Visualization of Learners' State Of Learning Using a Task Analysis Diagram

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Abstract

Learners sometimes feel stumped during mathematics lessons due to insufficient understanding or inability to apply previously learned material (Watanabe 1984). However, according to Nakamura (2016), no national survey on high school mathematics has been conducted in recent years. Hence research on students' learning status is insufficient in this regard. Inagaki and Suzuki (2018) have suggested that a "task analysis diagram," which illustrates the skills required to attain a learning objective is effective in grasping students' learning status. Therefore, we aimed to visualize students' learning status by creating a task analysis diagram in this study. To this end, we asked high school students to solve a quadratic function problem. We conducted a correlation analysis to analyze how students felt about the question as well as their actual answers to the problem. The results suggested that a sufficient understanding of the sub-objectives (i.e., prerequisites) is crucial to answering the questions on the upper objective correctly.

Keywords: task analysis, Hierarchy Analysis, task analysis diagram, Learning Objectives

Introduction

According to Watanabe (1984), learners stumble in all situations in mathematics classes due to their inability to apply previously learned knowledge and due to insufficient understanding. Furthermore, when learners try to solve what they don't understand, they find themselves in a situation where they "don't know what they don't understand" (Inaba et al., 2012). In addition, according to the Courses of Study (Ministry of Education, Culture, Sports, Science, and Technology 2019), Mathematics I is a compulsory subject in upper secondary school mathematics departments; therefore, all students who take upper secondary school mathematics take it. However, according to Nakamura (2016), no national Mathematics I survey has been conducted in recent years, which makes it difficult to determine whether research on students' learning status is sufficient. As a solution, Inagaki and Suzuki (2018) suggest performing task analysis as an effective method of grasping what learners understand and to what extent. Suzuki (2002) defines task analysis as the identification of the elements and their relationships necessary to achieve learning goals. He further divided learning objects according to Gagné's five learning outcomes categories, each of which has its task analysis method. Mathematics has a clear hierarchical structure (Kim 2021); for a subject like this, we perform a hierarchical analysis, which is one of the task analysis methods. (Inagaki and Suzuki 2018). A graphical representation of task analysis results is called a task analysis diagram (Takahashi et al. 2008).

Therefore, in this study, we utilized task analysis diagrams to understand students' learning status and clarify the relationship between the students and their prior knowledge of mathematics.

Purpose

We aimed to visualize students' learning status by analyzing tasks based on Gagné's five categories. As a sub-objective, we also aimed to create a task analysis diagram and investigate whether learners perform tasks hierarchically based on the task analysis diagram.

Methods

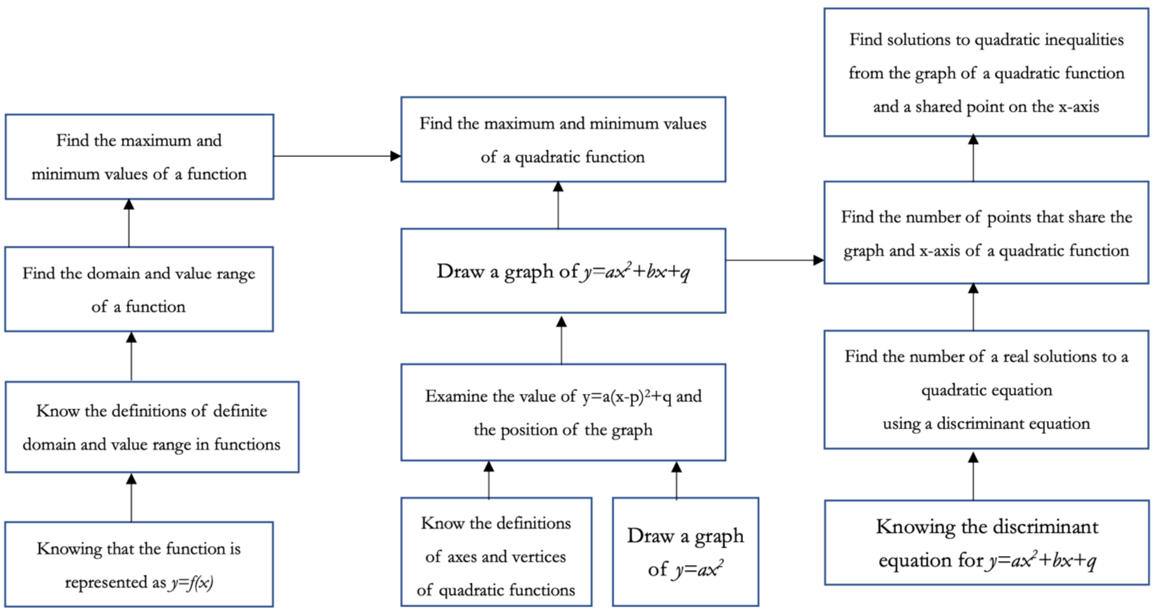
To this end, we created a task analysis diagram from November to December 2021 and conducted a practical evaluation of a task analysis diagram for 70 first-year students from a private high school S in Tokyo.

Creation of Task Analysis Diagrams

In this study, we created a task analysis diagram for quadratic functions. For the learning objectives for quadratic functions, we categorized the applicable items based on Gagné's five categories of learning outcomes. Then, each of the categorized learning objectives was embodied. We created an task analysis diagram to visualize the connections between the embodied contents **(Figure 1)**.

Figure 1

Task analysis diagram of quadratic function



Creating a quadratic function test

We created a test with 13 questions based on the task analysis diagram. The first author scored each question with a maximum score of two points and one partial point.

Results and Discussion

Out of the 70 participants who participated in this study, we analyzed only 68 participants who answered the test. We analyzed the test results by performing a Shapiro-Wilk normality test but did not find the normality for all items (p<.001); therefore, we performed a nonparametric test, Spearman's correlation analysis.

We performed a correlational analysis of the test results to determine if the learners understood the task hierarchically. **Table 1** shows the results for questions that require graphing. We also ranked the contents in **Table 1** in order of difficulty, i.e., from easiest to most challenging, from 1 to 10. The "problem of finding the maximum and minimum of a quadratic function (6)" showed significantly positive correlations with the "problem of finding the maximum and minimum of a linear function (3)," "problem of drawing the graph of a quadratic function (4)(5)," and "What is the definition of the area/region of a function (2),". We compared these results with the task analysis diagram and determined that learning mathematics is generally hierarchical. However, the correlation coefficients were insignificant for "finding the number of points shared by the graph of a quadratic function and the x-axis (7)" and "drawing the graph of a quadratic function (5)". Learners did not answer the questions as intended by the question text. Therefore, we considered it necessary to support them to help them realize the connection with their existing knowledge.

Table 1
Results of correlation analysis to ascertain the relevance of the problem

Level	subject content	1	2	3	4	5	6	7	8	9	10
1	Show that y is a function of x										
2	Definition Range and Value Range Definition	-.07									
3	$y=2x+7\ (1<x\leqq4)$	-.07	.38**								
4	$y=2x^2$	-.13	.26*	.33**							
5	$y=2x^2+6x-1$	-.05	.27*	.24*	.48**						
6	$y=-2x^2+3x-1\ (0<x\leqq2)$	-.08	.31**	.53**	.41**	.45**					
7	$y=x^2-2x+2$	-.02	.13	.27*	.01	.20	.31*				
8	$y=-9x^2+6x-1$	.10	.01	.28*	-.03	.18	.30*	.57**			
9	$x^2-2x-2>0$	-.19	.19	.39**	.22	.13	.40**	.28*	.07	.37**	
10	$-2x^2+6x-1\leqq0$	-.04	.26*	.42**	.18	.31**	.47**	.39*	.22	.47**	.39**

Note. n = 68, Values in the table are correlation coefficients r $^{*}p$ < .05, $^{**}p$ < .01

Conclusion

In this study, we analyzed tasks according to Gagné's five categories of learning outcomes and created a task analysis diagram for quadratic functions. We then examined learning situations by investigating whether they have a hierarchical understanding of the tasks. The results showed that learners' understanding of the problem at the top of the hierarchy is affected by their understanding of the problem at the bottom of the hierarchy. As a future study, we need to develop a system that allows learners to feel a connection to their existing knowledge of mathematics as they learn it.

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