

# An IMS-QTI Compliant Multimedia Assessment Management System with SPC and Student Response Time to Analyze Learning Activities

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## Abstract

The purpose of this study is to develop a Multimedia Assessment Management System (MAMS) based on IMS-QTI architecture with interoperability. The MASM has been discussed based on IMS-QTI architecture for a long time, but it is not implemented yet so far. Through this architecture, it could easily integrate external functionalities without redeveloping the system. This MAMS system can record the students' response time of each item and use an integrated analyzing method of SPC (Student-Problem Chart) to analyze the students' response patterns. This study takes the exam results to analyze the students' response patterns and the items, calculates the indices for the students and the items, produces the students' diagnostic figure and the item diagnostic figure, then, integrates IRS to calculate the ordering coefficient of the items to produce the figures of the item relational structure for each group students. The results of this study show that different types of the students construct different concept structure because they have different item relational structure. The implication of this study can provide the instructor to conduct the teaching and prepare remedial materials for the students.

**Keywords:** IMS-QTI, Multimedia assessment management system, SPC.

## 1 Introduction

In e-learning environment, computer-based assessment provides a simulation for learners to understand what they have learned from instructors through various ways. Besides the advantages from digital resources, computer-based assessment could make review time shorter than traditional paper-and-pencil based test and reduce the mistakes that could happen when reviewing by human. IMS (IMS Global Learning Consortium) proposed a unified standard named QTI (Question and Test Interoperability) for computer-based assessment in 1999. It utilizes the XML (eXtensible Markup Language) to format the assessment content and users could easily share these content based on it. The IT (Information Technology) has developed more and more

robust as days go by. The integration between e-Learning and other technologies becomes no longer an assistant but a key point [26] for the last years; the research [2] pointed out that "The General Model of Instruction" consists of four elements in the basic teaching procedure: (1) objectives, (2) pre-assessment, (3) instruction, (4) evaluation, shown as the Figure 1. He especially emphasized the feedback and the positive function of evaluation in this book. From the model, the evaluation is not the last stop of teaching. Evaluation is used to analyze advantages and disadvantages of teaching as a basis of teaching guidance and individual remediation.

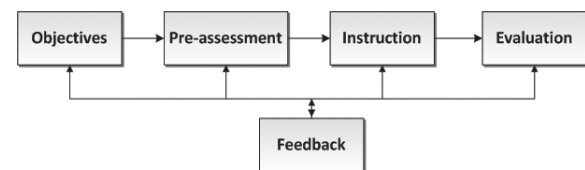


Figure 1 The General Model of Instruction

Due to evaluation as an important source of feedback from the students, an instructor may have some quizzes or examinations for the students before, during or after teaching. In traditional quiz, an instructor often use paper-and-pencil test before instead of computer-based or web-based assessments implemented popularly in every school and college [24]. This may because of un-accessible, un-reusable, non-uniform assessment system. In this study, a QTI based on-line assessment system is proposed. While traditional quiz cannot easily get much more details and meanings from these score, a graphical analysis method [5], Student-Problem Chart (SPC) developed by the research [12], to analyze the response patterns of each student. Each concept might consist of one or more items.

In this paper, an on-line multimedia assessment management system (MAMS) is proposed based on IMS Question and Test Interoperability specification (QTI) with sharable, reusable and format-unified among different platforms. Besides, this study applies Student-Problem Chart (SPC) and student response time. The purposes of this study are:

- (1) An MAMS, compliant with IMS-QTI with time-record mechanism is developed.
- (2) An empirical study was conducted while the SPC is design to get the indices of each student via using the diagnostic diagram of the students and the items.

The organization of this paper is shown in 6 sections as follows: Section 1 introduces the motivation and objective of this paper. Section 2 introduces the relevant works that widely used in the world. Research sample and research process are shown in Section 3. In Section 4, an analysis of the empirical results is conducted. MASM system interface is presented in Section 5. Finally, a brief conclusion and the future works are included in Section 6.

## 2 Related Work

### 2.1 The Development of SPC Table

Educational technologies were designed for diagnosing misconceptions held by students. Sato [7] developed the Student-Problem Chart (SP chart), which provides learning attitude hints for students and quality of test items for instructors. Other researchers have proposed new methods based on the SP chart [1]. undertook a survey with the following contributions: (1) the class-based analysis unit of the SP chart; (2) the diagnosis of students' learning outcome with respect to the SP chart; (3) the diagnosis of test item quality according to the SP chart; (4) the forecast of students' placement; (5) facilitation of the learning analysis and testing the test quality of the related subjects of test bank, and (6) a blend tool for constructing the web-based test. [3] presented an SP model to incorporate the response time, the difficulty index and the discriminatory index of each test item.

To improve the original SP table, the research [13] developed the Student-Problem-Course (SPC) table to analyze the relations among students, problems, and courses. The SPC table integrates the SP table with course information to provide three aspect domains, namely course-problem (CP), student-problem (SP), and course-student (CS) [25]. The SP domain is the same as the SP table, which stores the relationship between learners and questions. The CP domain records the relationship between courses and questions. The CS domain presents the relationship between learner and course.

The research [8] designed a rule space model for diagnosing the abstract sources of misconceptions among students. Many investigations have applied the rule-space model in different research. The research [4] proposed a rule space model for cognitive analysis of math learning behavior among students, and employed their model to measure knowledge of Algebra among students. A 32-item test was performed on 231 eighth and ninth graders.

The rule space model classifies examination candidates by their level of knowledge. The research [9] developed a modification to the diagnostic classification procedure of the rule space model. The underlying cognitive model of generalized problem-solving skills can be performed to determine the comprehensive set of knowledge states for examinee classification. The research [10] applied the rule space model in a semantically-rich domain (Architecture knowledge) with three attributes, namely (1) understanding, (2) solving, and (3) checking. Understanding comprises processes for building an initial representation of an item. Solving consists of processes, goals, and actions performed based on the goals. Checking whether the goals have been attempted and satisfied.

### 2.2 IMS Question and Test Interoperability Specification (QTI)

More and more groups or organizations, no matter in Taiwan or other countries, try to establish on-line learning or assessment system to enhance the facility of learning and assessment. It is a good trend and prospect, but most of these systems have their own formats, it means that the items and the assessments cannot be reusable or sharable on the different platforms. In order to solve this problem, some organizations start to formulate standards to let the system builders to adopt.

Instructional Management System Global Learning Consortium (IMS GLC, 2001) [5] is a non-profit collaboration among the world's leading educational technology suppliers, content providers, educational institutions, school districts, and government organizations dedicated to improving education and learning through the strategic application of technology. Their main activity is to develop interoperability standards and adoption practice standards for distributed learning, some of which like QTI and Content Packaging are very widely used.

In an overview of Question and Test Interoperability specification (QTI) (IMS GLC, 2002), the IMS QTI specification describes a basic structure for the representation of question (item) and test (assessment) data and their corresponding results reports. Therefore, the specification enables the exchange of this item, assessment and results data between Learning Management Systems, as well as content authors and, content libraries and collections. The IMS QTI specification is defined in XML to promote the widest possible adoption. XML is a powerful, flexible, industry standard markup language used to encode data models for Internet-enabled and distributed applications. The IMS QTI specification is extensible to permit immediate adoption, even in specialized or proprietary systems. Leading suppliers and consumers of learning products, services and content contributed time

and expertise to produce this final specification. The IMS QTI specification, like all IMS specifications, does not limit product designs by specifying user interfaces, pedagogical paradigms, or establishing technology or policies that constrain innovation, interoperability, or reuse. QTI version 1.2 is most widely used, which was finalized in 2002. Version 2.0 was released in 2005; the IMS GLC withdrew QTI 2.1 in 2009, and QTI 2.1 is still a public draft so far [6].

**2.3 Students’ Response Time**

The research [17] discussed about the online assessment behavior of students in university of Louisville with the course ECE 2002 Network Analysis I, the online behavior of the students was monitor using web-based parameter-passing strategies [21] and cookies and they found that most of students repeated the tutorials a sufficient number of time to get perfect scores, on the other hand, students have more opportunity to repeated tutorials for additional practices [22]. In anecdotal reports, students praise the effectiveness of the online tutorials and rate them highly as an efficient component of their learning.

The research [16], want to reduce the workload of teachers and to improve the effectiveness of face-to-face courses, it is desirable to supplement them with Web-based tools, and also presents the approach for supporting computer science education with software components which support the creation, management, submission, and assessment of assignments and tests, including the automatic assessment of programming exercises. This components includes Lls Multiple Choice, EC Assignment Box, EC Auto Assessment Box and which extend a general purpose CMS with educational content types for tests.

The research [15], presents a novel methodology for modeling collaborative learning as multi-issue agent negotiation using fuzzy constraints. Agent negotiation is an iterative process through which the proposed methodology can aggregate students’ marking to reduce personal bias. In the framework, students define individual fuzzy membership functions [23] based on their evaluation concepts and agents stand for students to negotiate with each other in the assessment process, and they have an example application to negotiate the assessment among three students is provided to illustrate the assessment process of the framework.

The research [14] proposed an issue that how to perform the learning performance assessment in the web-based learning field, and proposes a learning performance assessment approach which combines four computational intelligence theories including grey relational analysis, K-means clustering method, fuzzy association rule mining and fuzzy inference to perform this task based

on the learning portfolio of individual learner, and the experimental results indicate that the evaluation result of proposed method is positive relevance with those of summative assessment.

**2.4 Item Relational Structure (IRS)**

Ordering theory [8][17] discovered the hierarchical relationships and structure of the items and instructional units. The researches [9][18] proposed a new method which called Item Relational Structure (IRS) to calculate the ordering coefficient of the items by extending and modifying ordering theory. IRS was used in analyzing dichotomous items. The research [18] adopted Takeya’s IRS to examine the item relationship of fraction problems and they found 16 chains of the items that had discernibly common features. The research [19] compared ordering theory [8] and an extended research, item relational structure, analysis by the research [20]. IRS is suitable for dichotomous items. It bases on the response data and calculates the precondition and the ordering hierarchical relationship of the items. After getting the relational structural diagram, the teacher can know the cognitive condition of the students and the items. Take dichotomous item *i* and item *j* for instance, as shown in following Table 1. The correct answer is represented with 1, and the wrong answer is represented with 0. According to the table 2.5, there are four response patterns: (1, 1), (1, 0), (0, 1), (0, 0).  $Q_{1*}$  is the ratio of answering item *i* correct;  $Q_{0*}$  is the ratio of answering item *i* wrong.  $Q_{*1}$  is the ratio of answering item *j* correct;  $Q_{*0}$  is the ratio of answering item *j* wrong. The pattern (0, 1) is an inaccurate pattern and cannot satisfy that the item *i* is the precondition of item *j*.

Table 1 The Ratio of Examinees between Item *i* and Item *j*

		Item <i>j</i>		Total
		1	0	
Item <i>i</i>	1	$Q_{11}$	$Q_{10}$	$Q_{1*}$
	0	$Q_{01}$	$Q_{00}$	$Q_{0*}$
Total		$Q_{*1}$	$Q_{*0}$	$1 = Q_{11} + Q_{10} + Q_{01} + Q_{00}$

**3 Research Methods And Research Process**

**3.1 Student-Problem Chart (SPC)**

Traditional paper-pencil test cannot identify what is problem for each student while students attaining the same score might have different misconceptions in their mind. SPC is used to analyze students’ response pattern which is the vector formed with the original responses of each item in a test. SPC uses indexed data as diagnosis to analyze whether the students’ response patterns of the assessment

items are unusual or aberrant. The brief frame of SPC is shown in Figure 2.

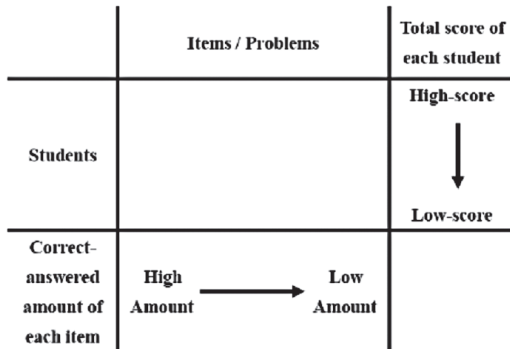


Figure 2 The Brief Frame of SPC

Common coefficient and indices of SPC are: (1) disparity index; (2) student caution index; and (3) item caution index. When using SPC, we have to calculate and analyze the caution indices for students and items. Using caution indices is to analyze whether response patterns of students and items are unusual or aberrant.

Caution index is the ratio of difference between the actual and the perfect response patterns to the perfect response pattern on anomalous condition. There are two caution indices, caution index for the items/ problems (CP) and caution index for the students (CS). In this study, the caution index for the items/ problems (CP) and caution index for the students (CS) are to make an analysis. The formula of item caution index is shown as below:

$$CP \text{ of item } j: cp_j = 1 - \frac{\sum_{i=1}^N (y_{ij})(y_i) - (y_j)(\mu)}{\sum_{i=1}^N y_i - (y_j)(\mu)} \quad (1)$$

$y_{ij}$  is the response condition of student  $i$  on item  $j$ .  $y_i$  is the total score of student  $i$ .  $y_j$  is correct-answered amount of item  $j$ .  $\mu$  is the average score of the students. The formula of student caution index is as below:

$$CS \text{ of student } i: cs_i = 1 - \frac{\sum_{j=1}^n (y_{ij})(y_j) - (y_i)(\mu')}{\sum_{j=1}^n y_j - (y_i)(\mu')} \quad (2)$$

$y_{ij}$  is the response condition of student  $i$  on item  $j$ .  $y_i$  is the total score of student  $i$ .  $y_j$  is correct-answered amount of item  $j$ .  $\mu'$  is the average correct amount of the items. After calculating the caution indices for the items and the students, to analyze the value is to see the response patterns are normal or abnormal. If  $CS/CP = 0$ , that means it is a perfect response pattern; if  $CS/CP = 1$ , or approach to 1,

that means it is a random response pattern. The range of  $CS/CP$  is:  $0 \leq CS/CP \leq 1$ .

If  $0 \leq CP_j(CS_i) < 0.50$ , it means the item or the student is normal and in the range of admissible response errors. If  $0.50 \leq CP_j(CS_i) < 0.75$ , it means this is a serious aberrant response pattern of students or items, mark \* on the item or the student. If  $0.75 \leq CP_j(CS_i)$ , it means this is a very serious aberrant response pattern of students or items, mark \*\* on the item or the student. After getting the CP and CS, we can analyze the item and the student with diagnostic diagram of the items and the students which are shown as Figure 3 and Figure 4.

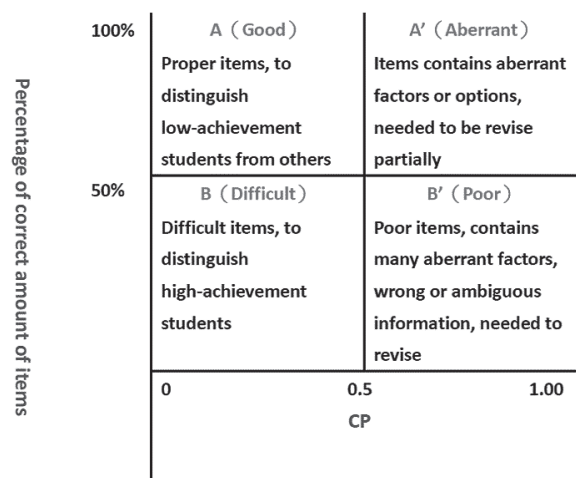


Figure 3 Diagnostic Diagram of the Items (CP)

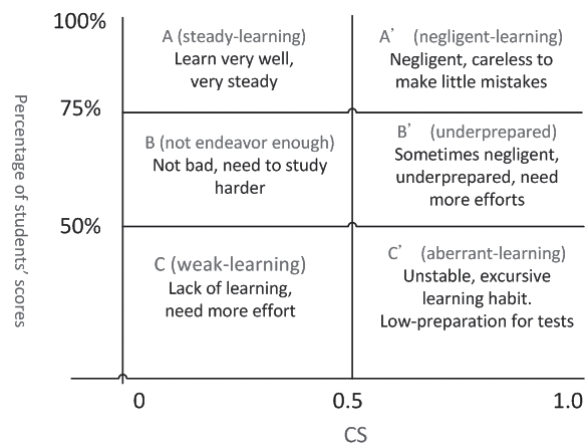


Figure 4 Diagnostic Diagram of the Students (CS)

With the diagnostic diagram, the detail situation of items and students will be realized. In this study, SPC methods are used to identify the detail situation of items and students. If we want to check the quality of assessment item in Figure 5, we can calculate the caution index for the items/problems (CP) and the percentage of correct amount of items. For example, if the percentage of correct amount of items are over 50% and the CP value of the items are between 0 and 0.5, such as item 2, item 3, item 4, item 9

in Figure 5. It indicates this items/problems is good and proper items that distinguish low-achievement students from others. Otherwise, as Figure 6, if we want to realize the learning situation of the students, we can calculate the percentage of student's score and caution index for the students (CS). And we can distribute student's learning situation into 6 blocks. For example, if a student has CS value equal to 0.6 and his percentage of exam score is 40% (such as student 14 in Figure 6), it indicates that the student is belong to c' type (aberrant learning) which is unstable and excursive learning habits. With previous methods, it can help both instructors and students on items situation and student's learning status. In this study, we use the SPC methods to complete our analysis.

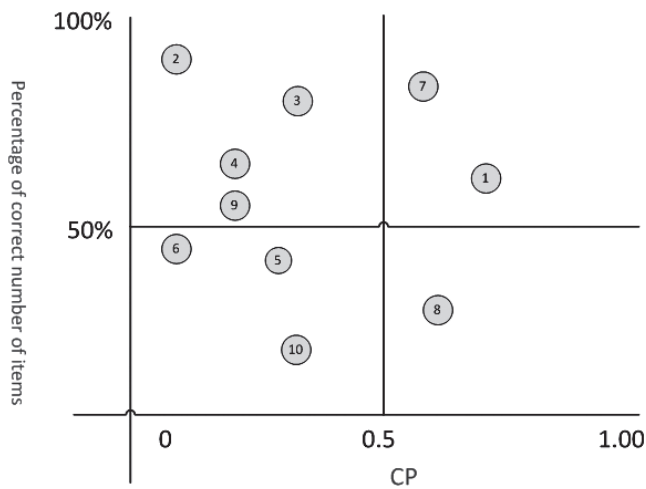


Figure 5 Sample of Item Diagnostic Figure (CP)

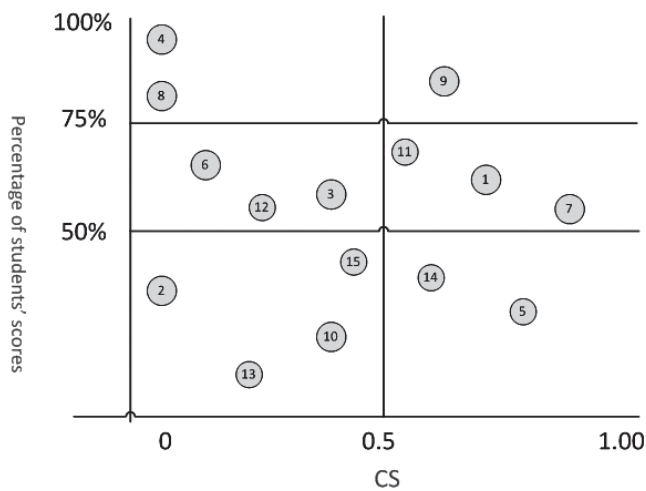


Figure 6 Sample of Student Diagnostic Figure (CS)

**3.2 Research Background and Research Tool**

The subjects of this study consist of 90 freshmen from a private university in Taiwan. Those 90 students are divided into two classes; class A has 40 students are from the department of banking and finance, and class

B has 50 students are from the department of business administration. Over 90% of subjects are freshman.

Most researchers took mathematics as their test subject, especially on fraction addition and subtraction items [9-11]. Basic information is also an important and extensively-learned subject, but fewer studies took this as main research purpose among SPC related studies. Maybe it is because the concepts and the contents of basic information are too complex and separated. Owing to the reasons above, this study chooses test subject on Introduction to Information Technology class.

In this study, 10 concepts are taken from 11 chapters of basic information topic and 32 assessment items are authored based on these materials. All these items are checked before testing by instructors and teaching assistants of the class. The concepts of the exam are shown as Table 2. These assessment items are authored and put to test on the assessment management system which we proposed before.

Table 2 The Concepts of the Exam

Chapter	Concept
2	Analog and digital signals
3	Computer hardware and software
4	Network classification
5	Understanding of knowledge management
6	Privacy and Intellectual Property Rights
7	Computer System Architecture
8	Computer media and devices
9	
10	Coded representation of computer system data
11	Understanding of computer operating systems
14	Database

**3.3 Research Process**

This study utilizes MAMS for the instructors and the students, integrates student-problem chart and item relational structure theory, and analyzes the structure of the students' concepts from the items for basic information topic. According to the research objective, the research process of this study is shown as Figure 7.

According to the research process, the data will be calculated with SPC method at first and the analyses from SPC will be shown too. Calculating with SPC method, we can get a matrix of students' response patterns, indices for students and items, diagnostic figures for students and items. If we have N students and n items, it will get a Nx n student-item matrix that can help instructors realize the situation between students and test items. And we define this matrix as C. C can be shown as below:

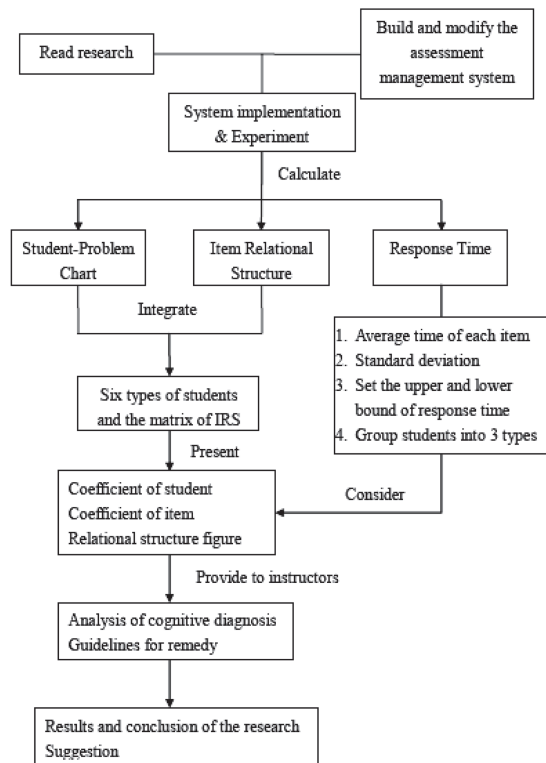


Figure 7 The Process of the Research

$$C = \begin{bmatrix} C_{11} & \dots & C_{1n} \\ \vdots & \ddots & \vdots \\ C_{N1} & \dots & C_{Nn} \end{bmatrix}_{N \times n} \quad (3)$$

If we order  $n$  items and  $M$  concepts into a  $n \times M$  item-concept matrix, and define this matrix as  $D$  which can help students and instructors the relationship between test items and concepts,  $D$  can be shown as below:

$$D = \begin{bmatrix} D_{11} & \dots & D_{1M} \\ \vdots & \ddots & \vdots \\ D_{n1} & \dots & D_{nM} \end{bmatrix}_{n \times M} \quad (4)$$

With IRS, the ordering coefficient  $r_{ij}^*$  of 32 items for Class A, Class B and the group types that come from SPC will be calculated. And the relationships among the items can be shown according to the ordering coefficient. We calculate all data with these matrixes by SPC and IRS on the assessment management system. All combined analyses of cognitive diagnoses and relational structure figures will be gotten.

After getting all combined analyses from integrated method of SPC and IRS, students' response time is also taken as consideration, and the compared results between these two parts will be shown to the instructor. About the students' response time, most of related research often discusses the correlation between response time and speed, speed and ability, item difficulty and time intensity, or

among item completion, responses and response time. But those factors are hard to explain the student's ability or understanding level from the students' response time and response pattern, because in real-world, speed and ability of a person is always fluctuated.

Owing to the reasons above, we considered response time and calculate the average response time, standard deviation of the students' response time. To give students more detail feedback, many variables need to be considered, such as response time, response pattern, item difficulty, item completion and so on. If we want to observe or calculate more accurately, some variables must be set or assumed constant. Hence, we assume that all the students have steady speed when they are testing, and require students have to complete all the items in a fixed time interval of 20 minutes. We also demonstrate how to use assessment management system before testing to reduce the unfamiliarity of the system. First, the average response time and the standard deviation of the response time for each item will be calculated. Second, the bounds for the groups need to be set.

$$\begin{aligned} & (\text{Average response time}) - (\text{standard deviation}) \\ & = \text{upper bound} \end{aligned}$$

$$\begin{aligned} & (\text{Average response time}) + (\text{standard deviation}) \\ & = \text{lower bound} \end{aligned}$$

Third, group the students into three types; if the student's response time of the item is less than the upper bound, this student belongs to A type; if the student's response time of the item is greater than the upper bound and less than the lower, this student belongs to B type; if the student's response time of the item is greater than the lower bound, this student belongs to C type. Fourth, compare the students' response time with the analyses of SPC.

## 4 Analyses of the Experiment Results

### 4.1 The Analyses from S-P Chart

The subject of this study consist of Class A and Class B. The former one has 40 students which from department of banking and finance. The later one has 50 students from department of business and administration. 10 concepts and designed 32 items is to test the students; this test is one of their midterm exams. After the assessment experiment, those data are sorted by the research process. At the first part, the original SPC of the experimental data is shown as Appendix 1 which is the response patterns of class A, and Appendix 2 is the response patterns of class B. When we have original response pattern matrixes, we have to consider the students' score and the correct answer rate to order the matrixes. After analyzing with SPC, we can get

the ordered matrixes as Appendix 1 and Appendix 2 with Red solid line (curve S) and blue dotted line (curve P). From the matrix, we can see that the score of the students in two classes are not low. In these two classes, 11 students have full score, many other students also have high score; about the half of the items also have high correct-answered rate; this may means that most students really studied hard and prepared well for this midterm exam.

Then calculating the CS of each student and CP of each item (the calculate methods was mentioned on Section 2), we can get the data as Appendix 3 and Appendix 4 in class A. CS can let us know that if the students' learning is normal or aberrant; CP can let us know that if the items are good or bad. At the Class A, 19 students are diagnosed as type A, these students are learning steadily and do not need to be worried. 8 students are diagnosed as type A', these students are also learning well but sometimes they may be negligent and make some little mistakes. 9 students are diagnosed as type B, these students do not endeavor enough and need to study harder. 4 students are diagnosed as type B', these students are sometimes negligent, unprepared and need more efforts. And there is no student that diagnosed as type C or C'. Figure 8 is the students' diagnostic figure for Class A; students' diagnostic figure takes the scoring rate and CS as two axes. On the Figure 8, the distribution of the students is more clearly.

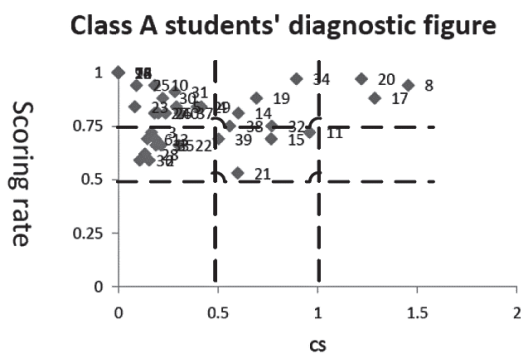


Figure 8 Students' Diagnostic Figure for Class A

From the analysis of the items for Class A, 19 items are diagnosed as type A, that means these items are good and proper items. And 13 items are diagnosed as type A', that means these items may contains some aberrant factors or options and can be revised partially. There is no item that diagnosed as type B or B'. Figure 9 is the item diagnostic figure for Class A; this figure takes correct answer rate and CP as axes. With this figure, we can realize the distribution of the items more clearly.

To calculating the CS of each student and CP of each item in class B, we can get the data as Appendix 5 and Appendix 6. At the Class B, 26 students are diagnosed as type A, these students are learning steadily and do not need

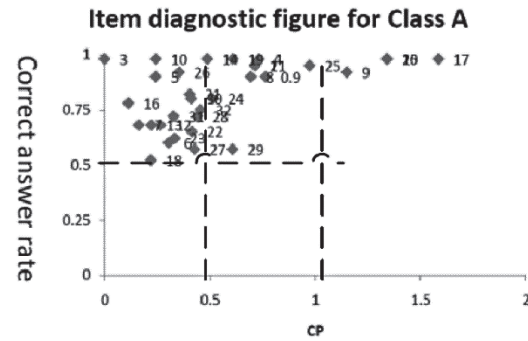


Figure 9 Item Diagnostic Figure for Class A

to be worried. 12 students are diagnosed as type A', these students are also learning well but sometimes they may be negligent and make some little mistakes. 9 students are diagnosed as type B, these students do not endeavor enough and need to study harder. 3 students are diagnosed as type B', these students are sometimes negligent, unprepared and need more efforts. And there is no student that diagnosed as type C or C'. Figure 10 is the students' diagnostic figure for Class B; students' diagnostic figure takes the scoring rate and CS as two axes. With the students' diagnostic figure we can realize the distribution of the students more clearly.

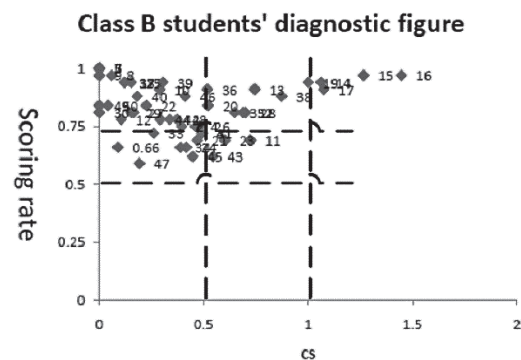


Figure 10 Students' Diagnostic Figure for Class B

From the analysis of the items for Class B, 15 items are diagnosed as type A, that means these items are good and proper items. And 17 items are diagnosed as type A', that means these items may contains some aberrant factors or options and can be revised partially. There is no item that diagnosed as type B or B'. Figure 11 is the item diagnostic figure for Class B; this figure takes correct answer rate and CP as axes. On the figure, we can realize the distribution of the items more clearly.

With the analysis for students and items, students have obvious improvement after the remedy. Such as the student diagnosed as type A, there are over 40% of student have improvement, and over 50% of type A' and Type B' students also have improvement. About the item design, professors and TA in this two class have identification on

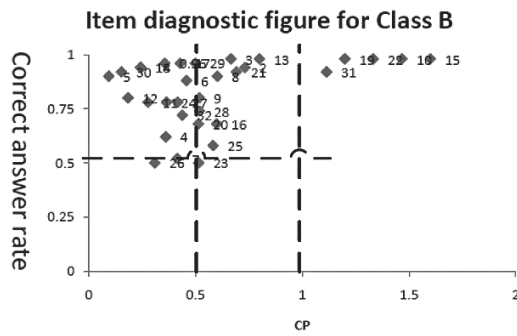


Figure 11 Item Diagnostic Figure for Class B

the analysis results for item design via the analysis of Item diagnostic.

#### 4.2 Students' Response Time

At this part, the average response time and the standard deviation of each item are calculated; the upper bound and lower bound of each item are set too. Appendix 7 and appendix 8 are the response time of each 32 items from Class A and Class B students. In the tables, the average response time, standard deviation, upper bound and lower bound are shown at the bottom of the tables. For each item, the average response time minuses standard deviation is the value of upper bound, and the average response time adds standard deviation is the value of lower bound.

According to the upper bound and lower bound which we discussed before, the students can be grouped into 3 types: type A, type B and type C. Type A means the student spend less time than other students on the item and the students in this type have the fastest response time for the item. Type B means the student spend normal time on the item and the number of the students in this type is the most. Type C means the student spend more time than other students on the item and the students in this type have the slowest response time for the item. In the Appendix 7 and Appendix 8, pink represents Type C, yellow represents Type A, and the others are Type B. From this table, we can clearly see that which type the student's response time is classified for each item, and we can count how many As, Bs and Cs each student gets.

Appendix 9 and Appendix 10 are the ordered results of number and percentage of response time type for Class A and Class B students. Class A and Class B students are classified into four types with SPC analyses (type A, type A', type B, type B'), so we ordered the students with different types which come from SPC and listed them at the left of the tables. This can easily compare the results of students' response time with the analyses of SPC. In the middle of table is the response time type, this shows the number of response time type, so the sum of response time type is 32; this can let us know how many As, Bs and Cs the student

gets from 32 items. Right side of the table is the percentage of response time type, this can let us know how many rate the student gets in three types from 32 items. Take Class A as description template, we can find that most Group A students have higher percentage in Type A and Type B of response time classification, this means students spend less or normal time on the most items. In the analyses of SPC, Group A students have steady and good learning condition, and they also get higher grades; compare to their response time, they also have faster speed on the items, this means they should be proficient at most items, in other words, they also should master most concepts that contained in these 32 items.

Group A' students in Class A, we can see that they have more percentage in Type A and Type B, but they also have some percentage in Type C; this means Group A' students spend some less or normal time on the items, but they also spend a little more time on some other items. In the analyses of SPC, Group A' students have good learning condition, but sometimes they are careless and may make some mistakes, they also can get good grades; compare to their response time, they have normal speed on the items, but they also have lower speed on some items. This means they should be proficient at most items, but they may not be good at some items, in other words, they also should master most concepts, but they are also careless or not good at some concepts.

Group B students in Class A, they have more percentage in Type B and Type C, this means they spend normal or more time on the items. In the analyses of SPC, Group B students do not endeavor enough, they get regular grades and they have to study harder; compare to their response time, they have normal speed on some items and lower speed on some other items. This means they should be proficient at some items, but they also may not be good at some items, in other words, they should master some concepts, but they are also not so good at some concepts.

Group B' students in Class A, they have higher percentage in Type B and Type C, this means they spend normal or more time on the items. In the analyses of SPC, Group B' students are unprepared and sometimes negligent, they get lower grades and they need more effort on their study; compare to their response time, they have normal speed on some items and lower speed on more items. This means they should be proficient at few items, and they may be not good at most items, in other words, they should master few concepts, and they are also not so good at some concepts, this may make them guess the answer on some items at which they are not proficient. There are no Type C and Type C' students in Class A, so we do not discuss the group of these two types here. The analyses of the response time for Class B students are almost the same as



Class A, the condition of Class B can refer to the result that discussed above.

## 5 System Interface

### 5.1 Item and Assessment Authoring Interface

Figure 12 is the item authoring interface, on the top of the page, six item types are listed. The instructor can choose the item type, and then type the title, the content, the tag, and the answer of the item; the instructor also can upload the media file, no matter the image, video or audio file. Figure 13 is the assessment authoring interface. At the right side, the instructor can type the assessment title, the author's name, and the description of the assessment. The instructor can search or choose the item type and the items from the left side, add these items to the assessment. The order of the items can be changed while click the item up or item down button. After submit the assessment, the instructor can distribute the score of each item at the score distribution interface.

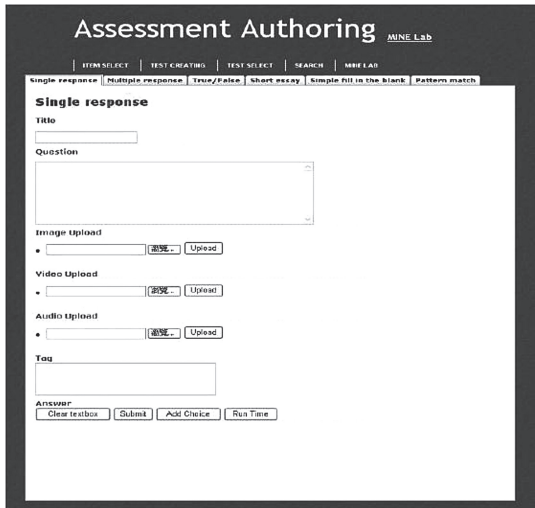


Figure 12 Item Authoring Interface

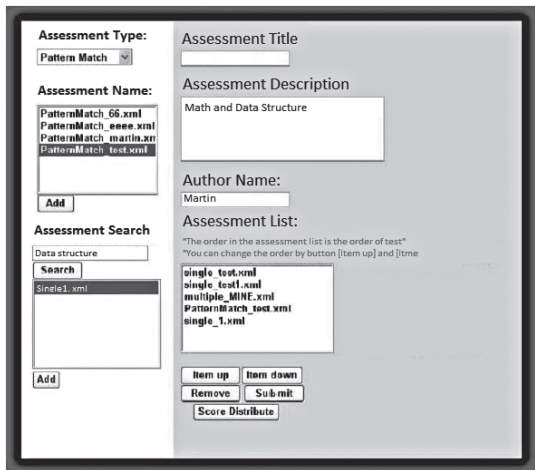


Figure 13 Assessment Authoring Interface

### 5.2 Students' Testing Interface

The interfaces of different item types are very similar, they all constitute with the content part, the answer part and the media file. All the item types, except the short essay, would give the score and the correct answer automatically after the student answering and the item and submitting. The answer of the short essay would be saved for the instructor to comment on and correct. Figure 14 is testing interface sample of a single response item. If there is a media file for the item, the media file would be displayed in the middle, and the image is displayed at the upper right side. After the student choosing the correct answer from the bottom and submitting it, the correct answer and the feedback are displayed at the right side. When the student finishes the test, the result of the test would be displayed. Figure 15 is the result interface sample of the test. The score of each item, the total score, and response time of each item are displayed on the page.

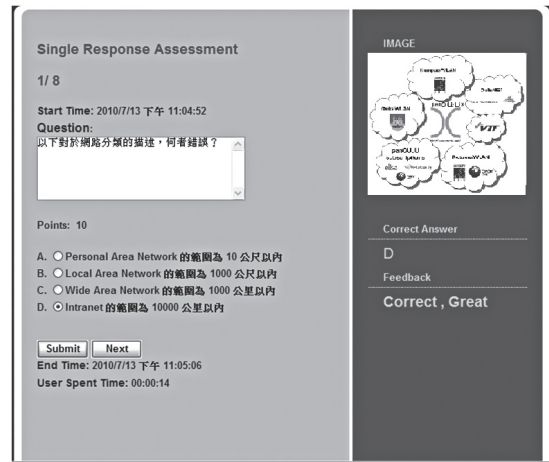


Figure 14 Testing Interface

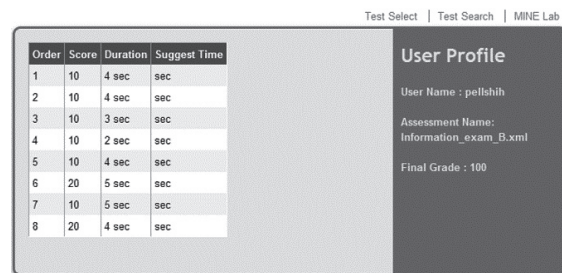


Figure 15 Result Interface of the Assessment

## 6 Conclusion and Future Works

In this study, we proposed a multimedia assessment system which integrated multimedia into assessment content. With the multimedia resources, instructors have more interaction with students, and the student feels more interest when taking exam. The MASM is based on IMS-QTI architecture with interoperability. The instructor and

the students used the MAMS in this study to take some experimental assessment, and then analyze the experimental data via using the method of SPC; the response time on each item of each student is also considered. This MAMS implements the idea and the research objectives we set at the beginning. The conclusion of this study consists of two parts: the system mechanisms, and analyzing method. To the analyzing method, it uses method of SPC and provides plentiful and multiple analyses for the instructor; comparing these analyses with each other can let the instructor know the students' performance about the subject, and speculate about the students' learning condition.

From the analyses results of the experimental examination, we found that there are complicated relational structures among these items. Especially, for the students of different types, the item relational structure is different; this means that different type students construct their cognitive knowledge with different ways. We can know how the students construct their concept for the items from the item relational structure figures, and this provides the information for the instructor to prepare the remedial teaching materials. In the field of educational testing and evaluation, many points and variables can be discussed and considered. From the performance of the exams, the instructor can identify what students are not so proficient beyond assessment results and the statistical analyses of the students. The invisible variables are still a big problem in the issues of educational testing and evaluation because these variables are hard to observe and record.

Therefore, we hope we can take these invisible but important variables as consideration, try to find a record way and an analyzing method for the students' behavior. If we take these variables as consideration and know how to evaluate and present with a statistical analysis, we may know and speculate the reasons that affect the students' learning. This would be more helpful for the instructor. Besides, let the students author the items and assessment is also a good idea, thus, the students can provide their ideas and items about the subject matters to the instructor; on the other hand, if the students can author the items by themselves, that means they have equivalent understanding for that concept. And we also may add the students' learning portfolio into the system, thus, all the learning processes and the testing results can be recorded and saved more completely, the learning schedule and condition can be easily controlled by the instructor or the students themselves. For the further analysis work, our research will include the student response time, we believe the similar score but different response time for student may indicates totally different learning situation for each student. With the response time, we can analyze the testing status, and give different feedback

## Acknowledgements

Pell Shih, former master student in National Taipei University of Education, we sincerely appreciate her effort on data collecting and experiment. Without her, we don't have this complete research results.

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### Appendix 5 The Ordering Coefficient of 32 Items for Class B

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	-	-0.064	-0.02	0.194	0.444	0.432	1	0.444	-0.25	-0.02	0.359	1	-0.02	-0.064	-0.02	-0.471	0.479	0.468	-0.02	-0.471	0.457	-0.02	0	-0.282	0.138	1	0.359	-0.351	-0.042	0.457	-0.087	-0.389
2	-0.042	-	-0.02	0.462	0.259	-0.136	0.359	-0.111	0.583	-0.02	0.145	0.167	-0.02	0.291	-0.02	0.02	-0.042	-0.064	-0.02	-0.471	-0.087	-0.02	0.333	-0.282	-0.149	0.333	0.145	0.099	-0.042	-0.087	0.275	-0.389
3	-0.042	-0.064	-	-0.613	-0.111	1	-0.923	-0.111	-0.25	-0.02	-0.282	-0.25	-0.02	-0.064	-0.02	-0.471	-0.042	-0.064	-0.02	1	-0.087	-0.02	1	-0.282	1	1	1	1	-0.042	-0.087	-0.087	-0.389
4	0.013	0.048	-0.02	-	0.123	0.043	0.494	0.006	0.079	-0.02	0.258	0.276	-0.02	0.104	-0.02	0.071	0.013	-0.008	-0.02	0.149	-0.03	-0.02	0.263	0.123	0.183	0.368	0.123	0.075	-0.042	0.085	0.027	0.123
5	0.167	0.149	-0.02	0.677	-	0.091	0.615	-0.111	0.25	-0.02	1	0.5	-0.02	0.149	-0.02	0.412	0.167	0.149	-0.02	0.118	0.13	-0.02	-0.2	0.487	0.189	0.487	0.189	0.189	-0.042	0.348	-0.087	0.167
6	0.132	-0.064	0.15	0.194	0.074	-	0.038	0.074	0.375	-0.02	0.145	0.375	-0.02	-0.064	-0.02	-0.225	-0.042	0.113	-0.02	0.265	0.094	-0.02	0.333	0.359	0.425	0.333	0.573	0.324	-0.042	-0.087	-0.087	-0.157
7	0.045	0.025	-0.02	0.328	0.074	0.006	-	0.028	0.01	-0.02	0.145	0.115	-0.02	0.069	-0.02	0.081	0.045	0.069	-0.02	-0.042	0.049	-0.02	0.417	0.038	0.138	0.417	0.092	-0.126	0.045	0.094	0.004	0.016
8	0.167	-0.064	-0.02	0.032	-0.111	0.091	0.231	-	-0.25	-0.02	-0.026	0.25	-0.02	-0.064	-0.02	0.412	-0.042	0.149	-0.02	0.706	0.348	0.184	0.6	-0.282	-0.034	0.6	-0.282	-0.081	-0.042	-0.087	-0.087	0.444
9	-0.042	0.149	-0.02	0.194	0.111	0.205	0.038	-0.111	-	-0.02	0.103	0.25	-0.02	0.149	-0.02	0.412	-0.042	-0.064	-0.02	0.118	-0.087	-0.02	0	0.359	-0.207	0	0.231	0.459	0.062	0.022	-0.087	0.306
10	-0.042	-0.064	-0.02	-0.613	-0.111	-0.136	-0.923	-0.111	-0.25	-	-0.282	-0.25	-0.02	-0.064	-0.02	-0.471	-0.042	-0.064	-0.02	1	-0.087	-0.02	-1	-0.282	-0.724	-1	-0.282	-0.351	-0.042	-0.087	-0.087	-0.389
11	0.053	0.033	-0.02	0.56	0.394	0.07	0.476	-0.01	0.091	-0.02	-	0.432	-0.02	0.13	-0.02	0.198	0.053	0.13	-0.02	0.064	0.012	-0.02	0.091	0.417	-0.097	0.273	0.301	0.263	-0.042	0.209	-0.087	0.242
12	0.167	0.043	-0.02	0.677	0.222	0.205	0.423	0.111	0.25	-0.02	0.487	-	-0.02	0.149	-0.02	-0.029	0.062	0.149	-0.02	0.265	0.022	-0.02	0	0.359	0.138	0.2	0.487	0.189	-0.042	0.239	-0.087	0.306
13	-0.042	-0.064	-0.02	-0.613	-0.111	-0.136	-0.923	-0.111	-0.25	-0.02	-0.282	-0.25	-0.02	-0.064	-0.02	1	-0.042	-0.064	-0.02	1	-0.087	-0.02	1	-0.282	1	1	-0.282	1	-0.042	-0.087	-0.087	-0.389
15	-0.042	-0.064	-0.02	-0.613	-0.111	-0.136	-0.923	-0.111	-0.25	-0.02	-0.282	-0.25	-0.02	-0.064	-	-0.471	-0.042	-0.064	-0.02	-0.471	-0.087	-0.02	-1	-0.282	-0.724	-1	-0.282	-0.351	-0.042	-0.087	-0.087	-0.389
16	-0.042	0.003	-0.02	0.093	0.097	-0.065	0.159	0.097	0.219	-0.02	0.119	-0.016	0.043	0.069	-0.02	-	0.023	0.003	0.043	0.173	0.049	-0.02	0	0.038	-0.078	0.25	-0.122	0.24	0.023	-0.087	-0.019	0.306
17	0.479	-0.064	-0.02	0.194	0.444	-0.136	1	-0.111	-0.25	-0.02	0.359	0.375	-0.02	-0.064	-0.02	0.265	-	-0.064	-0.02	-0.471	-0.087	-0.02	-1	0.359	0.138	1	1	-0.351	0.479	0.457	-0.087	0.306
18	0.306	-0.064	-0.02	-0.075	0.259	0.242	1	0.259	-0.25	-0.02	0.573	0.583	-0.02	0.291	-0.02	0.02	-0.042	-	-0.02	0.02	0.638	-0.02	1	0.573	0.425	0.333	-0.282	0.099	-0.042	0.275	-0.087	0.074
19	-0.042	-0.064	-0.02	-0.613	-0.111	-0.136	-0.923	-0.111	-0.25	-0.02	-0.282	-0.25	-0.02	-0.064	-0.02	1	-0.042	-0.064	-	-0.471	-0.087	-0.02	-1	-0.282	1	-1	-0.282	-0.351	-0.042	-0.087	1	-0.389
20	-0.042	-0.064	0.043	0.194	0.028	0.077	-0.082	0.167	0.063	0.043	0.038	0.141	0.043	0.003	-0.02	0.173	-0.042	0.003	-0.02	-	-0.019	0.043	0.25	0.038	0.461	0.375	-0.042	0.24	-0.042	0.049	-0.087	0.219
21	0.219	-0.064	-0.02	-0.21	0.167	0.148	0.519	0.444	-0.25	-0.02	0.038	0.063	-0.02	-0.064	-0.02	0.265	-0.042	0.468	-0.02	-0.103	-	-0.02	0.5	0.038	-0.293	0.5	-0.282	-0.351	-0.042	-0.087	-0.087	0.306
22	-0.042	-0.064	-0.02	-0.613	-0.111	-0.136	-0.923	1	-0.25	-0.02	-0.282	-0.25	-0.02	-0.064	-0.02	-0.471	-0.042	-0.064	-0.02	1	-0.087	-	-1	-0.282	-0.724	-1	-0.282	-0.351	-0.042	-0.087	-0.087	-0.389
23	0	0.021	0.02	0.161	-0.022	0.045	0.385	0.067	0	-0.02	0.026	0	0.02	0.021	-0.02	0	-0.042	0.064	-0.02	0.118	0.043	-0.02	-	-0.026	0.241	0.36	0.026	0.081	0	0.043	0	0.056
24	-0.042	-0.064	-0.02	0.267	0.192	0.174	0.126	-0.111	0.318	-0.02	0.417	0.318	-0.02	0.033	-0.02	0.064	0.053	0.13	-0.02	0.064	0.012	-0.02	-0.091	-	0.06	0.091	0.417	0.14	0.148	0.209	0.012	0.495
25	0.008	-0.013	0.028	0.155	-0.005	0.08	0.176	-0.005	-0.071	-0.02	-0.038	0.048	0.028	-0.013	-0.02	-0.05	0.008	0.037	0.028	0.3	-0.035	-0.02	0.333	0.023	-	0.524	-0.038	0.035	0.008	0.017	0.068	0.008
26	0.042	0.021	0.02	0.226	0.111	0.045	0.385	0.067	0	-0.02	0.077	0.05	0.02	-0.021	-0.02	0.118	0.042	0.021	-0.02	0.176	0.043	-0.02	0.36	0.036	0.379	-	0.077	0.081	0.042	0.043	0	0.111
27	0.053	0.033	0.072	0.267	0.192	0.277	0.301	-0.111	0.205	-0.02	0.301	0.432	-0.02	0.033	-0.02	-0.203	0.148	-0.064	-0.02	-0.07	-0.087	-0.02	0.091	0.417	-0.097	0.273	-	0.14	0.148	0.209	-0.087	0.242
28	-0.042	0.018	0.058	0.132	0.06	0.126	-0.331	-0.026	0.327	-0.02	0.211	0.135	0.058	0.182	-0.02	0.321	-0.042	0.018	-0.02	0.321	-0.087	-0.02	0.231	0.112	0.072	0.231	0.112	-	-0.042	-0.003	-0.087	0.252
29	-0.042	-0.064	-0.02	-0.613	-0.111	-0.136	1	-0.111	0.375	-0.02	-0.282	-0.25	-0.02	-0.064	-0.02	0.265	0.479	-0.064	-0.02	-0.471	-0.087	-0.02	0	1	0.138	1	1	-0.351	-	0.457	-0.087	1
30	0.219	-0.064	-0.02	0.597	0.444	-0.136	1	-0.111	0.063	-0.02	0.679	0.688	-0.02	0.202	-0.02	-0.471	0.219	0.202	-0.02	0.265	-0.087	-0.02	0.5	0.679	0.138	0.5	0.679	-0.014	0.219	-	-0.087	0.306
31	-0.042	0.202	-0.02	0.194	-0.111	-0.136	0.038	-0.111	-0.25	-0.02	-0.282	-0.25	-0.02	-0.064	-0.02	-0.103	-0.042	-0.064	0.235	-0.471	-0.087	-0.02	0	0.038	0.569	0	-0.282	-0.351	-0.042	-0.087	-	-0.389
32	-0.042	-0.064	-0.02	0.194	0.048	-0.055	0.038	0.127	0.196	-0.02	0.176	0.196	-0.02	0.012	-0.02	0.37	0.033	0.012	-0.02	0.265	0.068	-0.02	0.143	0.359	0.015	0.286	0.176	0.228	0.107	0.068	-0.087	-

### Appendix 6 The Ordering Coefficient of 32 Items for Class B with Threshold 0.5

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32			
1	-	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0			
2	0	-	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
3	0	0	-	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	1	0	0	0			
4	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
5	0	0	0	1	-	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0			
6	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0			
7	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
8	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0			
9	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
10	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0			
11	0	0	0	1	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
12	0	0	0	1	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
13	0	0	0	0	0	0	0	0	0	0	0	0	-	0	1	0	0	0	1	0	0	1	0	1	1	1	0	1	0	0	0	0			
14	0	0	0	1	0	0	1	0	1	1	0	-	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0			
15	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
17	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0			
18	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	-	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0			
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	-	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0		
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0		
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	1	0	0	1	0	0	0	0	0	0			
22	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-	0	0	0	0	0	0	0	0	0	0			
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0			
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0			
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1	0	0	0	0	0	0			
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0			
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0			
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0			
29	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	-	0	0	1		
30	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	-	0	0	
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-	0	0	
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0

### Appendix 7 The Response Time of Each 32 Items from Class A Students

S\T	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27	T28	T29	T30	T31	T32
1	17	15	21	18	11	19	10	15	14	10	13	11	10	8	13	12	14	15	9	11	10	12	18	17	14	16	14	10	17	18	18	14
2	18	16	15	19	19	20	18	13	15	11	18	8	15	19	15	16	14	17	15	14	11	19	14	17	18	15	18	17	19	18	14	16
3	15	19	20	19	19	23	19	15	17	9	19	16	17	17	16	19	18	20	18	18	19	17	12	15	16	17	12	18	14	11	17	14
4	19	15	18	11	19	18	13	8	15	10	10	11	15	9	15	15	17	17	15	11	15	16	13	16	12	16	12	14	15	16	13	17
5	12	17	19	18	10	13	12	17	11	12	14	17	17	11	15	14	15	17	19	18	18	18	14	18	17	16	17	15	14	16	17	17
6	11	20	11	7	20	20	13	11	17	16	17	19	11	7	16	15	17	18	18	19	19	18	15	19	16	14	13	16	18	14	18	14
7	18	11	19	18	17	18	11	18	13	14	16	16	12	18	17	12	13	15	17	18	15	14	18	15	10	13	18	12	15	12	11	13
8	12	21	18	11	16	15	12	19	18	15	9	13	18	16	14	17	14	16	16	13	17	14	17	14	13	17	18	15	8	17	11	11
9	17	19	19	18	11	14	15	16	17	13	14	15	17	11	18	17	16	15	17	18	16	17	11	14	14	16	15	17	17	12	13	12
10	19	18	18	17	18	15	17	17	16	16	16	11	13	17	18	15	17	17	18	14	13	13	16	17	17	16	17	15	15	17	15	13
11	18	20	19	19	19	14	17	17	14	15	18	19	17	19	19	18	19	17	14	17	18	17	20	18	17	18	18	19	16	18	19	17
12	19	18	18	15	19	13	15	18	13	14	11	15	17	17	17	16	15	14	18	10	16	17	14	17	12	16	12	11	15	14	16	12
13	15	14	15	13	14	16	14	19	17	11	15	17	18	16	18	16	18	16	14	17	15	18	15	14	12	18	18	7	13	19	14	18
14	9	15	15	15	18	12	11	18	16	13	17	12	14	16	13	17	15	13	16	15	14	14	12	17	13	12	15	16	10	12	16	15
15	17	19	20	13	16	15	16	17	17	14	17	13	16	17	14	18	17	15	16	16	19	17	15	15	16	18	14	17	14	18	15	14
16	8	19	18	13	8	13	16	11	15	16	17	17	7	16	15	17	13	16	17	17	15	18	14	13	14	8	13	11	12	10	11	14
17	18	11	15	15	17	12	14	15	17	14	18	15	14	17	18	17	15	14	16	17	16	12	18	12	15	19	15	8	13	16	10	17
18	19	19	13	17	16	14	12	17	15	11	16	15	14	16	16	14	14	15	17	17	13	18	18	14	12	17	16	15	15	14	13	12
19	19	14	11	16	16	15	19	15	16	12	17	14	15	18	14	13	12	14	11	16	13	8	8	10	8	11	13	18	13	12	8	9
20	19	11	11	12	15	14	17	17	19	18	18	15	16	14	17	15	14	10	19	18	17	14	16	18	14	16	15	17	16	19	14	17
21	19	16	23	17	19	17	15	17	18	16	17	13	17	19	17	19	15	16	19	17	19	15	17	19	19	18	16	17	17	19	14	19
22	20	19	14	14	18	15	14	16	11	17	15	12	14	18	17	14	14	16	15	19	17	19	16	18	17	14	18	16	17	16	15	15
23	18	16	15	14	17	13	16	14	15	15	16	16	12	18	18	16	13	17	15	14	11	14	18	16	16	15	12	15	16	12	16	17
24	19	17	11	13	16	17	15	16	16	15	17	14	16	16	17	13	17	13	19	18	15	16	18	17	12	16	17	15	15	15	16	16
25	15	13	18	11	18	16	17	14	14	11	15	11	12	16	15	15	16	17	18	11	17	15	17	14	14	13	15	14	15	13	17	18
26	19	18	17	18	15	14	17	13	14	14	14	12	15	15	15	14	15	13	19	16	12	17	17	17	15	13	16	13	11	14	13	15
27	18	18	18	17	19	15	12	16	17	15	14	14	16	16	17	15	14	10	19	12	16	16	18	18	14	14	16	15	14	15	14	16
28	16	14	14	9	19	18	19	19	10	11	18	14	16	14	10	16	17	15	19	17	16	18	19	10	16	10	17	15	11	12	14	18
29	17	19	19	10	18	17	9	13	12	12	14	15	15	17	18	16	17	17	19	10	15	18	17	13	17	13	15	14	11	12	16	17
30	11	18	18	16	19	16	12	18	16	16	17	16	17	14	10	13	15	16	18	17	15	14	18	18	16	14	15	16	11	10	15	14
31	12	16	19	18	11	14	15	18	16	14	11	16	16	18	10	13	10	17	14	18	17	18	16	18	17	14	17	14	11	14	16	15
32	16	19	14	18	14	17	16	18	17	10	17	18	19	17	16	17	17	17	15	18	10	18	14	18	17	14	16	17	16	14	15	16
33	17	21	18	10	19	14	17	17	19	20	19	10	17	14	17	16	18	15	18	10	14	14	13	17	15	16	14	15	14	16	16	18
34	15	16	19	15	16	14	17	18	14	18	17	11	10	18	18	17	15	16	19	17	17	18	16	18	19	16	15	11	15	16	14	17
35	11	18	21	20	14	16	15	17	11	17	11	15	15	16	11	15	16	17	19	18	14	17	15	17	14	15	16	14	16	14	13	17
36	16	18	11	19	17	15	17	16	14	18	14	14	16	18	18	18	17	10	19	14	17	19	15	16	14	12	13	11	13	13	15	16
37	11	10	13	16	14	18	15	18	17	14	8	10	17	14	18	16	17	16	18	17	14	18	14	14	13	9	12	12	12	12	14	15
38	17	15	11	20	15	18	14	14	15	7	14	16	19	17	18	15	17	14	11	16	16	18	13	15	15	12	15	14	13	17	17	15
39	20	15	17	19	16	17	14	18	14	15	17	18	14	16	19	17	18	16	18	15	18	17	15	14	18	18	16	17	16	18	19	18
40	7	11	18	18	17	16	13	16	14	16	17	16	11	15	10	12	11	14	13	15	14	16	18	15	19	13	8	17	14	16	12	16
Average	15.825	16.45	16.52	15.4	16.22	15.75	14.75	15.97	15.15	13.87	15.3	14.25	14.92	15.62	15.67	15.5	15.4	15.32	16.6	15.57	15.32	16.15	15.55	15.8	14.92	14.7	15.05	14.5	14.17	14.77	14.6	15.35
SD	3.5365	2.943	3.242	3.357	2.877	2.372	2.508	2.423	2.201	2.830	2.747	2.628	2.654	2.879	2.615	1.867	2.035	2.116	2.529	2.697	2.421	2.359	2.459	2.266	2.474	2.574	2.229	2.726	2.363	2.596	2.405	2.213
Upper bound	12.288	13.50	13.28	12.04	13.34	13.37	12.24	13.55	12.94	11.04	12.55	11.62	12.27	12.74	13.05	13.63	13.36	13.20	14.07	12.87	12.90	13.79	13.09	13.53	12.45	12.12	12.82	11.77	11.81	12.17	12.19	13.13
Lower bound	19.361	19.39	19.76	18.75	19.10	18.12	17.25	18.39	17.35	16.70	18.04	16.87	17.57	18.50	18.29	17.36	17.43	17.44	19.12	18.27	17.74	18.50	18.00	18.06	17.39	17.27	17.27	17.22	16.53	17.37	17.00	17.56
	531	348	725	735	274	238	896	805	198	513	749	874	934	453	041	74	558	193	982	246	699	938	941	682	936	403	975	688	804	172	512	359

### Appendix 8 The Response Time of Each 32 Items from Class B Students

S\T	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27	T28	T29	T30	T31	T32
1	16	13	14	16	16	11	17	13	14	14	17	16	14	15	16	14	16	14	16	14	17	16	14	11	14	18	14	14	14	15	16	14
2	8	14	14	12	15	14	10	14	14	12	14	16	12	14	14	15	16	16	14	13	14	14	14	15	15	12	15	12	15	15	16	16
3	15	11	13	14	11	12	15	14	14	15	15	14	13	13	15	15	13	14	13	14	14	13	16	16	13	15	15	16	14	14	15	15
4	14	13	10	11	15	13	14	15	13	14	10	13	16	15	15	14	16	15	13	15	16	11	16	16	16	15	15	14	16	15	14	13
5	15	12	14	11	14	12	14	15	12	10	14	11	15	13	14	14	16	15	13	14	16	15	16	13	14	16	16	15	16	15	14	15
6	15	14	13	14	15	12	15	14	11	14	11	15	14	10	12	12	16	15	14	15	15	14	15	14	14	15	13	13	15	14	12	15
7	16	11	14	14	15	14	12	11	13	14	15	14	16	15	16	13	15	14	12	14	16	13	16	15	15	14	12	15	16	15	12	15
8	8	12	14	14	15	10	14	15	12	15	14	12	16	15	16	14	15	14	14	11	14	13	16	15	14	15	16	12	13	14	12	13
9	14	14	14	14	15	14	15	15	13	11	10	16	14	13	14	14	13	14	15	13	16	15	16	16	14	16	15	13	14	15	14	14
10	16	14	11	12	14	11	13	12	14	14	11	14	16	14	16	15	16	12	15	16	15	15	15	15	13	15	14	14	15	15	16	11
11	17	15	14	15	13	14	15	15	13	15	15	13	15	13	16	15	13	15	14	14	16	14	16	16	14	18	13	13	15	14	14	20
12	15	14	11	14	15	14	12	15	14	14	11	16	15	15	14	15	15	15	14	16	16	15	15	16	13	15	14	14	15	15	15	15
13	14	15	12	10	14	15	15	14	13	13	11	14	15	14	13	12	13	11	14	14	16	14	15	16	16	16	15	14	16	14	16	15
14	15	15	11	14	14	14	15	14	11	15	11	15	11	12	12	15	16	16	15	11	14	14	14	14	14	15	16	15	14	19	16	12
15	16	14	12	13	14	15	13	15	13	14	15	14	16	12	13	15	14	15	14	18	16	14	13	13	16	16	14	16	15	15	15	12
16	8	10	11	12	10	14	8	10	8	13	11	16	15	14	14	15	16	14	18	15	15	15	16	14	16	16	9	13	16	15	16	14
17	14	14	14	11	15	12	14	13	12	10	13	18	14	17	16	14	14	14	15	15	14	14	15	15	15	16	16	9	15	14	15	15
18	16	13	13	13	14	14	14	13	13	12	14	11	15	14	15	13	15	14	13	12	16	15	16	16	13	13	14	14	14	15	13	16
19	16	14	14	9	12	14	15	15	14	14	17	14	20	15	18	15	14	14	15	16	15	15	16	16	15	14	14	15	19	14	16	19
20	13	12	8	12	14	14	15	13	15	16	8	14	12	14	16	14	15	15	12	14	15	13	14	12	16	16	17	14	10	15	13	10
21	16	15	14	15	15	15	16	14	15	14	11	16	14	13	15	16	18	14	14	15	14	12	13	14	14	14	16	14	15	13	15	15
22	14	11	14	14	15	12	14	14	12	14	14	16	14	13	15	15	13	13	13	14	16	14	15	16	14	13	15	15	14	13	15	16
23	15	15	14	15	15	13	17	18	14	15	15	14	15	15	16	17	16	16	15	15	15	15	14	16	15	14	14	15	16	14	18	17
24	12	15	9	12	15	16	12	15	14	16	11	14	14	17	11	14	13	14	14	16	14	13	14	15	14	18	19	16	14	15	14	15
25	12	10	12	13	12	14	12	15	12	12	11	16	13	14	13	13	15	11	14	16	16	15	15	15	15	16	14	15	12	15	15	14
26	16	14	14	12	14	13	13	12	12	13	11	15	13	13	14	14	14	13	15	14	15	13	13	14	14	15	15	14	14	15	14	15
27	11	12	13	14	15	15	15	13	14	13	11	13	12	15	14	15	15	13	14	14	16	13	16	14	13	14	16	13	16	14	15	14
28	13	11	10	15	13	13	13	9	11	11	14	16	17	8	14	15	9	15	15	13	16	15	14	16	13	15	16	15	12	15	9	14
29	12	14	12	13	13	13	12	14	11	13	13	15	13	13	14	14	13	13	13	13	13	13	13	13	13	15	14	14	15	14	15	13
30	12	14	13	12	14	13	14	14	14	17	15	14	13	13	13	14	15	14	15	14	16	13	14	16	15	13	16	15	16	15	14	15
31	14	11	12	13	14	15	10	12	10	12	11	12	15	15	13	15	13	12	16	14	14	13	15	13	16	15	13	16	14	13	15	12
32	11	12	12	14	13	14	15	15	14	13	14	16	14	13	16	15	16	13	15	12	15	14	16	15	14	17	17	14	15	15	12	12
33	11	13	15	14	15	14	13	15	12	14	12	14	13	12	14	16	13	13	14	15	14	14	15	14	15	15	13	12	16	15	17	14
34	12	14	14	13	15	13	12	13	15	12	14	13	13	14	13	15	14	16	14	15	14	15	15	16	15	15	14	14	13	17	16	13
35	15	14	12	13	15	13	10	12	13	15	18	16	15	15	16	14	16	15	13	15	14	15	16	14	19	16	14	15	10	14	14	14
36	16	11	13	14	15	15	12	14	12	13	12	13	14	14	15	18	12	13	15	16	14	13	14	15	15	16	13	15	14	13	16	15
37	16	15	10	13	13	14	15	12	14	15	12	13	15	13	15	16	18	14	16	16	14	15	14	17	16	14	16	14	13	15	15	14
38	15	16	17	14	15	14	13	15	14	13	14	16	13	12	12	15	13	18	15	13	16	15	16	16	14	16	14	13	13	13	13	15
39	15	13	9	14	14	13	12	15	11	11	11	16	16	14	15	12	15	15	14	13	13	15	13	15	15	14	16	15	12	15	16	16
40	16	11	12	14	15	12	13	15	13	15	15	18	15	14	12	15	15	14	13	16	15	13	15	15	14	14	16	14	17	15	15	14
41	13	13	13	15	14	15	14	13	14	15	16	13	14	15	17	17	16	16	13	16	14	13	17	13	14	14	13	13	14	13	16	14
42	12	14	12	14	13	14	12	13	12	12	12	14	14	12	15	15	13	15	10	13	15	16	15	14	15	15	13	15	10	14	13	14
43	13	14	16	15	17	16	18	12	14	16	11	14	13	12	16	15	19	17	13	18	15	15	15	15	16	14	16	13	14	15	15	13
44	14	12	12	11	14	12	12	12	11	12	11	12	12	14	14	15	15	12	15	16	14	14	16	14	15	13	13	15	16	15	15	16
45	16	13	15	14	13	14	14	11	12	15	12	15	16	13	16	14	16	15	12	14	17	13	14	14	16	14	13	16	15	14	11	16
46	14	12	13	12	13	14	15	15	12	13	13	14	15	11	13	14	14	13	14	16	16	13	14	18	14	16	13	11	12	14	14	13
47	15	12	13	11	16	13	10	11	13	15	14	13	14	12	15	15	13	14	16	15	11	12	15	13	15	15	14	16	15	14	16	15
48	15	13	12	14	13	13	15	14	14	13	15	15	16	12	13	14	13	15	16	14	15	16	14	15	16	15	14	15	16	13	14	15
49	13	11	14	12	15	12	12	14	10	12	13	15	16	15	15	18	15	14	15	16	15	13	18	14	13	15	16	15	15	15	13	14
50	14	15	12	13	14	14	14	12	10	14	13	16	15	12	14	12	16	15	15	13	16	14	15	16	15	15	16	12	13	15	16	13
Average	13.88	13.08	12.68	13.14	14.14	13.48	13.48	13.56	12.7	13.54	12.92	14.46	14.44	13.54	14.46	14.6	14.66	14.18	14.16	14.52	14.94											

### Appendix 9 Number and Percentage of Response Time Type for Class A

SPC Type	Student No.	Response Time Type			Percentage of Response Time Type		
		A	B	C	A-%	B-%	C-%
Group A Students	2	5	26	1	15.625	81.25	3.125
	3	4	27	1	12.5	84.375	3.125
	4	4	27	1	12.5	84.375	3.125
	5	5	27	0	15.625	84.375	0
	6	6	26	0	18.75	81.25	0
	7	6	25	1	18.75	78.125	3.125
	8	6	25	1	18.75	78.125	3.125
	9	2	30	0	6.25	93.75	0
	10	4	27	1	12.5	84.375	3.125
	12	1	31	0	3.125	96.875	0
	18	5	27	0	15.625	84.375	0
	22	4	28	0	12.5	87.5	0
	25	5	27	0	15.625	84.375	0
	26	1	31	0	3.125	96.875	0
	27	3	28	1	9.375	87.5	3.125
	29	2	29	1	6.25	90.625	3.125
	30	1	30	1	3.125	93.75	3.125
	37	1	25	6	3.125	78.125	18.75
	39	7	25	0	21.875	78.125	0
	40	3	27	2	9.375	84.375	6.25
42	2	29	1	6.25	90.625	3.125	
44	7	25	0	21.875	78.125	0	
46	3	28	1	9.375	87.5	3.125	
48	1	30	1	3.125	93.75	3.125	
49	4	26	2	12.5	81.25	6.25	
50	3	28	1	9.375	87.5	3.125	
Group A' Students	13	3	26	3	9.375	81.25	9.375
	14	5	24	3	15.625	75	9.375
	15	3	25	4	9.375	78.125	12.5
	16	7	23	2	21.875	71.875	6.25
	17	4	25	3	12.5	78.125	9.375
	19	2	25	5	6.25	78.125	15.625
	20	7	20	5	21.875	62.5	15.625
	28	10	20	2	31.25	62.5	6.25
Group B Students	32	4	25	3	12.5	78.125	9.375
	35	2	27	3	6.25	84.375	9.375
	36	3	27	2	9.375	84.375	6.25
	38	2	27	3	6.25	84.375	9.375
	1	2	21	9	6.25	65.625	28.125
	21	2	23	7	6.25	71.875	21.875
	24	2	23	7	6.25	71.875	21.875
Group B' Students	31	8	20	4	25	62.5	12.5
	33	2	27	3	6.25	84.375	9.375
	34	0	29	3	0	90.625	9.375
	41	2	23	7	6.25	71.875	21.875
	45	3	24	5	9.375	75	15.625
	47	6	23	3	18.75	71.875	9.375
Group B' Students	11	0	26	6	0	81.25	18.75
	23	0	23	9	0	71.875	28.125
	43	0	21	11	0	65.625	34.375

### Appendix 10 Number and Percentage of Response Time Type for Class B

SPC Type	Student No.	Response Time Type			Percentage of Response Time Type		
		A	B	C	A-%	B-%	C-%
Group A Students	1	13	14	5	40.625	43.75	15.625
	4	10	22	0	31.25	68.75	0
	5	6	24	2	18.75	75	6.25
	7	9	22	1	28.125	68.75	3.125
	9	5	26	1	15.625	81.25	3.125
	10	3	29	0	9.375	90.625	0
	12	7	25	0	21.875	78.125	0
	16	11	20	1	34.375	62.5	3.125
	18	5	27	0	15.625	84.375	0
	23	6	26	0	18.75	81.25	0
	24	4	28	0	12.5	87.5	0
	25	6	25	1	18.75	78.125	3.125
	26	4	28	0	12.5	87.5	0
	27	3	29	0	9.375	90.625	0
	29	8	24	0	25	75	0
	30	6	26	0	18.75	81.25	0
	31	8	24	0	25	75	0
37	8	24	0	25	75	0	
40	9	22	1	28.125	68.75	3.125	
Group A' Students	8	7	20	5	21.875	62.5	15.625
	14	9	23	0	28.125	71.875	0
	17	6	25	1	18.75	78.125	3.125
	19	12	18	2	37.5	56.25	6.25
	20	4	25	3	12.5	78.125	9.375
	32	2	28	2	6.25	87.5	6.25
	34	3	27	2	9.375	84.375	6.25
	38	5	25	2	15.625	78.125	6.25
Group B Students	2	4	19	9	12.5	59.375	28.125
	3	4	18	10	12.5	56.25	31.25
	6	6	16	10	18.75	50	31.25
	13	4	20	8	12.5	62.5	25
	22	1	25	6	3.125	78.125	18.75
	28	8	20	4	25	62.5	12.5
	33	4	22	6	12.5	68.75	18.75
	35	4	25	3	12.5	78.125	9.375
36	4	24	4	12.5	75	12.5	
Group B' Students	11	1	17	14	3.125	53.125	43.75
	15	0	27	5	0	84.375	15.625
	21	0	21	11	0	65.625	34.375
	39	0	21	11	0	65.625	34.375