UIA-SE model for effective introductory statistics education. In addition, we also suggested some methods and frameworks for the use of UIA-SE model.

In this study, we sought answers that were related to the following research questions.

- How can the teacher understand all the student's background knowledge and comprehension in the class in real-time?
- How can the teacher make timely interactions with all the students?
- How can the teacher make activity-based learning with every student in the class simultaneous?

To solve the above research questions, we progressed through the following steps:

(1) We examined the aspects of the educational environment from the change in ICT. We also examined a common element with the use of ICT to improve education effect.

(2) We examined the teaching and learning methods to help student's learn effectively. In particular, we focused on the principles of excellent or good teaching, and summarized the common characteristics and principles.

(3) Based on the above study, we proposed new educational methods that considered ICT and the common principles of excellent teaching. Finally, we present a teaching and learning model (UIA model) that is related to the following topics:

- Real-time understanding of students' comprehension
- Timely interaction
- Simultaneous activity-based learning

(4) For effective introductory statistics education, we proposed a new educational model based on the UIA-model in the previous step. This model considers the characteristics of statistics education. We call this model the 'UIA-SE model'.

(5) We presented the design of general concepts and the framework of the Real-Time Statistics Education System (RT-SES). This system aims to apply the suggested methods to the class efficiently.

(6) We implemented the educational contents to an actual classroom class with the RT-SES. We investigated the comments and reactions of students. We also investigated whether the system and content was useful to the teacher.

7.2 Conclusions

Many students commented that the teaching and learning style, which is based on the UIA-SE model, was more helpful and interesting to their learning. Some students expressed that it helps to keep their concentration during the whole class. We also found that this model was useful to the teacher. Through real-time evaluation system and simple quizzes, we could monitor the understanding of student's comprehension easily. Also, we can improve student's participation and active learning in the classroom, because we can monitor every student's activities during the class.

In this thesis, we presented a new educational model that makes the real-time understanding of students, timely interaction and simultaneous activity-based learning possible. It could not be implemented in traditional instruction methods. In addition, we presented the framework of the methods to propose. We implemented the RT-SES and contents that included the function of real-time monitoring.

Nowadays, we can not help avoiding the use of ICT in the class. Therefore, it can no longer be a problem of whether to apply the practical use of ICT in the class. Now, we focus on "How do we apply it?" or "Which strategy do we use for the design of educational content and teaching and learning?"

In this study, we proposed a new model for effective statistics education. This model shifts from traditional instructional methods to more efficient and effective electronic methods that better suit everyone involved.

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