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Cubaritme in the trajectory learning of multiplication concept

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Abstract. Physiological structural disorders in blind students because blind people to have their own obstacles in constructing knowledge and developing conceptions of a mathematical object. As an abstract object of mathematics, it turns out that the concept of multiplication has great potential to be memorized rather than understood by the blind. To be able to teach and understand the concept of multiplication, a teacher needs a description of the possibility of learning trajectories that will be developed by students in achieving learning goals. Thus the teacher can make learning devices that are in accordance with the level of thinking that exists in the trajectory of student development. Therefore, the aim of this research is to describe the process and produce student learning trajectory in learning multiplication concepts using guided discovery. This research includes the type of design research with the Gravemeijer and Cobb's model. This study produces a trajectory of learning the concept of multiplication of blind students by using guided discovery methods. The trajectory is obtained from the learning trajectory hypothesis which is designed through three stages, i.e preparing for the experiment, design experiment, and retrospective analysis. Based on the results of the study, it was found that in the trajectory of learning the concept of multiplication of students known they optimized tactile abilities when they used cubaritme in learning multiplication concepts. A tactile ability that is influenced by the perception of synthetic touch, helps students understand the concept of multiplication well and achieve the defined KKM.

Introduction

Mathematics is a science with the object of study that is abstract and hierarchical so that the learning experience of students will influence the learning process when they learn a new mathematical topic. With the object's characteristics of the study it is certainly not easy for a teacher to be able to teach a mathematics material to students, especially students with special needs such as blind people who have limitations or even lose visual experience.

Loss of visual facilities that can integrate all objects of observation can affect cognitive development and the conception of a blind student. If the sighted students use their visual senses to develop his conception, then the blind students will use their sense of hearing and touch.

The tactual ability of blind students is influenced by analytic and synthetic tactic perceptions that must be actively trained. Although tactual ability is used to replace visual visualization, it still has limitations in integrating the shape of an object, especially objects with certain characteristics such as abstract objects of mathematics.

The abstractness of the mathematical object can cause its own constraints to be studied by students who are in the concrete operational stage. Generally, abstract objects such as concepts will be taught to students in concrete stages by relating them to real-world problems, using the help of concrete media or

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certain models. Even so, there are still many students who still have difficulty understanding mathematical concepts so that students memorize concepts more.

One material that has the potential to be memorized by students is multiplication operation. The multiplication count operation is the material contained in the Basic Competency reference for at least Mathematics lessons for grade IV semester 1, but in reality, blind students who are in grade V still don't understand the concept of multiplication operation and only memorize one digit multiplication. Whereas multiplication operation is needed by blind students to learn mathematics to the next stage.

According to Rey [1], to study counting operation of students requires skills in numeracy, concrete experience, and language skills. If students only memorize, then the ability to express the counting operation will be less.

Based on the results of observations and interviews conducted by researchers at SLB-A Yaketunis Yogyakarta on 12 September 2018, it was found that understanding the concept of multiplication and the ability multiplication operation of two-digit (digit) of blind children is still low. This is because the knowledge of the multiplication concept is done by memorizing so that students do not know the meaning of the concept of multiplication counting operation. In addition to learning that is done verbally, teachers also don't use media and learning methods that are appropriate to the needs of the blind in learning this multiplication operation.

Whereas students who have obstacles in understanding a material must use a lot of concrete objects rather than just oral explanations which can confuse students [2]. In line with this, assistive technology or concrete devices will be able to help greatly improve functional abilities and access to disability student learning [3]. By utilizing learning tools or media, students can be helped to understand the material and the teacher is helped to convey the material to students with special needs.

To date, many blind learning media are only used to teach one skill or competency, whereas for the other competencies will be used different media. For example, to develop basic Braille reading and writing skills for blind students, the teacher uses cubaritme or reken plank. With cubaritme, students are taught about the setting and configuration of Braille dots that symbolize certain letters or numbers. Furthermore, the cubaritme that contains certain Braille dots will be arranged on the letterboard. This Cubaritme turned out to be very helpful in learning the beginnings of reading and writing blind students because it was in accordance with its limitations and optimizing the tactual ability of the blind as an active substitute for the configuration of Braille dots.

The usefulness and familiarity of blind students towards the use of cubaritme can be used by teachers to help students' difficulties in teaching the concept of multiplication counting operations. Cubaritme is not only used to teach alphabetic reading and writing but can also be used to teach blind students to express counting operations. Such learning can include the ability to represent verbally and written mathematical expressions, multiplication of two natural numbers, the ability to construct a definition of multiplication obtained through associated with other mathematical concepts, and multiplication problem-solving abilities. So that in learning multiplication concept, students not only have the ability to calculate the results of multiplication of two numbers but also able to interpret the calculation operation and can apply it to solve real-world problems.

By utilizing cubaritme media which involves the active role of students directly, the abstraction of blind students can develop in the activities of understanding concepts and problem-solving.

In addition to the selection of media and learning methods that are tailored to the needs of blind students, to help students learn the abstract mathematical concept, the teacher also has an overview of the possible trajectories or paths that students go through to achieve the learning objectives. Because each student has different abilities, which will also affect the difference in learning trajectory in achieving the same learning goals.

According to Clements and Sarama [4], learning trajectory is a complex arrangement consisting of shared considerations about learning goals, students 'thinking models, teacher and researcher models regarding students' thinking, a sequence task of the learning, and interactions at the level that detailed of process analysis. The trajectory learning can be supported by choosing the right learning strategy through activating students in the classroom.

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One method that requires students to be active in learning to find concepts independently with teacher guidance is a guided discovery method. Guided discovery methods can help the teacher to know the learning trajectory of students during learning. This guided discovery method provides an opportunity for students to find new information in the form of concepts, formulas, or principles in a student's own mental process with the teacher guidance [5].

According to the results of study, the average understanding of students' mathematical concepts and learning completeness of students who participated in guided discovery learning methods were higher than students who took conventional learning [6]. So that the guided discovery method is said to be effectively applied to the ability to understand students' mathematical concepts.

Based on the problems and constraints experienced by blind students in the learning of multiplication concept above, students need to be invited to find, interpret and understand the concept of multiplication through their own discoveries through student-centered learning and the teacher only as a facilitator during learning. So it is hoped that later students will no longer memorize and find difficulties in solving the multiplication operation problem.

To find out the learning trajectory of students, researchers will conduct design research by designs and tests a series of learning activities and other aspects of designing. Learning trajectory can be known by designing hypothetical learning trajectory first. Hypothetical learning trajectory is the main instrument in design research.

Based on the description above, the research question proposed in this study is how the process of designing and the results of learning trajectory of blind students in learning the concept of multiplication through guided discovery using cubaritme. This study aims to describe the process and results of learning trajectories of blind students in learning the concept of multiplication through guided discovery using cubaritme

1.1 Guided discovery method

One of the learning developed based on the constructivism approach is discovery learning model. This model emphasizes the understanding of structures and important ideas in learning, so students are encouraged to learn to involve themselves in the process of finding concepts, principles, and formulas, and the teacher is only a facilitator who encourages students to have experience and conduct experiments.

The discovery learning is learning in which the subject matter to be delivered is not delivered in the final form, but students are encouraged to be actively involved in identifying what they want to know and then continue to find information themselves then organize or construct what they know and they understand in the final form [5].

In line with this, Bruner [7] said that discovery learning is defined as the learning process that occurs when students aren't presented with lessons in their final form but are expected to organize themselves. Learning discovery is also the result of students in manipulating, structuring, and transforming information so that it finds new information [5].

Referring to some of the opinions above, discovery learning is learning that is not delivered in a final manner so that it allows students to found and search for information to construct a new concept.

Furthermore, defines guided discovery learning is a learning in which the teacher guides students if needed and students are encouraged to think for themselves, so they can find general principles based on the material provided by the teacher [8].

Guided discovery learning is one that is able to condition students to be accustomed to finding, searching, and discussing something related to learning, and is expected to be able to construct themselves what has been learned with the help of the teacher [9]. With the guided discovery, students are given the opportunity to compile, process, organize data provided by the teacher [10].
From some of these opinions, guided discovery learning is a student-centered learning method to find and conclude a concept of learning independently with teacher guidance.

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1.2 Design reseacrh
Design research is a systematic study of designing and developing an educational intervention (such as programs, strategies and learning materials, products and systems) as a solution to complex problem-solving in educational practice [11]. The essence of design research is the cyclic process of designing or testing a series of learning activities and other aspects of designing. Design research also used to increase knowledge about the characteristics of an educational intervention as well as the process of designing and developing interventions (eg learning processes, learning environments, etc.) to develop or validate the theory. In research design, Gravemeijer and Cobb compile steps of design research and develop the main instrument in design research known as Hypothetical Learning Trajectory (HLT) which is used as a guide during the research. According to Gravemeijer and Cobb [12], there are three stages in design research, namely: (1) preparing for the experiment, (2) design experiment, and (3) retrospective analysis.

1.3 Hypothetical learning trajectory (HLT) and learning trajectory (LT)
According to Gravemeijer [13], the hypothetical learning trajectory is a hypothesis that is studied further from day to day during the study based on plans in learning activities. Meanwhile, the flow of hypothetical learning is the hypothesis of researchers about the possibility of learning flow that occurs in class when designing learning. Because it is hypothetical, it is not always true. What happens in the classroom is often not in accordance with what is desired. Therefore, the researcher conducted a trial which will be obtained by the actual learning path. In the next cycle, the learning flow can be used as a new hypothetical learning path for subsequent learning [14].

Of the opinions of these experts, hypothetical learning trajectory is a hypothesis about how students 'thinking and understanding develop during learning by considering learning objectives, learning activities, students' thinking process and anticipation by the teacher.

Hypothetical learning trajectory consists of three components, namely learning objectives to define the direction and achieve meaningful learning goals, learning activities in the form of a set of tasks, and hypotheses of learning process in the form of predictions about how students' thoughts and understanding develop during learning activities [15]. The functions of the hypothetical learning trajectory (HLT) in each stage of design research are as follows: HLT is designed to guide the learning process that will be carried out at the stage of preparing for the experiment. At the design experiment stage, HLT is used as an indicator or guidance for teachers and researchers about what will be focused on research. Changes to HLT are caused by student events or behavior that cannot be anticipated, strategies that have not been implemented, and activities that are difficult to do. HLT acts as a guide in determining the focus in the research when it is in the retrospective analysis stage. After making hypothetical learning trajectory, in design research will be made a learning trajectory. Trajectory learning is a complex arrangement consisting of shared considerations about the purpose of mathematics learning, student thinking models, teacher and researcher models regarding students' thinking, the sequence of learning tasks, and interactions at the levels that detailed of process analysis [4].

With this trajectory learning the teacher will be given instructions to determine and formulate the learning objectives to be achieved. After determining the learning objectives the teacher can develop steps, strategies, models, or methods to achieve the learning objectives. According to Clements and Sarama [16] there are three parts of Learning Trajectories, namely: 1) Goals: The Big Ideas of Mathematics. The big ideas of mathematics in question is the goal of teacher learning in the form of grouping concepts and abilities mathematically and interconnected, consistent with students' thinking and useful in subsequent learning. 2) Development Progressions: The Paths of Learning. In this section included the level of thinking, beginning from the easy and guiding students to achieve the learning objectives of mathematics. 3) Instructional Tasks: The Paths of Teaching. In this section included a set of tasks that correspond to the level of students' thinking. The task is structured to help students learn about the ideas and abilities needed to achieve a thinking level.

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2. Method

This research includes the type of design research that designs learning trajectory of blind students in learning multiplication concept through guided discovery using cubaritme. The design research model used is the Gravemeijer and Cobb model [12] which is carried out in three stages as follows.

Preparing for the experiment. At this stage, a literature study was conducted about the guided discovery method, multiplication operations subject, and applicable curriculum analysis. After that, the HLT design was carried out as the researchers suspected the students' thinking that developed during learning.

Design experiment. At this stage, the designed HLT was tested on two cycles, namely the pilot experiment cycle and the teaching experiment. The pilot experiment cycle involves two students consisting of a student with severe low vision and a totally blind student. This trial is intended to find out whether HLT has been designed according to student activities. The results of the pilot experiment cycle are used to revise HLT to become LT which will be used in the teaching experiment cycle. The test subjects of the teaching experiment cycle are students in one class without involving the subject of the pilot experiment cycle.

Retrospective analysis. At this stage, the data obtained from the stage of design experiment will be analyzed. HLT that has been designed and tested in the pilot cycle of the experiment will be compared to the teaching experiment learning cycle.

3. Result and discussion

Referring to Gravemeijer and Cobb model design research [12], the stages in this study were carried out as follows.

3.1. Preparing for the experiment

At this stage, researchers collected literature relating to the guided discovery method, cubaritme, mathematical expressions, and 2013 curriculum analysis on multiplication. Next, the researcher designed HLT which is outlined in Figure 1.

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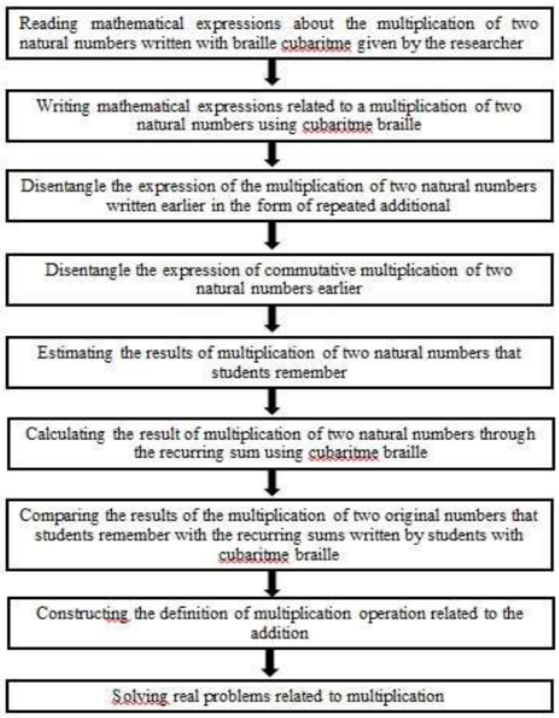

Figure 1. Outline HLT

3.2 Design experiment
At this stage, HLT which is used as a research guide during learning will be piloted in two cycles. Each cycle is carried out for four days. On the first day, students are asked to read mathematical expressions about the multiplication of two natural numbers written with cubaritme braille given by the researcher and write mathematical expressions related to the multiplication of two original numbers using cubaritme braille. The second day, students are asked to describe the expression of the multiplication of two natural numbers written earlier in the form of repeated addition and disentangle commutative multiplication of the expression of multiplication of two natural numbers earlier. On the third day, students were asked to estimate the results of the multiplication of the two natural numbers he remembered and calculate the results of multiplication two natural numbers through repeated addition using the cubaritme braille. Next, students are asked to compare the results of the multiplication of the two natural numbers they remember with the recurring addition that they wrote with cubaritme. Then, students are asked to construct multiplication definitions related to addition. On the fourth day, students are asked to solve a contextual problem about the multiplication of two natural numbers. The following is a description of the process carried out during the research.

3.2.1 Pilot experiment Cycle
The subject of the trial in this cycle consisted of a class V student with low vision. Students read some mathematical expressions about the multiplication of two natural numbers the researchers wrote with cubaritme braille. Next, students are asked to write mathematical expressions related to the multiplication of two original numbers using cubaritme braille. The following are the results of writing students by using cubaritme braille.

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Figure 2. Writing an expression of the multiplication of two natural numbers

From Figure 2, it can be concluded that students can write expressions of the multiplication of two natural numbers using cube braille. Each cube contains a symbol that represents natural numbers and algebraic operations. Symbolizing the natural numbers and algebraic operations in cubaritme follows Figure 3.

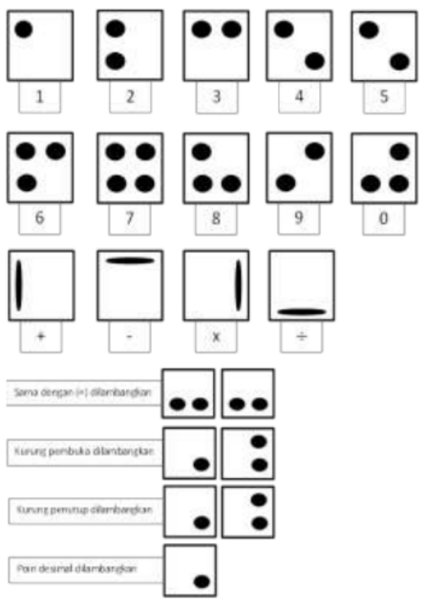

Figure 3. Rules of symbolizing at cubaritme

Students are then asked to disentangle the expression of the multiplication of two natural numbers written earlier in the form of repeated addition. The following is the repeated addition of the multiplication of two natural numbers carried out by blind students with cubaritme.

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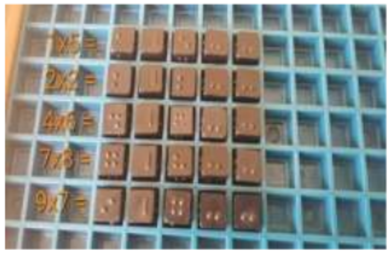

Figure 4. Repeated addition of the multiplication of two natural number

Figure 4 shows that students can arrange a repeated addition from the expression of multiplication of two natural numbers. The next step of learning is that students are asked to disentangle the expression of commutative multiplication of two natural numbers earlier. Students are able to disentangle the commutative multiplication of two natural numbers in the form of repeated addition correctly, even though it takes about 20 minutes to disentangle. For proof, students are asked to disentangle again the commutative multiplication of the expression of the multiplication of two original numbers in the other questions given earlier.

At HLT, researchers suspect students disentangle the multiplication of two natural numbers in the form of repeated addition in three ways, including (1) $1 \times 6 = 6$; (2) $1 \times 6 = 1 + 1 + 1 + 1 + 1 + 1$; (3) $1 \times 6 = 6$. The expression of repeated addition in the way (1) shows the hypothesis researchers related to the possibility of students directly writing the results of the multiplication of these two numbers according to their retention in memorization. The expression of repeated addition in the way (2) shows the hypothesis researchers related to the possibility of students writing the addition of the number 1 (one) as much as 6 (six). While the addition expression is repeated in the way (3) shows the hypothesis researchers related to the possibility of students writing the addition of numbers 6 (six) as much as 1 (one). However, in the trial, the hypothesis of (1) and (2) was not seen during the study.

In describing the commutative multiplication of the expression of the multiplication of two natural numbers earlier, the researcher also has the same hypothesis. For example, the commutative of the multiplication expression of 1×6 is 6×1. But it turns out the students disentangle in the repeated addition expression correctly.

To estimate the results of multiplying the two natural numbers they're remembered, students can mention quickly. Whereas to calculate the result of multiplication two natural numbers through repeated addition using a cubaritme braille, blind students need a long time because they must calculate the sum of the natural numbers they disentangle. The results of student calculations in the repeated addition are presented in Figure 5.

Figure 5. The result of counting of repeated addition

However, when students asked to compare the results of the multiplication of two natural numbers they remembered with a repeated addition in cubaritme braille, students didn't experience confusion. In fact, they firmly answered the results of the multiplication in both ways are the same.

So that by generalizing multiplication as a recurring addition, students are said to be able to construct the definition of multiplication associated with the concept of repeated addition. Students are then asked to conclude the definition of multiplication based on the results of their learning activities. From the students' answers, it is known that multiplication is the addition of a certain number that is repeated as many multiplier numbers. For example, in the multiplication expression 1×6, the number called multiplier is 1, while the number referred to as a certain number is 6. So the number behind the multiplication operation is the number that will be added as many the number that in front of the multiplication operation symbol. The student's representation appeared unexpectedly in designing HLT. So that definition will be added to the new HLT.

Furthermore, students are asked to solve multiplication problems related to daily life. In this case, students can express the multiplication operation and related it to the real problem. Students can disentangle multiplication in the form of repeated addition as in Figure 6.

Figure 6. Expression of multiplication for real problem-solving

When asked to explain the meaning of their answer, students can interpret it well that the medicine to be taken is three teaspoons, twice a day.

3.2.2 Teaching experiment siklus

The subject of the trial in this cycle consisted of 7 students. Of the 7 students, there were 2 people with low vision, while 5 students were totally blind by birth and totally blind at a certain age.

When the subject was asked to read some mathematical expressions about the multiplication of two natural numbers written by the researcher and asked to write mathematical expressions related to the multiplication of two natural numbers using cubaritme braille, the subject could do his job well. However, the subject requires a longer time to write the multiplication expression because the students are mostly totally blind, so to put and arrange the braille cube on the board is an active tactile sensitivity. In disentangle the expression of the multiplication of two natural numbers in the form of repeated addition, a subject of this cycle write the same as the expression of the multiplication of two natural numbers in the pilot experiment cycle. However, when the subject is asked to disentangle the commutative multiplication of the expression of the multiplication of two natural numbers earlier, some total blind subjects find it difficult so they write the same expression with the previous repeated addition expression.

In accordance with the revised HLT to become LT, the subject describes multiplication in the form of a repeated addition as in the number (3) method, but there are also 2 students who use the number (1) method. From both ways, students estimate and calculate the results of multiplication two natural numbers. Like test in the pilot experiment cycle, students are asked to estimate the results of multiplication two natural numbers they remember and students can mention quickly. While the results of the calculation of the multiplication two natural numbers with the repeated addition using cubaritme braille are carried out by students in a longer time.

When asked to compare the results of the multiplication two natural numbers they remembered with a repeated addition in cubaritme braille, some totally blind students experienced confusion, but they were still awkward to answer. After being asked a second time, they just replied that the results were the same. However, some other totally blind students and low vision students added that even though

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the results were the same, the way to get them was different. So that by generalizing multiplication as a repeated addition, some students are said to be able to construct the definition of multiplication associated with the concept of repeated addition.

Next, students are then asked to conclude the definition of multiplication based on the results of their learning activities. From the students' answers, it is known that the definition constructed by students in this cycle is the same as that of students in the pilot experiment cycle. While some totally blind students answered directly the results of the multiplication as they remembered through memorizing activities.

In this cycle, when students are asked to solve multiplication problems related to daily life, not all students can express multiplication operations and relate them to the real problem. Some students are totally blind and low vision students can disentangle multiplication in the form of repeated addition and explain the purpose of the answer related to the problem solving given by the researcher. Some other total blind students have not been able to express the multiplication operation and relate it to the real-world problems given by the researcher. Their answers are only oriented to the results. To find out the students' understanding of the multiplication matter that has been taught, each student is given a test using one assessment sheet and asks students to work on it in the allotted time.

3.2.3 Retrospective analysis

At this stage will be analyzed about the anticipated learning using HLT with actual learning using LT, besides that the results of the student assessment sheet will be analyzed. The results of the study were obtained, that overall the subject of the pilot cycle is more active than the subject of the teaching experiment cycle. This is possible because the subject of the teaching experiment cycle is more varied in the level of blindness than the subject of the pilot cycle experiment that low vision, so the subject's thinking in the teaching experiment cycle is much more diverse. Some subjects who were totally blind felt awkward to express their opinions and were slower in representing repeated addition expressions or multiplication with cubaritme. They need a longer time to touch the cubaritme they have to reach and put it on the board.

Total blind subjects in the experimental teaching cycle are also accustomed to learning mathematics concepts by memorizing, so they are awkwardly actively involved in learning mathematics that involves discovery methods and certain teaching aids. This is different from the subject of the pilot experiment cycle, students have more confidence because he had previous visual experience and ever involved in mathematics learning which is student center, even though the rest of his vision had little function. The hypothesis in HLT of the researcher were not all realized during the trial pilot experiment cycle, but this hypothesis was seen when testing the teaching exeriment. Whereas HLT which can't be predicted by researcher added to HLT which will be revised to become LT by considering the opinion of the class subject teachers.

Analysis of the results of the student assessment sheet showed that as many as 7 students took the test. Of the 7 students, 4 students consisting of 2 low vision students and 2 total blind students who scored more than or equal to the KKM score set by the partner school, while 3 other students did not exceed the defined KKM. So that the completeness of learning is only achieved 57.14%.

From the results of the test analysis using the assessment sheet, it is known that students haven't understood how to disentangled the commutative of the multiplication of two natural numbers. Students interpret commutative multiplication if disentangle in the form of repeated addition will produce the same summation because the multiplication results are the same. So that students experience difficulties when dealing with multiplication problems related to the real world as in Figure 7. Students can calculate how many drugs they should take in a day, but students haven't been able to interpret the intent of the repeated summation written by the pharmacist when prescribing medication.

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Figure 7. Problems related to drug dosage

4. Conclusion

Based on the proposed research questions, the following conclusions were obtained. At Preparing for the experiment, the researcher does a literature review on guided discovery methods, multiplication matter and curriculum analysis apply to design the HLT outline. At Design experiment, the researcher designed HLT was tested on two cycles namely pilot experiment and teaching experiment. The subject of the pilot experiment cycle consists of a heavy low vision student. The subject of the teaching experiment cycle consisted of 7 students consisting of 2 low vision students and 5 total blind students who had blindness by birth and blindness at a certain age. HLT which isn't visible during pilot trials appears when testing the teaching experiment cycle due to variations in student blindness rather than the pilot experiment cycle. Students in this cycle, not only low vision students but also total blind students who are not accustomed to and have awkwardness with a student-centered learning atmosphere.

To measure students' understanding during ongoing learning, students are given a test using an assessment sheet and asking students to work within the allotted time. At Retrospective analysis, the researcher does an analysis of the learning that anticipated using HLT with actual learning and analysis of test results using an assessment sheet. The researcher's hypothesis that can't predict will be added to HLT which will be revised to become LT. Changes to HLT also consider the opinions of the subject teachers in the class.

It can be concluded that the HLT that was predicted by the researcher did not change much. Change only occurs in the thinking process experienced by blind students. But in broad outline HLT is designed according to the actual learning, so that it produces trajectory learning of blind students in the learning multiplication matter with guided discovery methods. The test results showed that 57.14% of students completed the assessment sheet, namely 4 students from 7 students who were able to exceed the KKM determined by the partner school.

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