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應用問題解決教學策略於小學程式設計教育

摘要

本研究的目的是檢視小學階段的程式設計教育實務情形，透過問題解決策略幫助學生運用程式設計思維，更深入地了解身心障礙者。在日本，小學階段已全面實行程式設計教育，因此目前教學現場迫切需要發展程式設計相關的學習活動，以促進「程式設計思考教育」的實踐。日本小學階段的程式設計教育目標是在未來為所有人創造安全的社會。我們相信了解身心障礙人士的相關實務活動，有助於學生運用資訊科技與程式設計以協助視障／聽障人士消除障礙，並提升學生重視視障／聽障人士的需求。本研究設計了一個小學四年級學生實作活動，讓他們利用 Micro:bit 和 MakeCode 為視障／聽障人士開發安全到校的工具。在開始進行設計前，學生透過模擬視障／聽障人士的思考體驗，與檢視學校的平面圖來發現可能的問題，而每位學生皆成功利用 Micro:bit 開發出工具來解決各自發現的問題。本研究結果為：（一）利用 MakeCode 和 Micro:bit 學習程式設計可提升小學四年級學生對程式設計的興趣；（二）事先理解身心障礙者的經驗，有助釐清所需要運用程式設計來解決的問題；（三）透過設計程式來消除障礙可產生對程式設計的正面感覺。

關鍵詞：小學程式設計教育、綜合領域學習時間、輔助科技

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Trial practices of programming education using problem-solving strategy in elementary school

Tetsuya BANDO[1], Shunsuke TOMINAGA[2], Hitoshi CHONO[2], Naoto SONE[1], Nobuhiko FUJIHARA[1], Tetsuya YAMADA[3] & Yosuke ITO[1]
Naruto University of Education[1]
Fuzoku Elementary School Attached to Naruto University of Education[2]
Fuzoku Middle School Attached to Naruto University of Education[3]

Abstract

The purpose of this research is to examine programming education practices in elementary schools to help pupils notice the programming thinking process by problem-solving to better understand disabilities. Japan has fully implemented programming education in elementary schools. There is an urgent need to develop practices to foster “Programmatic thinking” through learning activities that incorporate programming. A goal of programming education for elementary schools in Japan is aimed at creating a safe society in the future for everyone. We believe that practices associated with the understanding of disabilities will lead to increased awareness of the use of information technology and programming to remove barriers for people with vison/hearing impairment. We planned practices for fourth-grade pupils to develop tools useful for inviting vision/hearing impaired persons to school by utilizing “Micro:bit” and “MakeCode.” The pupils discovered problems by performing a simulated experience of thinking as the vision/hearing impaired persons and checking the floor plan in the school before working on the programming. Each of them was able to develop tools utilizing Micro:bit to solve the problems that they found. As a result of the trial practices, 1) Learning programming with MakeCode and Micro:bit raises interest in programming for fourth graders, 2) Incorporating the experience of understanding disabilities in advance helped clarify the problems to be solved using programming, 3)Working on programming to remove barriers creates positive feelings toward programming.

Keywords: Elementary Programming Education, Period for Integrated Study, Assistive Technology

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1. Introduction

The purpose of this research is to examine the practices of programming education in elementary school to help pupils notice the programming thinking process by problem-solving to better understand disabilities.

In recent years, computer science has become increasingly important. From PISA2021, OECD's Education Today (2019) has announced that it will set up the framework of computational thinking. Moreover, since the latter half of the 2010s, some countries have made computer science compulsory, starting from elementary courses. In response to this trend, Japan has fully implemented programming education in elementary schools (elementary programming education) since 2020. In Japan, it is recognized that it is important to develop problem-solving skills using information technology in the future society, and elementary school programming education has been implemented in schools for this purpose. The Japanese Cabinet Office (2016) uses the "Society 5.0" framework as its Science and Technology Guideline. Society 5.0 utilizes IoT, big data, and AI, which are the technologies that represent the Fourth Industrial Revolution, aiming to provide a safe place to live for men and women of all ages and disabilities toward the realization of "Society 5.0," there are high expectations for systematic information education, including programming education, from elementary to high schools in Japan.

In Japan's National Curriculum Standards (Japanese course of study), the Ministry of Education, Culture, Sports, Science and Technology (MEXT) organized the goals of programming education into three pillars: "knowledge/skills"; "ability of thinking, judgment, and expression"; and "motivation to learn, humanities, etc." Among these, the core of programming education was shown to be the development of "programming thinking," which is positioned as the "ability of thinking, judgment, and expression." Programming thinking is a phrase coined based on the premise of logical and computational thinking. "Programming thinking," is defined as the ability to think logically about "what kind of movement combination is necessary, how to combine symbols corresponding to each movement, and how to improve combinations of symbols in order to realize the series of activities intended by you (MEXT, 2018)." Elementary programming education in Japan does not aim to acquire skills that enable programming in a specific programming language, but to develop problem-solving abilities that utilize information technology such as computers.

In Japan, there are no subjects related to computer science, including programming. This will be conducted within the existing subjects. In the course of study for elementary school, examples of learning content were presented in specific subjects such as mathematics, science, and the period for integrated study (MEXT, 2018). Two examples of programming-related learning content are drawing

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regular polygons in mathematics and using electricity in science. On the other hand, although the theme is not decided in the period for integrated study, it is shown that it is positioned as an inquiry-based study. Thus, there is concern that the subject-related lesson goals may be confused with the programming-related lesson goals because computer science-related subjects, including programming, have not been established for elementary schools in Japan (Ozaki & Ito, 2017).

To address this concern, two learning models of elementary programming education have been proposed so that the learning goals that incorporate programming become clearer. Figure 1 shows the proposed learning model. The first learning model is the "Phase 1: training model" for learning the concept of programming. The second is the "Phase 2: utilization model" of problem-based learning through programming (Bando et al., 2018). The "training model" mainly aims to develop programming thinking through learning activities related to information and information technology among the learning contents of each subject. On the other hand, the "utilization model" aims to deepen the content of the subject by utilizing the programming thinking cultivated in the "training model." The "utilization model" can be viewed as engaging in learning activities that incorporate programming in order to deepen subject area content learning. There is an urgent need to develop the

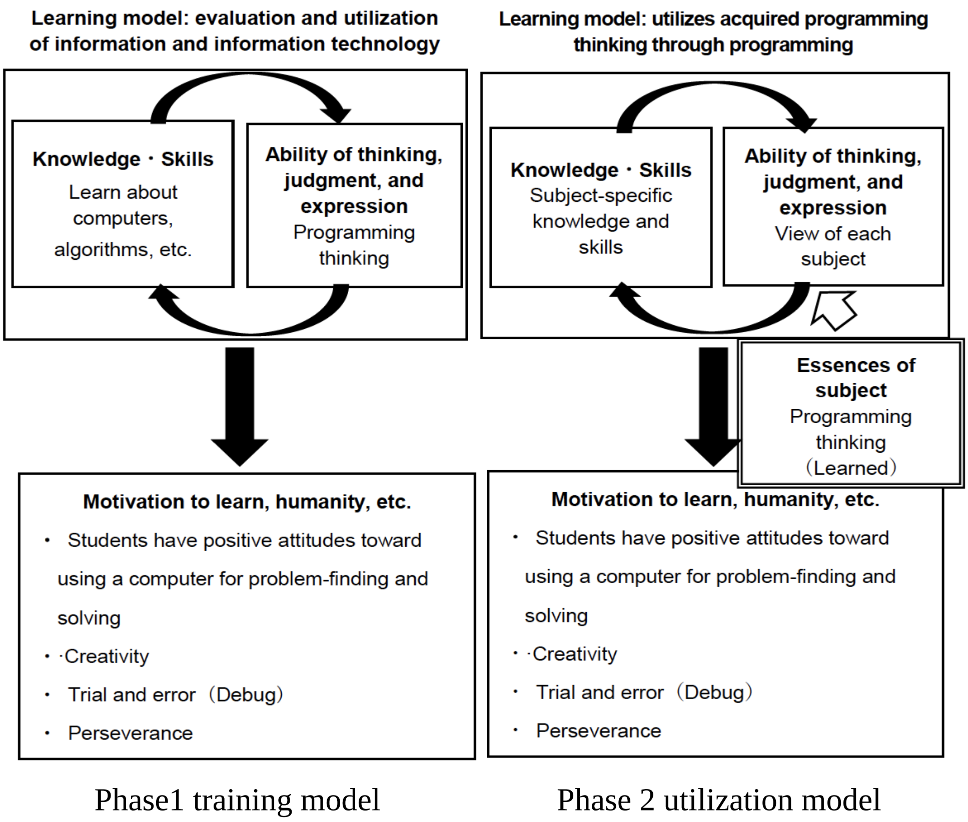

Figure 1. Two learning models in elementary programming education.

Note. From "Proposal of a primary programming education curriculum and management based on fostering information literacy" by Bando, T., Fujihara, N., Sone, N., Chono, H., Yamada, T., & Ito, Y, 2019, *Journal of Information Education in Naruto University of Education*, *16*, 27-36. Copyright 2019 by Center of Information Technology Service, Naruto University of Education.

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learning content of the model to foster programming thinking in order to implement the utilization model. Therefore, we decided to plan learning activities for pupils to find problems in their daily lives and solve them by programming, and to investigate their effects. In this research, we focused on a learning model – “training model” – that aims to foster programming thinking and developed learning content that incorporates problem-solving in the period for integrated study.

2. Learning that incorporates programming based on understanding disabilities

Regarding how to proceed with elementary programming education, MEXT (2020) has published the “Guide for Elementary Programming Education (3rd Edition).” As an example of learning content in the period for integrated study, a lesson to solve local community matters by programming was introduced. Given the local community matters, it is assumed that these are mainly related to agriculture, and currently they are trying to solve the problems of harvesting and crop transportation. As another study, it was reported that programming a robot vacuum cleaner and engaging in learning activities that make pupils think about how to interact with computers. This practice was said to foster an awareness of the desire to make effective use of computers in response to the declining birthrate and aging population (Ito & Hasegawa, 2019). In addition, at the elementary school level in Japan, there have been reports of practical examples of physical computing using Wedo2.0 (Kuroda & Moriyama, 2019) and Shpero (Yamamoto et al, 2017). The purpose of all of these is to make students aware of how programming is used in society.

As mentioned above, elementary programming education is positioned as an education that contributes to the development of qualities and abilities corresponding to Society 5.0. However, it is also necessary to be able to solve local issues and improve the environment. In light of the recent requirement of a better understanding of diversity, it is possible to assist people with disabilities in leading a safe and secure life through understanding their disabilities. In primary and secondary education, the importance of promoting understanding of persons with disabilities has been shown as a step toward the realization of an inclusive society (Central Board of Education, Primary and Secondary Education Section, 2012). Few studies have focused on problem-based learning that incorporates programming with the theme of understanding disabilities at the elementary school stages.

It is expected that children will deepen their understanding of programming as well as their understanding of disabilities by learning about the problems of people with disabilities and working on problem-solving using technology. Regarding education for understanding disability, it has been shown that understanding of disabilities can be deepened through pre-learning, wherein disabilities

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are understood by how they interact with the environment and how they can do more by devising ways (Takano & Kataoka, 2014). The problem-solving technology used by people with disabilities is called assistive technology. The Individuals with Disabilities Education Act defines assistive technology (AT) devices as any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of a child with a disability (20 U.S.C. 1401(1)).

From this aspect, in order to engage with people with disabilities, we decided to develop learning content through this research that can develop students' problem-solving abilities using technology from the perspective of AT and investigate its educational impact. The results showed that the children's interest in programming increased and their understanding of disabilities deepened. The findings of this study will be useful not only in promoting understanding of diversity, but also in developing technological literacy, which is the goal of technology education as general education.

3. Method

3.1 Participants

The participants were 27 fourth-grade students of a national elementary school in Japan (14 males and 13 females; valid rate 93.1%). They have never experienced programming in 4th grade learning activities.

3.2 Overview of learning activities

It was set around the mastery of basic operation methods related to programming and the design to solve problems. In the fourth grade, students will deepen their learning about relationships with people with disabilities, such as the vision/hearing impaired (Table 1). The unit goals of this lesson were set as follows.

1) By finding issues through encounters with people with disabilities and simulated experiences, reviewing the surrounding environment from various standpoints, and investigating tools and mechanisms that are easy for everyone to use, it is possible to deepen the perspective and way of thinking about things.

2) Based on your experiences and research, you can think from various standpoints, consider what you can do as a member of society, and try to act.

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Table 1
Unit planning

Period	Outline of learning activities
1st ~ 4th Period	Think about universal and barrier-free design Experience the world of the visual / hearing impaired vision impaired “eye mask experience” hearing impaired “lip-syncing game”
5th ~ 6th Period	Find the barriers for people with vision / hearing impairments in our school
7th ~ 12th Period (programming)	We are AT developers Pupils design problem-solving methods for inviting people with vision / hearing impairments to school and solve the problems for the invitees by the program Micro:bit.
13th ~ 14th Period	Learn from the people with vision / hearing impairment

3.3 Survey items

There were two evaluation items related to the period for integrated study: “I was able to achieve what I wanted to do” and “I could program based on what I planned” (scored on a scale of 1-4; “4: I really think so”; “3: I think so”; “2: I don’t think so”; “1: I don’t think so at all”). In addition, there were five evaluation items related to programming: “I enjoy programming classes,” “I worked on the programming without giving up until the end,” “Thinking about the order of the instructions, I worked on the programming,” “What I learn in programming is useful in my daily life,” and “I became interested in programming” (scored on a scale of 1-4; “4: I really think so”; “3: I think so”; “2: I don’t think so”; “1: I don’t think so at all”).

3.4 Teaching materials using single-board microcontroller

The main teaching material is a single board computer called Micro:bit. It was adopted to develop a tool that would allow people with disabilities to visit the school safely. Micro:bit has a 5x5 LED screen, and you can control how it shines. In addition, sound can be controlled by connecting sensors and speakers as peripheral devices. The visual programming environment “MakeCode” can be used for Micro:bit. Since the interface is user-friendly, even elementary school pupils can easily program (Figure 2).

We made it possible for pupils to solve problems without aid using the “Tutorial” function of the visual programming environment MakeCode and preparing the manuals of MakeCode. In addition, we grouped pupils with similar input/output programming tasks to facilitate collaborative learning. We prepared a worksheet to understand what kind of AT device the pupils will develop. The worksheet was filled with details of the type of impairment (vision/hearing), the problems to be tackled and their function to solve, and the behavior of Micro:bit.

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4. Results and Discussion

First, we analyzed the worksheets filled out by the pupils. As a result of classification by the developed functions, five functions were obtained: “Communication,” “Understanding the location and direction,” “Detection of obstacles and stairs,” “Reassuring the user’s feeling,” and “Other.” Communication includes displaying greetings on Micro:bit’s LED screen . Understanding the location and direction includes reading the direction with a Micro:bit magnetic sensor and displaying it with light or expressing it with sound. Detection of obstacles and stairs included counting the number of stairs and installing a Micro:bit in front of a dangerous place, then sounding an alarm when the Micro:bit vibrates. Reassuring the user’s feelings includes LED screens that display words of encouragement. Another included those that attempt to measure the user’s condition.

Table 2 shows the types of impairment that were tackled and the functions that were developed based on the pupils’ design. Regarding the response by type of impairment, seven pupils (25.93%) designed ATs for people with vision impairments, 14 pupils (51.85%) designed ATs for people with hearing impairments, and 6 pupils (22.22%) designed ATs for both. Although no statistically significant difference was observed, about half of the pupils worked on dealing with people with hearing impairments ($\chi2(2)=4.22$, ns, $w=0.40$). On the other hand, there was a significant difference in the developed functions ($\chi2(4)=15.41$, $p<.01$, $w=0.76$). As a result of multiple comparisons by the accurate binomial test, more functions to promote “understanding the location and direction” were tackled than “reassure the user’s feelings” and “Other.”

Table 3 shows the mean and standard deviation of each item in gender. Regarding the two items of evaluation on the period for integrated study, the average value of the answers to “I was able to achieve what I wanted to do” and “I could program based on what I planned” was high at 3.0 or more. Thus, it can be seen that the pupils were able to work on problem-solving using information technology, and the period for integrated study was substantial for them. This trial practice with the task of “developing assistive technology using Micro:bit” for pupils to discover and overcome problems in the school through the experiences of being blind and deaf was effective.

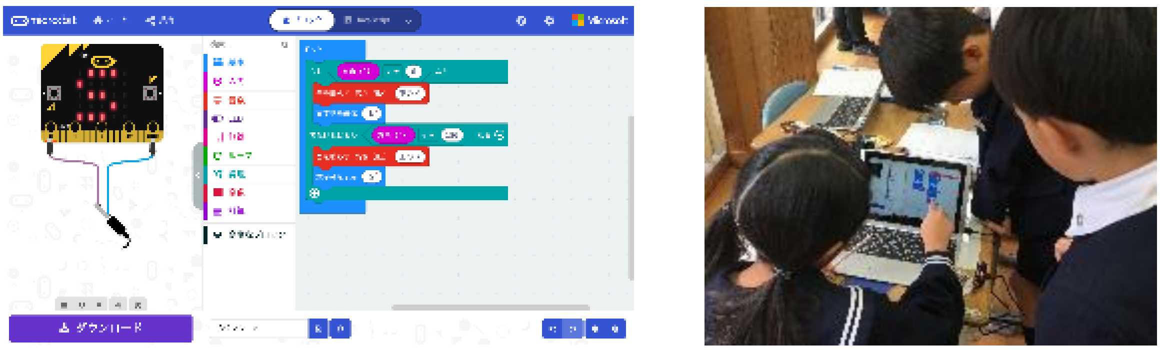

Figure 2. Program examples created by pupils using MakeCode and learning activities.

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Table 2
Types of impairment and functions that pupils worked to solve

Type of impairment	n	%
Visual	7	25.93
Hearing	14	51.85
Both	6	22.22

Type of function	n	%
communication	4	14.81
Understanding the location and direction	13	48.15
Detection of obstacles and stairs	6	22.22
Reassuring the user’s feelings	2	7.41
Other	2	7.41

Table 3
Mean and SD of evaluations for “the period for integrated study” and programming

Item	Female		Male		All	
	Mean	SD	Mean	SD	Mean	SD
I was able to achieve what I wanted to do.	3.46	0.52	3.07	0.92	3.26	0.76
I could program based on what I planned	3.38	0.51	3.29	0.83	3.33	0.68
I enjoy programming classes	3.62	0.51	3.71	0.61	3.67	0.55
I worked on the programming without giving up until the end	3.54	0.52	3.57	0.85	3.56	0.70
Thinking about the order of the instructions, I worked on the programming	3.54	0.66	3.57	0.51	3.56	0.58
What I learn in programming is useful in my daily life	3.77	0.44	3.36	0.84	3.56	0.70
I became interested in programming	3.69	0.48	3.64	0.63	3.67	0.55

In addition, regarding the evaluations during programming activities, “I worked on the programming without giving up until the end” and “Thinking about the order of the instructions, I worked on the programming” both received extremely high scores of 3.4 or higher. The evaluation of items related to programming, “I enjoy programming classes” and “I became interested in programming” were extremely high, with an average response of 3.5 or higher. It can be said that the programming tackled in this trial practice was attractive to children and increased their interest in programming. The average value of responses to “What I learn in programming is useful in my daily life” were also extremely high at 3.4 or higher, probably because programming was used to solve the problems found in the school. It was shown that this trial practice raised the interest for programming in the pupils and made them feel the usefulness of it.

Next, text mining was performed on the descriptions obtained using KH-Coder (Higuchi, 2017). The following reflective responses were obtained. “What I have learned in today's class is that programming is an important device that connects people to people. The next time I do programming,

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I want to make harder blocks and help people with disabilities one after another. Next time, I want to show the flashing lights and help people in wheelchairs.", "When I was programming, I noticed something. In the future, I would like to use programming more to create things that are useful to the blind and deaf. In the future, I would like to use programming more to make things that are useful for people with disabilities." and so on. As a result of morphological analysis, a total of 1,814 words were extracted from the learners' reflections on this study. When the extracted words with more than 10 occurrences were sorted out, in order of the most frequent occurrences, "programming" was used 35 times, "think" 22 times, "make" 17 times, "person" 16 times, "inconvenience" 13 times, and "self" and "class" 11 times.

Then, co-occurrence network analysis was conducted to explore the relationships among the extracted words, and nine co-occurrence relationships were obtained. Figure 3 shows the obtained co-occurrence network. From the nine co-occurrence relationships obtained, we focused on 1, 2, 7, 8, and 9, which are a series of four or more words. The following were the co-occurrence relationships we considered relevant. (1) This included content related to cooperating with friends and being able to utilize it in daily life. It can be said that the goodness of the program was felt through learning to develop AT through programming. (2) This included an interest in devising a mechanism to help people with disabilities. From this, it can be said that the pupils' motivation to help others had increased. (7) There was a description of pressing the button on the Micro:bit and its function. It was presumed that the pupil's understanding of the programming teaching material, Micro:bit, had deepened. (8) There was a description that the user noticed that he or she was informed of his / her situation by making a sound. It turns out that the pupil became aware of the functionality of sound. (9) This included a description of the outline of this class. It can be said that the children worked on learning to incorporate programming after understanding the concept of developing AT for people with vision/hearing impairment through this practice. The following groups of co-occurrence relationships were obtained: (1), corresponding to the review of the learning activities of this trial practice; (2), (7), (8), corresponding to the understanding of AT / programming; and (9), corresponding to the understanding of disabilities. Based on these findings, it was shown that this trial practice was a learning experience that led to better understanding of disabilities and the removal of barriers, with the aim of being able to interact with anyone.

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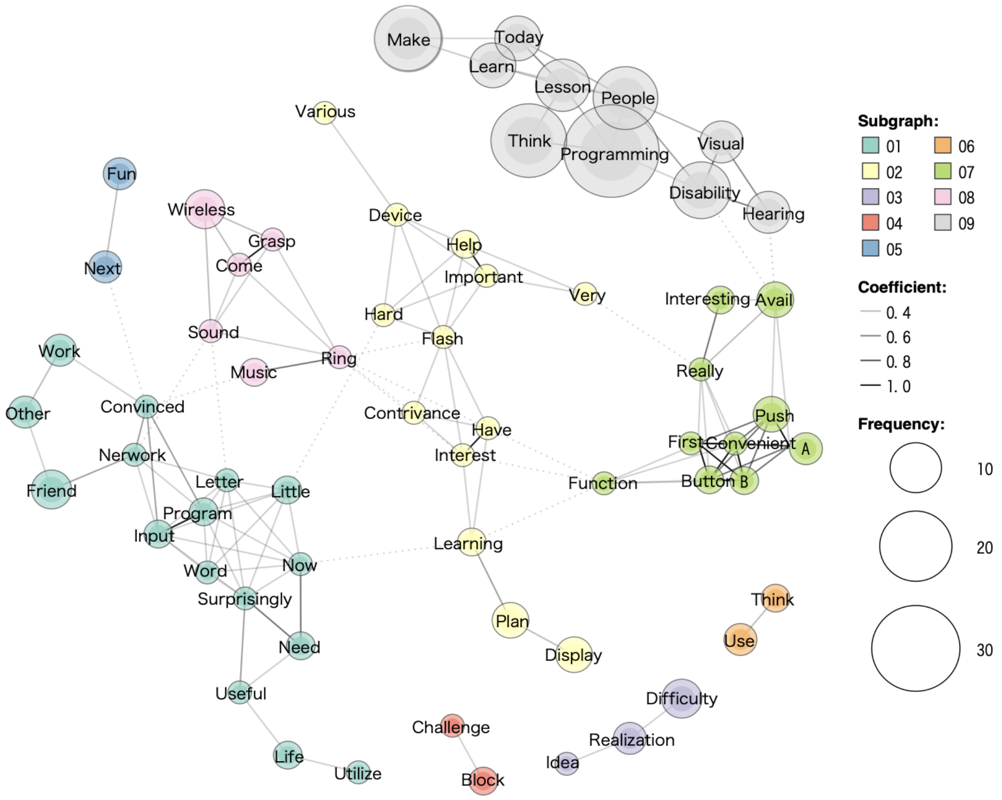

Figure 3. Co-occurrence network diagram for the retrospective description of this learning.

5. Conclusion

As mentioned, we tried to develop learning content incorporating programming from the viewpoint of understanding disabilities, in the period for integrated study for fourth graders. Under the conditions of this study, the following conclusions were drawn:

1) Learning programming with MakeCode and Micro:bit raises interest in programming for fourth graders

2) Incorporating the experience of understanding disabilities in advance helped clarify the problems to be solved using programming.

3)Working on programming to remove barriers creates positive feelings toward programming

In the future, it is thought that understanding disabilities will be further deepened by setting up opportunities to discuss ways to overcome barriers together through learning programming with people with disabilities. We would like to continue our research so that we can develop the technical literacy of pupils who can appropriately apply programming and information technology toward the realization of a society where everyone can live with peace of mind, regardless of age or gender, with or without disabilities.

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