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Assessment with Using the Handheld Graphing Technology in Mathematics Classroom[1]

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In this paper, we discuss how to assess students' understanding of concepts during class, after class and in regular exams in the mathematics classes using the handheld graphing technology. We show some methods of assessment that are compatible with the class using the handheld graphing technology. These methods are adjustable to students' learning during class, homework after class or in regular exams. As a feedback of these methods we give students additional opportunity to understand concepts by giving additional concept provoking problems or giving additional help if necessary.

Keywords: assessment, handheld graphing technology, students' learning
ZDM classification: U54
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I. INTRODUCTION

Various efforts were attempted in mathematics class to stimulate students' interest in mathematics and application of mathematics to real world problems (*cf.* Dede 2000; Dede & Lewis 1995). One of them is the use of technology in mathematics class. Many teachers choose it for two reasons. One reason is that most of students are familiar with technology, so stimulating students' interest and studying several parts of mathematics are relatively easier. Another reason is the importance of technology in solving real world problems in mathematics class.

Several kinds of technologies are used in mathematics class, but we consider the use of the handheld graphing technology in mathematics class. We choose it because we think that the learning environment with the handheld graphing technology provides more interaction between students and teachers, and the process and result of students' understanding to teachers.

But, teachers using the handheld graphing technology have thought that classical methods of assessment are not compatible with their class. It is because the classical method of assessment has nothing to do with technology. Actually this is one of main reasons that why many teachers hesitate to use technology in their class. So, it is necessary that the assessment matched with their class be suggested. In this paper, we discuss following methods of assessment, practices of them and analysis of the results.

- How to assess students' understanding of concepts during class.
- How to assess students' understanding of concepts after class.
- How to assess students' understanding of concepts in regular exams.

II. ASSESSMENT IN UNDERSTANDING OF CONCEPTS DURING CLASS

We suggest three ways; analysis of worksheets, observation of students' activities, and analysis of saved files in the handheld graphing technology.

2.1. Analysis of worksheets

By analyzing students' worksheets, we can see students' understanding of concepts. For example, Figure 1[2] is the worksheet for finding the x-intercepts. Most students usually draw graphs and find intercepts with the handheld graphing technology in class.

[2] Worksheet used in Busan Electronic Technical High School (2001)

Not so many students approach this problem algebraically. This shows what teachers emphasized in class and the way students preferred. This also shows that students did not understand the relationship between quadratic functions and quadratic equations.

Figure 1. Worksheet of quadratic function

Figure 2. x-intercepts

2.2. Observation of class activities

The second method for understanding of concepts during class is to observe students' activities, especially the discussion with other students. We can recognize their activities either in a prepared checklist or as an overall opinion. In our study, we used items, although we know this is not perfect. The followings are the items we used.

- Showing willingness and endurance in learning
- Showing interests in discussion
- Showing skillfulness in using the handheld graphing technology
- Following the instruction carefully
- Communicating with fellow students
- Justifying their opinions
- Summarizing the content of discussing and applying it

The information on the list informs the teacher about students' abilities and attitude so that the teacher can adjust his/her teaching method in class.

2.3. Analysis of saved files in the handheld graphing technology

By analyzing the process of students' works using the saved files (the history of [HOME MODE], graph) we can get information about students' understanding of concepts.

For example, when it contains the above figure, then the students probably understand the effect of quadratic coefficients. Nowadays, the biggest difficulty for this method in Korea is that students do not possess the handheld graphing technology. So after one class use them, we have to erase the saved files before we use them in another class. So in

reality, we do not have enough time to check all saved files. Using TI-navigator, these barriers may disappear.

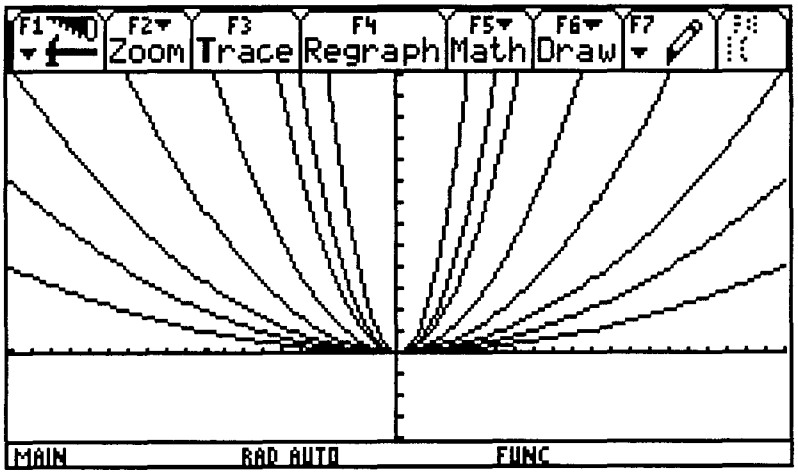


Figure 3. Graphs of quadratic functions (2001)

2.4. Meaning of doing assessment

Using information from worksheet to improve teacher's teaching method is much more important than giving marks on them. And if we use the results of these assessments for the adjustment of our teaching method, these are very useful. Thus we suggest under the current Korean circumstance to use these assessments not as ways to give grades to students, but as ways to get information to improve classroom teaching quality.

III. ASSESSMENT IN UNDERSTANDING OF CONCEPTS AFTER CLASS

The evaluation after class is mainly the homework. Homework varies from one-day homework to two week's team project. To assess students' understanding of concepts after class, we developed a standard of assessment. We also select the types of project so that we can see the level of students' understanding of concepts easily.

3.1. The standard of assessment for project

The standard of assessment for project is discussed in detail. We distinguish projects according to grade, area and pattern as in the following Table 1. On each grade and area, we develop various items we can use in school.

Table 1. Format of project

Grade	Area	Pattern		Time		Mark
		Form	Term			
7 8 9 10	Numbers and Operation Variables and Expressions involving variables Regularity and Function Probability and Statistics Geometry Measuring	Written Essay Observation Description/ Oral Project Journal	Diagnostic Formative Summative Performance	Short Middle Long	20 min 30 min 1 hour 2 hour 1 day 2 days 1 week	Assign to each item

The following Table 2 is the one we use to show which aspects of mathematical power and ability we want to access.

Table 2. Mathematical power and ability accessed

	Reasoning	Connections	Communications
Conceptual Understanding			
Procedural Knowledge			
Problem Solving			
Contents of Assessment			

For more detailed information about student's mathematical power and ability, analytical evaluation method is adopted. The following Table 3 is the one we use as standard of grading for problem. The category consists of nine areas appeared in Table 2.

Table 3. Analytic evaluating standard

Category	Level 1	Level 2	Level 3	Level 4
Category 1	Description of standard for this level	...	...	...
Category 2				
Category 3				

3. 2. Example of assessment for project

The following is an example used for project with the handheld graphing technology in grade 7. Table 4 is a part of standard of assessment for the following.

Project. *We often see 'direct proportion' and 'inverse proportion' in a newspaper. Read the following article and describe the concepts of direct/inverse proportions.*

It is direct proportion, ratio of entrance into a college and that of seeing education broadcasting.

City	Ratio of seeing education broadcasting	Ratio of studying at home for oneself	Ratio of entrance into a college
Seoul	11.6	62.1	58
Suwon	22.6	61.7	66
Busan	50.6	50.4	72
Gwangju	71.6	58.8	82

Figure 4. An example of project (2002)

Table 4. Suggestions for grading

Category	Level 1	Level 2	Level 3
Procedural Knowledge Communications	Drawing the graphs, but Cannot connect graph with concepts of direct/ inverse proportion	Drawing the graphs, and describe parts of relationship between the graphs and concepts of direct/ inverse proportion	Drawing the graphs, and describe perfectly relationship between the graphs and concepts of direct/ inverse proportion

By this analytical evaluating method, the detailed and specific information about students' conceptual understanding, procedural knowledge, and communication could be somewhat comprehensively grasped. We also could get information about students' abilities of expressing concepts in mathematical symbols, of using several representations of the handheld graphing technology, and of explaining what appeared in the handheld graphing technology.

3.3. Meaning of assessment of project

It is hard to expect that all students' understand mathematical concepts completely in the class. Individual student's ability in mathematics differs as well. From the information we can get by assessment of project, we can distinguish student's ability of understanding of concepts. So if we assign additional projects to students according to individual student's ability such as relatively deep meaningful problems to good or outstanding students, additional concepts provoking problems to poor or fair students,

and if we allow reasonably enough longer time to being needed students, then this can be additional opportunity for individual students to improve their understanding of concepts.

IV. ASSESSMENT IN UNDERSTANDING OF CONCEPTS IN REGULAR EXAMS

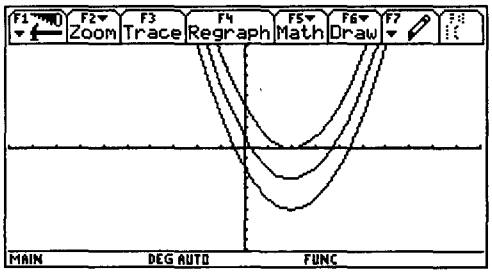
An important assessment in the school is regular exams in Korea. So if we use the handheld graphing technology in the class, then regular exams should contain problems that give information for the students' learning in that class.

We divide problems in regular exams into three areas; expressions of symbolic and terminology from arithmetic skill, procedure, setting and function from understanding and applying skill, and analysis, criticizing, applying and analyzing process.

4.1. Expressions of symbolic and terminology

We consider simple form of problems, which use the expression of figure, symbol and direction used in the handheld graphing technology. The following is an example[3] used in regular exam.

Problem. *The followings are three graphs of* $y = ax^2 + bx + c$ *appeared in Graph Mode. Choose right explanation.*



① *all* a *are different*
② *all* a *are same, but all* b *are different*
③ *all* c *are same*
④ *all* a *and all* b *are same respectively, but all* c *are different*
⑤ *all* a, b, c *are different respectively*

Figure 5. Example of regular exam (2002)

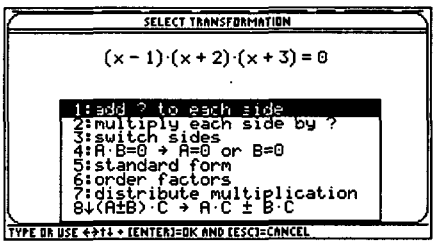
[3] Problem was used at Sindo High School and was made by Joe, Jae Ho, a mathematics teacher at the same school (2002)

The above problem is similar to a traditional problem. The only difference is that we provided the figure through the handheld graphing technology. In the beginning, it was difficult to understand symbolic and figures in the handheld graphing technology who are familiar with symbols and figures in the traditional texts and teacher's handwriting. The difficulty was even greater when they used the function [SCALE] or [ZOOM] in the handheld graphing technology. But this difficulty was recovered after using with the handheld graphing technology.

4.2. Procedure, setting and function

We consider the type of problems, which we can ask about procedure, setting, and function of the handheld graphing technology. The following is an example we used in a 10th grade regular exam.

Problem. *The following is a part of procedure of solving an equation in Symbolic Mathematics Guide of TI-92(Plus). In the procedure of solving equation,* $x^3+4x^2+x-6=0$, *what is the next step of* $(x-1)(x+2)(x+3)=0$?



① 1 : add ? to each side
② 2 : multiply each side by?
③ 4 : A•B=0 → A=0 or B=0
④ 6 : order factors

Figure 6. Example of regular exam (2002)

If students used the handheld graphing technology for a while, the above two problems in Figure 5 and Figure 6 are types of problems used in regular exams without any special difficulty.

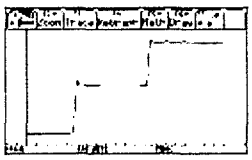
4.3. Analysis, criticizing and applying

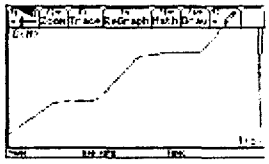
We consider the type of problems that require thinking in harmony with the way the handheld graphing technology work, without having the handheld graphing technology in hand. The following is an example used in regular exams after class with Calculator-based Ranger (we call it CBR).

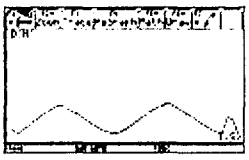
Even if students did not have class with CBR, they might be able to solve the above problem. However if they had class with CBR and experienced using it, then they could

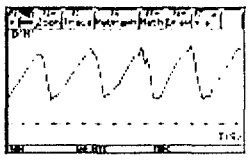
understand the above situation and solve them quickly.

Problem. *The followings are the graphs of distance functions, distance from a fixed place to a moving person with respect to time. Connect each graph with the correct description of it.*

a 

b 

c 

d 

① *Work forward slowly and then return with the same speed. Repeat it.*
② *Work forward slowly and stop. Repeat it from there.*
③ *Three man stand in a line with the same interval. The first man, the second and then the third man come out from the line with the same time interval.*
④ *Work forward fast and then return faster. Repeat it several times from there.*

Figure 7. Example of regular exam (2002)

4.4. Meaning of doing test of regular exams with handheld graphing technology

Even admitting that all examples appeared above probably can be solved without the help of the handheld graphing technology, we also need to admit that there are other types of problems which can only be solved with the help of the handheld graphing technology and which are good to assess the understanding of concepts. But under the circumstances in Korea that most students do not possess the handheld graphing technology, we could not give these types of problems in regular exams yet.

We comfort ourselves that we now started to use problems with the handheld graphing technology in regular exams. We need to endeavor to develop various types of problems with the handheld graphing technology, which are compatible with classroom environment and good to assess the understanding of concepts.

V. CONCLUSION

Through the assessment during class, we could see the current state of students' understanding of concepts and the current learning activities. Through the assessment after class, we confirm the state of students' understanding of concepts so that we can give them additional opportunity to understand concepts by giving additional concepts provoking problems or giving additional help if necessary. In the assessment of regular exams, we showed three different types of problems with the handheld graphing technology in regular exams. We are continuously trying to make types of problems with the handheld graphing technology in regular exams. We have discussed some methods of assessment that are compatible with the class using the handheld graphing technology. These methods are useful and adjustable to students' learning during class, homework after class or in regular exams.

VI. SUGGESTION

It is worthy to use these assessments because the information we can get from them can be used to give feedback to students and to adjust the design of teaching, curriculum and contents of teaching. There is different expectation between practical researchers and other teachers. Colleagues and principal want to see positive results soon. However researchers want to see the improved mathematical power and ability and a better way of teaching and learning rather than the improved marks after we used new ways of teaching and learning and new ways of assessment with the handheld graphing technology. Thus we have to find a way to fill the gap in future.

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