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Teaching and Learning Mathematics with Hearing Impaired Students

Ayse Tanridiler[1], Yildiz Uzuner[2] and Umit Girgin[3]

[1]Anadolu University, School for the Handicapped, Eskisehir, Turkey
E-mail: [1]<afidan@anadolu.edu.tr>
[2]Anadolu University, School for the Handicapped, Eskisehir, Turkey
E-mail: [2]<yildizuzuner@gmail.com>
[2]Anadolu University, Education and Research Center for Hearing Impaired Children, Eskisehir, Turkey
E-mail: [2]<ugirgin@anadolu.edu.tr>

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ABSTRACT The purpose of this action research was to analyze the teaching efforts of mathematics to seventh grade hearing-impaired students at the Education and Research Center for Hearing Impaired Children (ERCHIC). The data were collected via video recordings of the group and individual mathematical instructions; the audio recordings of the reflective meetings, lesson plans, exams, reflective diaries, data evaluation charts, and interviews; and the files related to the students' mathematics work in 2009–2010. Different quantitative and qualitative data analysis techniques have been applied before, during, and after the research process. It was observed that the students participating in the study have benefited from the application of balanced mathematics instruction (BMI). In addition, this study is thought to contribute to the related literature and to create a structure for teaching mathematics to hearing-impaired students. The study is also expected to contribute to the curriculum of mathematics that will be developed for hearing-impaired students in Turkey.

INTRODUCTION

Several studies indicate the academic performances of hearing-impaired students are behind their hearing peers. Mathematics learning, specifically, is difficult for hearing-impaired students (Pau 1995; Traxler 2000; Nunes and Moreno 2002; Kelly et al. 2003). The Primary Education Mathematics Course Teaching Program drafted by the Ministry of National Education is based on the principle that "every child can learn mathematics" (MEB 2013). This principle emphasizes the fact that children learn mathematics in a different manner and speed and that they can only learn mathematics when they are provided with conditions specific to them. Hearing-impaired children, just as hearing children, are supposed to learn mathematics in order to live as successful, effective, and independent individuals in society. Knowing mathematics well actually means having mathematical knowledge. Mathematical knowledge is a combination of information used in counting, calculating, solving routine mathematical problems, or conducting mathematics-related findings. Mathematics educators divide mathematical knowledge into two categories: conceptual knowledge and procedural knowledge. Conceptual knowledge is the inherent knowledge of an individual based on mathematical concepts and the relationships among them. Procedural knowledge consists of the rules and methods in fulfilling a routine mathematical task and of the symbols used in representing mathematical knowledge (Van De Walle 2004; Olkun and Toluk Ucar 2013). Conceptual knowledge and procedural knowledge are both important and necessary, complement each other, operate in a continuous cycle, and develop in mutual interaction. They should not be discrete from one another. To understand mathematical knowledge, one should be able to combine procedural and conceptual knowledge and understand the use of a concept in various situations. This allows for the use of appropriate operations in different cases (Olkun and Toluk-Ucar 2013).

Studies show that hearing-impaired children can learn mathematics just as their hearing peers but at a delayed pace (Wood et al. 1983; Traxler 2000). On the other hand, studies show that prin-

Address for correspondence:
Ayse Tanridiler
Assistant Professor
Anadolu University, The School for the Handicapped, Yunusemre Campus, Tepebasi, Eskisehir, Turkey
Telephone: +90 (222) 335 0580/4911
Fax: +90 (222) 335 0664
E-mail: afidan@anadolu.edu.tr

ciples and elements of balanced mathematics instruction (BMI) are important for hearing-impaired students (Pau 1995; Stewart and Kluwin 2001; Nunes and Moreno 2002; Pagliaro 2006).

Balanced Mathematics Instruction (BMI)

There are various approaches in the literature with respect to mathematics teaching. Ranking teaching approaches in the literature with respect to cognitive development and learning from teaching centered to student centered (Jones and Southern 2003), balanced mathematics instruction (BMI) is remarkable with strong features created in the classroom by two approaches: direct instruction and constructivism. BMI defends the balance in determining whether there is need for direct instruction or indirect support depending on the preliminary knowledge of a student. BMI adopts the principles stated in the Primary Education Mathematics Teaching Program. These principles are the following: (1) Teaching should start with concrete experiences. (2) Meaningful learning should be targeted. (3) Students should communicate with their mathematics teaching. (4) Association should be given importance. (5) Student motivation should be considered. (6) Technology should be used effectively. (7) Cooperation-based learning should be given importance. (8) Lessons should be organized by appropriate teaching stages.

BMI also adopts the principle of offering mathematical knowledge as a whole and studying it in various problem cases. In addition, it gives importance to teaching and associating mathematics with real goals. With respect to assessment and evaluation, BMI emphasizes that the process should be considered as much as the results and that student participation in the evaluation process should be supported (Ainsworth and Christinson 2006). At the same time, it emphasizes the need for including all sub-learning areas in mathematics teaching, such as numbers, geometry, evaluation, probability, statistics, and algebra.

Considering the learning-teaching cycle of BMI, there must be balance in every phase: objectives, content, teaching process, assessment, and evaluation. BMI objectives include the reasons for teaching mathematics to students. The importance of mathematics in real life and the level of association with real life in teaching mathematical skills is considered. A sensitive balance is established between teaching mathematical skills and mathematics used in real life.

BMI content reveals what will be taught to students in the mathematics course. Focus is on issues to be careful in preparing the teaching program, associating mathematical skills with context, adjusting the level of difficulty of the text types and mathematical knowledge, and using skills in the mathematics course.

BMI aims at teaching both mechanical operations and texts to be read, interpreted, and understood; therefore, classroom interaction in the BMI process, control level of the teacher in the classroom and the effectiveness level of students, and the manner of association between mathematical skills and teaching strategies.

Assessment and evaluation in BMI should be used in the learning process as an integral part of teaching in order to provide information on students, to create a complete profile of a student, to evaluate the effectiveness and quality of a teaching program, to provide feedback, to shape the teaching program, and to provide summative information on success levels of the students. When starting teaching, varying and numerous assessment and evaluation techniques are constantly used during and after teaching, and formal and informal assessment and evaluation methods are used (McLoughlin and Lewis 2004).

Studies support the fact that BMI is important for impaired students to learn mathematics, but no study is found to examine the principles and elements of BMI. Although the mathematics teaching applied at the Education and Research Center for Hearing Impaired Children (ERCHIC) is regarded as the application of this conceptual and theoretical framework, before the present study no previous scientifically based study has directly examined the dynamics of the mathematics teaching environment at ERCHIC. The basic reason for this study is to provide a systematic and reflective study of the mathematics teaching program at ERCHIC, which is a good example of BMI application. Thus, the BMI program was tested and it ensured the improvement of the existing program. In addition, this study created scientific grounds to show BMI as an example. Based on this objective, the research questions were as follows: (1) What was the process of balanced mathematics instruction applied to the hearing-impaired students? (2) What were the components of balanced mathematics instruction applied to the hearing-impaired students? (3) Which instructional strategies were applied during the lessons? (4) What was the impact of balanced mathematics instruction on the students?

METHODOLOGY

Research Design

In order to obtain data that would help us to understand the instructional process of BMI instruction implemented at ERCHIC, this project was developed as an action study. Furthermore, the research included systematical, reflective and cyclic analysis of BMI (Gay and Airasian 2003; Uzuner 2005; Yildirim and Simsek 2011).

Research Working Group

The participants of the research were the seventh-grade primary school students of ERCHIC for the 2009–2010 academic year. Five of the students were girls and three were boys. All students had severe or profound bilateral, sensorineural hearing loss. Two students had cochlear implants and others wore behind-the-ear hearing devices. The first author completed her degree in mathematics and post-graduate study in teaching hearing-impaired students. When the study was conducted, the first author had 14 years of experience in teaching mathematics to hearing-impaired students. She has also participated in various qualitative and action studies. She will be referred to as the teacher in the remainder of this article. The second and third authors are experienced field experts in teaching hearing-impaired students and research methodology, and they made up the "Validity and Reliability Committee" (Creswell 2005; Uzuner 2005).

Data Collection Instrument and Procedure

Various qualitative and quantitative data-collection techniques were used in the study (Johnson 2002). The data were collected via video recordings of group and individual mathematics instruction (Total amount of group mathematics lessons between September 28, 2009, and March 29, 2010, was 178 x 40 = 7120 minutes, and individual support was 38 x 40 = 1570 minutes). Because of the word limitation of the journal, this paper's main focus is the group instructional data and results. In addition, the data included in the study were the audio recordings of the reflective meetings (22 meetings), lesson plans for each lesson, exams, reflective journals (typed in Word program with 1.5 line space and 12 font size and consisting of 58 pages), data evaluation charts, interviews, and portfolios related to the students' mathematics works.

Data Analysis

An ongoing, reflective data analysis was performed on weekly occurring cyclical instruction sessions (see Fig.1) during and after the study. During the study, the teacher recorded each lesson. Each week, excluding some lessons, group and individual mathematics lessons were videotaped. After each lesson, the teacher reviewed the tapes, self-reflected by utilizing a control list and writing a research journal. The teacher and experts watched some of the video recordings, focusing on methodological and educational issues (Ratcliff 1996; Creswell 2005).

FINDINGS

Question (1)

The research consisted of two processes: "The Preparation" and "The Application" (see Fig. 2). At the end of the fall term, the research data was reviewed. Trying to solve the problems occurring during the pilot study, the authors decided to develop a research project to be applied to the Scientific Research Project (SRP) at Anadolu University.

The Representative Unit

Four units were taught in the implementation process. In planning and teaching each unit, components of mathematical knowledge were included in a cyclic and balanced manner as examined and approved by two mathematics field experts. It was decided that each unit be handled representatively in order to examine and analyze the mathematical information-sharing and teaching strategies. The "integers" unit was selected representatively (See Fig. 3). The reasons for this are as follows: a) Like in the other units, a balance of conceptual information, procedural knowledge and problem-solving activities were included. b) "Integers" are established

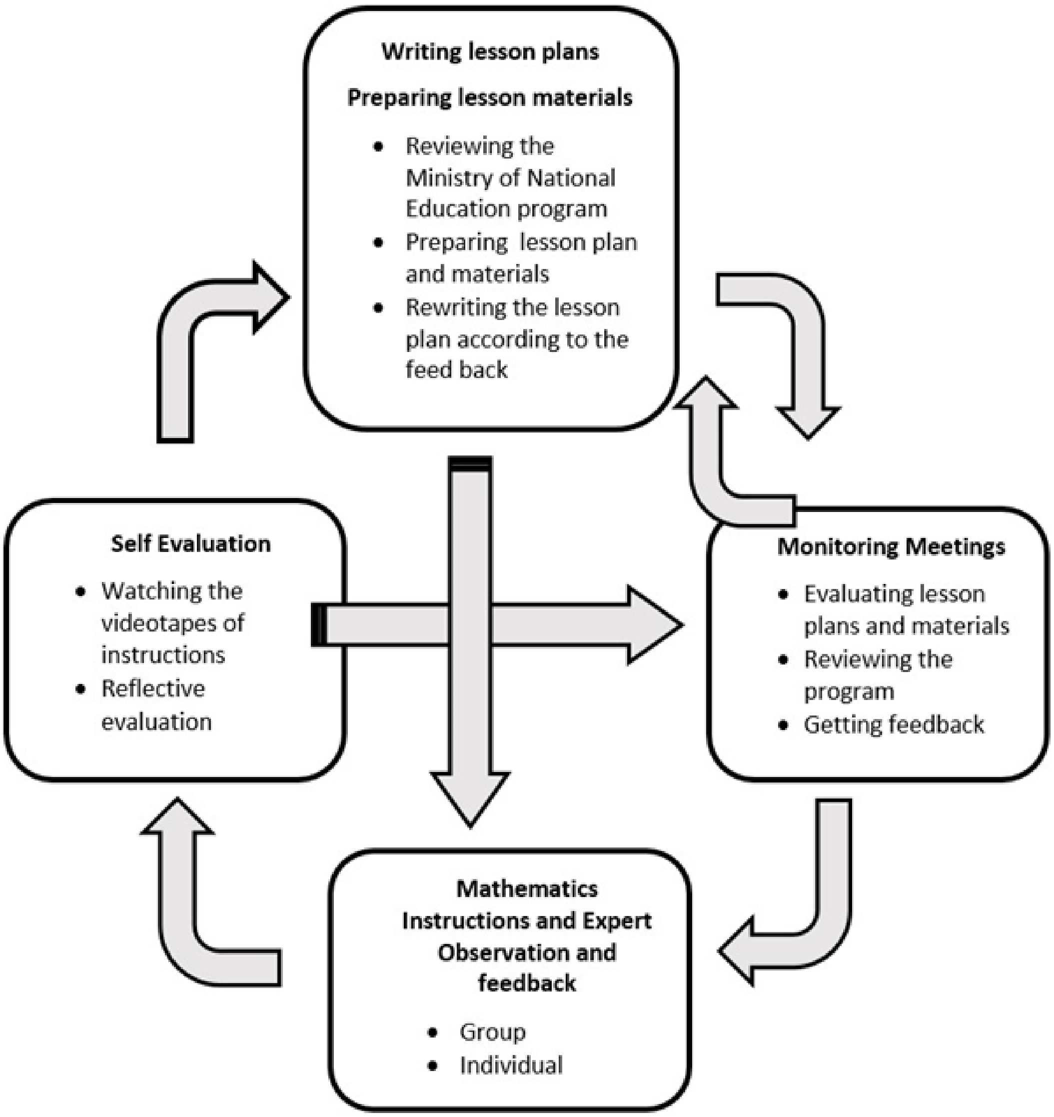

Fig. 1. Weekly instructional cycle
Source: Author Developed by Ayse Tanridiler (The first author of this paper)

on "natural numbers" that students previously learned and make up the basis of future units such as "rational numbers", "algebra expressions and equations" and even algebra works of high school like "exponential numbers", "root numbers" and "functions". Therefore, basic information and procedure skills related to integers directly affect future mathematics achievements of the students.

Teaching the "Integers" Unit

With respect to the integers unit, a total of 34 hours of mathematics group instruction was implemented between February 26 and March 29, 2010, with eight hours of group instruction and seven hours of individual support instruction each week. The lesson on March 10, 2010,

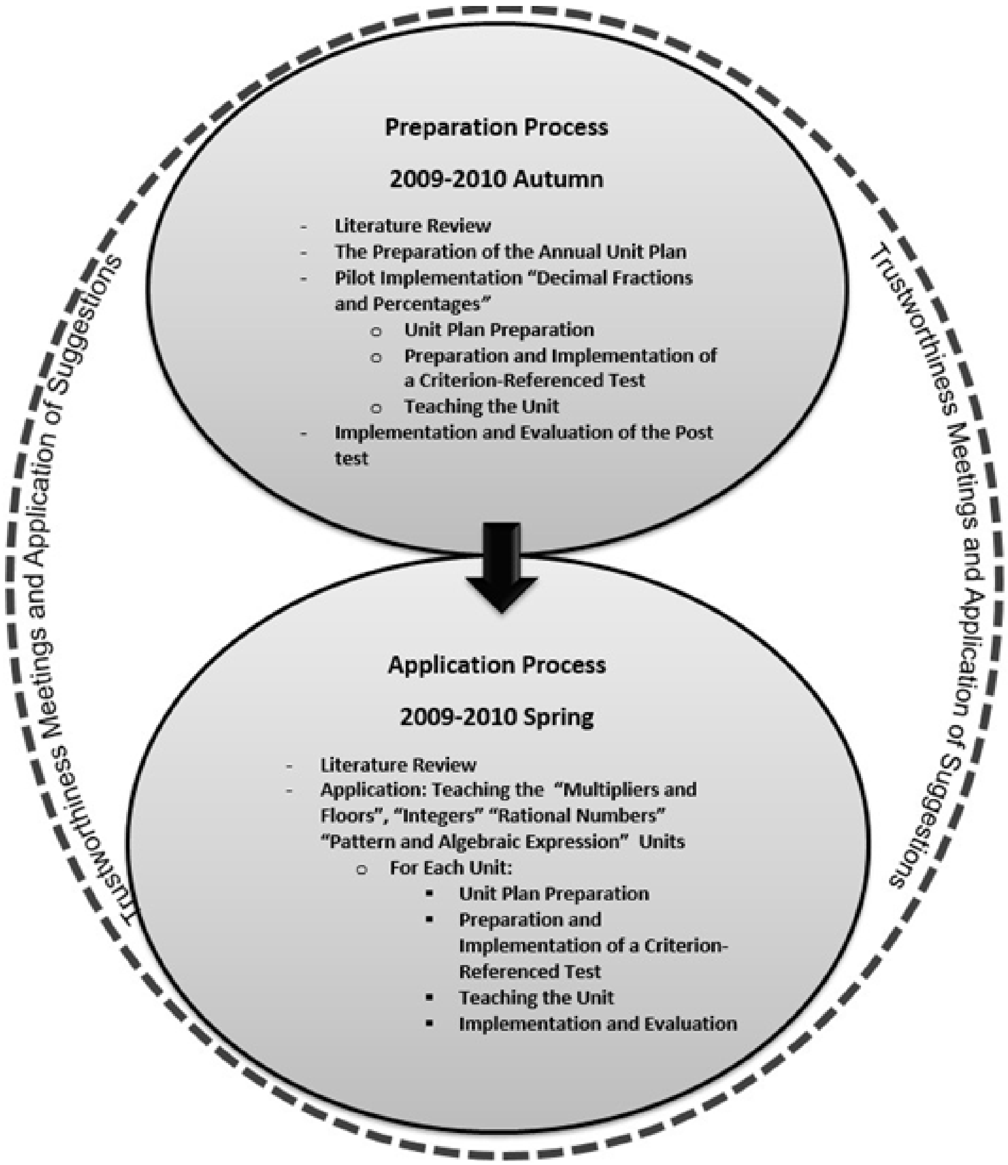

Fig. 2.The process of BMI applied to the hearing impaired students
Source: Author Developed by Ayse Tanridiler (The first author of this paper)

couldn't be recorded because of a technical failure. On the said dates, there are 26 x 40 = 1040 minutes of group mathematics instruction video recordings.

During the teaching process of the "integers" unit, conceptual knowledge activities were implemented in order to teach subjects like "What is an integer?" and "Where are integers used in daily life?" Conceptual and procedural knowledge activities were implemented in order to teach subjects like "How operations are done with integers?" and "How is it done like that?" Proce-

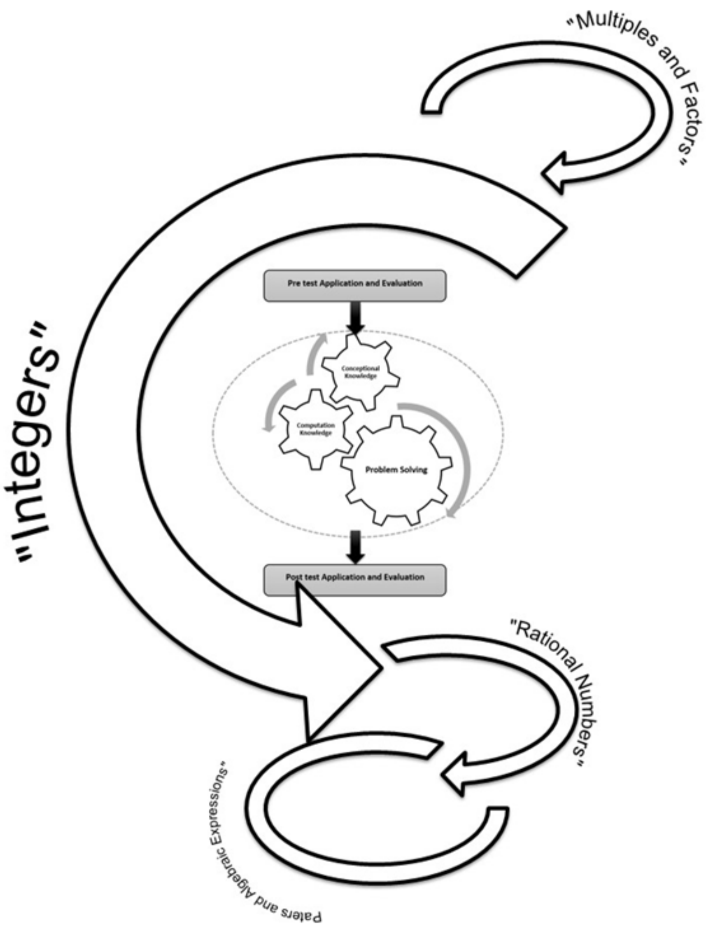

Fig. 3. The model of integers unit
Source: Author Developed by Ayse Tanridiler (The first author of this paper)

dural knowledge activities were implemented in order for the students to obtain rationality and practicality in operations with integers, and problem-solving activities took place in order to teach "How and where are integers used in our daily life." As seen in Figure 4, components of mathematical knowledge were included in a balanced way based on the BMI elements in teaching the "integers" unit. These components are hierarchical, simultaneous, and cyclic over time.

Additional language interactions were included in conducting lessons because of the delay of language development of hearing-impaired students, and several enhancement activities were planned and implemented during the course of the research effort.

Representatively Selected Group Mathematics Lessons

A total of 26 x 40 = 1040 minutes of group mathematics lessons were applied. In teaching the "integers" unit, two hours of conceptual knowledge (2 x 40 = 80 minutes); twelve hours of conceptual knowledge and procedural knowledge (12 x 40 = 480 minutes); six hours of procedural knowledge (6 x 40 = 240 minutes); and six hours of problem-solving studies (6 x 40 = 240 minutes) were applied. Validity meetings included a complete review of the data sources of the lessons related to the "integers" unit and contained balanced components of mathematical knowledge. It was decided to include lessons

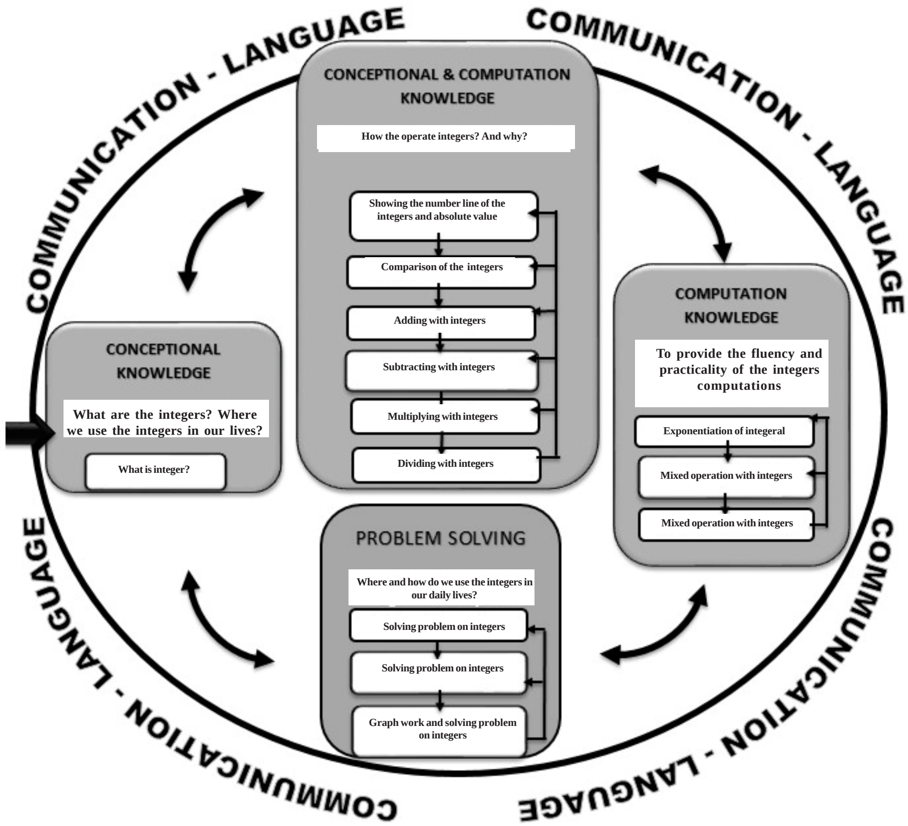

Fig. 4. Instructional model of "integers" unit
Source: Author Developed by Ayse Tanridiler (The first author of this paper)

representing the BMI principles. Therefore, as shown in Figure 5, mathematics lessons were selected representatively, and a detailed analysis of courses was done; namely, the lessons of February 26, 2010, as an example of "conceptual knowledge"; March 5, 2010, as an example of "conceptual knowledge and procedural knowledge"; March 12, 2010, as an example of "procedural knowledge"; and March 17 and 19, 2010, as examples of "problem solving" activities.

Question (2)

Each mathematics lesson was taught in two parts. The first part was lecturing, where the students and teacher work together. In this part, the teacher prepared various activities for teaching mathematical concepts related to the subject of the lesson, determining examples used in daily life with respect to these concepts, mathematically expressing these cases, realizing a mathematical operation and reaching generalization in realizing operations, and solving a mathematical problem. The second part of the lesson was the follow-up activity study. In this part, students were given worksheets and work cards with respect to the lesson topic and students studied individually. Students were asked to explain their work. Thus, students were allowed to explain the operation processes they did, encouraged by feedback on their correct work, allowed to correct their mistakes, ensured to learn with more hints for cases they couldn't correct. The teacher had the chance to determine strengths and weaknesses of each student on the taught subject.

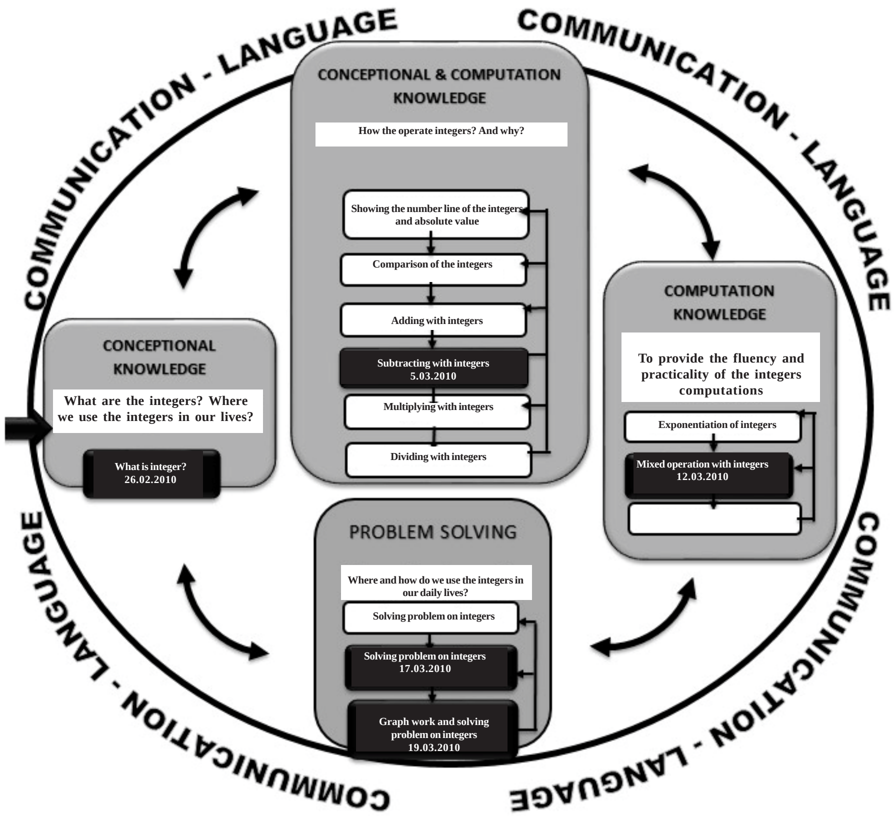

Fig. 5. The target lessons

Source: Author Developed by Ayse Tanridiler (The first author of this paper)

Question (3)

The data showed that the strategy was applied in all mathematics lessons realized in accordance with the BMI principles, and focus was on strategy teaching. The following strategies were used in the representative lessons:

Lesson on February 26, 2012: The present study determined that for conceptual knowledge, the goal was to teach *Definition* and *Exampling* strategies. Together with these strategies, strategies for *Combination and Discovery Questions*; *Detail Determination Questions*; *Think Aloud, Reading; Reading Back; Use of Mathematical Terms; Symbolic, Verbal and Pictorial Representation of Mathematical Knowledge* were enhanced The analysis determined the following themes in the flow of the lesson: a) definition of integer, b) symbolic illustration of the set of integers, and c) use of integers in our daily life.

Lesson on March 5, 2010: The objective was to teach *Mathematical Modelling and Definition* strategies. Together with these strategies, strategies for *Combination and Discovery Questions; Detail Determination Questions; Use of Mathematical Terms; Pictorial; Symbolic and Verbal Representation of Mathematical Knowledge; Think Aloud; and Exampling* were enhanced. The following themes were determined in the flow of the lesson in the analysis: a) conceptual teaching of integer subtraction by modelling with number marks; b) teaching procedural knowledge while reaching generalization; c) enhancing procedural knowledge. Conceptual teaching was done in two ways. The first way was teaching conditions where the subtrahend number is in the minuend number set: i) directly removing the subtrahend from the set, ii) writing the mathematical sentence, and iii) naming the terms in mathematical sentence. The second way was teaching conditions where the subtrahend number is not in the minuend number set: i) first adding an equal number of positive and negative numbers in the minuend number set, then removing the subtrahend number out of the set, ii) writing and reading mathematics sentence, and iii) naming the terms in the mathematical sentence.

Lesson on March 12, 2010: *Combination and Discovery Question Strategy* is one of the strategies used to activate preliminary knowledge and aims to teach *Detail Determination Question Strategies*. Together with these strategies, strategies like *Networking, Exampling, Think Aloud, Definition, Reading Operation Sentences, Using Mathematical Terms, Verbal and Written Symbol Representation of Operation Sentences* were enhanced. The analysis determined the following themes in the flow of the lesson: a) determining procedural knowledge with respect to "operation priority" and b) applying and enhancing procedural knowledge on "operation priority".

Lesson on March 17, 2010: The objective was to teach *Problem-Solving Steps* strategy. Together with this strategy, strategies of *Think Aloud, Pictorial, Verbal and Written Symbol Representation of the Mathematical Knowledge* were enhanced. The analysis determined the following themes: a) reading the problem, b) explaining the problem, c) drawing, d) operation selection, e) carrying out an operation, and f) determining the answer to the problem.

Lesson on March 19, 2010: The objective was to teach the *Graphical Reading Strategy*, which is a strategy used to create meaning from mathematical texts. Together with this strategy, *Use of Mathematical Terms, Combination and Discovery Questions, Pictorial, Verbal and Written Symbol Representation of Mathematical Knowledge, Definition, Exampling* strategies were enhanced. The analysis determined the following themes in the flow of the lesson: a) reading the elements of the graph, b) reading the features of the elements of the graph, c) combining and interpreting graphical elements, and d) interpreting all data in the graph.

Question (4)

All students showed significant improvement in mathematical skills. As shown in Table 1, the improvement of students is 32 points and above. Criteria referenced test items consisting of subitems related to the measurement of conceptual knowledge, procedural knowledge, and problem-solving skills. These subitems were analyzed separately. Three items of the test were asked to measure conceptual knowledge. Evaluation was made with 25 points over 100 points in total. Table 2 includes the results of the pre- and post-test examinations of the students related to the subitems measuring conceptual knowledge. As shown in Table 2, all students showed significant improvement in their development of conceptual knowledge.

Table 1: The students' general improvement

Student	*Pre-test*	*Post-test*
Ipek	4	35
Tuna	19	72
Can	9	60
Ozge	27	69
Talya	25	75
Gozde	17	79
Deniz	13	54
Inci	25	79

Table 2: The students' conceptual knowledge improvement

Student	*Pre-test*	*Post-test*
Ipek	4	6
Tuna	10	16
Can	1	11
Ozge	1	9
Talya	12	17
Gozde	2	18
Deniz	0	6
Inci	12	20

* It was evaluated on 25 points.

Eight items of the test measured the students' procedural knowledge. Evaluation was 44 points over 100. Table 3 includes the results of preliminary and post-test examinations related to the sub items measuring procedural knowledge. As seen in Table 3, all students showed significant improvement in their measurements of procedural knowledge development.

Six items of the test measured the problem-solving skills of the students. Evaluation was 31 points over 100. Table 4 includes the results of preliminary and post-test examinations related to the sub items measuring problem-solving skills. As seen in Table 4, all students had impor-

Table 3:The students' procedural knowledge improvement

Student	*Pre-test***	*Post-test***
Ipek	4	24
Tuna	8	37
Can	8	33
Ozge	26	41
Talya	12	36
Gozde	14	41
Deniz	4	33
Inci	11	41

**It was evaluated on 44 points.

tant problems in the pre-test. The post test conducted at the end of the application process showed marked improvement in problem-solving skills.

Table 4: The students' problem solving improvement

Student	*Pre-test****	*Post-test****
Ipek	0	9
Tuna	0	20
Can	0	16
Ozge	0	20
Talya	1	22
Gozde	1	21
Deniz	9	16
Inci	3	18

*** It was evaluated on 31 points.

Qualitative analysis of the students' test results showed that majority of students (6 students) correctly defined all integers-related concepts and expressed the daily-life examples of using integers. Again, a majority of students conducted procedures for addition, subtraction, multiplication and division. Two of these students made operational mistakes and wrongly determined the mark of the result while one student left the division section blank. With respect to problem-solving works, all students tried to solve the majority of the problems given (at least three of five problems). They selected the required works for the solution of the problems, reached the result of the operation, and expressed the result by writing a sentence explaining the answer to the problem.

DISCUSSION

This action research method required systematic, reflective, and cyclic analysis of various variables affecting BMI in a real classroom environment of hearing-impaired students (Johnson 2002; Gay and Airasian 2003; Mills 2003; Uzuner 2005; Yildirim and Simsek 2011). In action research, it is not possible to establish a cause-and-effect relationship between variables like "student qualities" or "implementation methods of the strategies applied" and to generalize findings to all hearing-impaired students. However, the goal of this study was to examine the systematic and reflective development and evaluation within the process of the difficulties faced by the teacher and students in BMI application in a classroom environment. On the other hand, based on the evidence, the study shows that BMI impacts mathematics learning of hearing-impaired students. Research data is provided within the framework of these restrictions.

The research also contributed to other fields in that it illustrated providing mathematical knowledge in a balanced manner as conceptual and procedural knowledge and establishing relations between problem-solving works and conceptual and procedural knowledge (Pau 1995; Fluentes 1998; Hartman 2000; Schirmer 2000; Stewart and Kluwin 2001; Barton et al. 2002; Pagliaro and Ansell 2002; Jones and Southern 2003; Kelly et al. 2003; Nunes 2004; Pagliaro 2006; Pearson et al. 2007; MEB 2013; Olkun and Toluk Ucar 2013). In other words, BMI was found to impact the mathematics learning of hearing-impaired students. A model based on BMI principles was formed.

On the other side, as a result of the research done, it was seen that students showed progress in conceptual knowledge, procedural knowledge and problem-solving skills. In addition, it was determined that the scores of students from all examinations were did not exceed 80 points. The cause is believed to be from the need for more time to improve mathematical skills and from the language and conceptual delays due to their hearing impairment, difficulty to understand what is read, and the nature of the mathematics language (Pau 1995; Nunes and Moreno 2002; Kelly et al. 2003). Therefore, there is need for studies to be enhanced over time (Stewart and Kluwin 2000).

The levels of students' understanding and learning were different according to their level of knowledge, skill, and language. However, each student progressed in line with their learning speed. In mathematics lessons, relationships were established between real life and the math, and students became aware of why they learned mathematics and started to use what they learned in real life. The works to associate the mathematics lessons with other lessons showed that mathematics is somehow related to those lessons, and students became aware of why they learned subjects in mathematics and therefore the importance of mathematics. They were given the chance to complete what they had missed in previous years.

CONCLUSION

The mathematics teaching program at ERCHIC is a good example of the application of BMI. The students improved their skills for asking and answering questions, sharing opinions, speaking, and effective listening to each other and to the teacher. They are aware of what they learn and what steps they will follow to learn, and when they are aware of what they learn, they are able to control their learning processes. Students started to correctly read mathematical texts used in lessons, and their reading and listening skills were improved. They used mathematical terms in their speeches about a certain subject and corrected their mistakes using feedback. They started to use mathematical language more competently. They noticed that mathematical knowledge is represented in different ways and became able to represent a given mathematical concept in different ways. They noticed and started to mention that the result of mathematical operations or problems doesn't consist of a number and refers to an opinion together with the solution.

RECOMMENDATIONS

This action research includes a systematic analysis of mathematics teaching to hearing-impaired students, and it is believed that it would contribute (1) to the literature and create a structure for mathematics teaching for teachers of hearing-impaired students and (2) to the mathematics teaching program to be developed for hearing-impaired students in Turkey.

However, regarding the limitations of this study, the following research suggestions can be considered: The research effort can be continued at the ERCHIC. Moreover, there must be more research on BMI with hearing-impaired students in various settings. Action research on BMI should prevail not only in this school but in other environments. In order for the cause-and-effect relationship of the variables, research can be conducted by utilizing the single-subject and quasi-experimental research designs.

NOTES

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