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**Regular Paper**

# Trial of Learning Support System Using Kinect in After School Care Programs

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***Abstract:*** The important roles of after school care programs are protecting the lives of students whose parents are working or unable to be at home after they finish school or on school holidays and helping them create self independence. We propose a learning support system for helping after school care students. The system is used for practicing the "Kuku" multiplication table and it has been implemented using the Kinect motion capture system to recognize "air characters" written by the body actions of learners. We conducted a trial to evaluate the proposed system by asking many students in after school care programs to participate and confirmed that this system was helpful for groups of students to learn. We explain here how we implemented the system, and report the results from the trial. We also suggest the future directions of the system.

***Keywords:*** Kinect, educational technology, body action, after school care

## 1. Introduction

After school care programs and facilities are important for students whose parents are not at home because of work or other commitments. These students spend a lot of time there, and they participate in various activities (for example playing games, doing homework, and even eating snacks) with other students, and they participate in these activities through cooperation and by teaching each other. After school care facilities are places where they can have safe reliable lives. Furthermore, these are places that provide help with their growth and development through various activities.

The use of information devices in educational settings has been increasing over the years. For example, information and communication technology (ICT) devices such as interactive white boards and tablet personal computers (PCs) are now being used in classrooms. Therefore, we believe it is important for students to be able to use various ICT devices, and to experiment using various ICT teaching materials even if the materials are different from their schools' materials. We previously proposed and reported our results from implementing a learning support system that expands on the original Kinect system by combining it with handwritten character recognition software [1].

We had a lot of after school care students operate the system, and they could pleasurably practice the $9 \times 9$ multiplication table "Kuku" using the proposed system through cooperative activities as a result of our evaluation. And we took into account that this system would help in the growth and development of after school care students.

Our paper is organized as follows: Section 2 presents the background to this paper. Section 3 summarizes our system. Section 4 describes the state and questionnaire results of a review. Section 5 concludes and gives our future tasks.

## 2. Background

### 2.1 After School Care

After school care is a childcare service held on the premises of elementary schools after classes have ended. Students whose parents are working or unable to be at home can use the service. Therefore, after school care is an alternate after school life for students.

#### 2.1.1 Target of After School Care

Target students are in grades 1 through 6. A survey [2] by the Ministry of Health, Labour and Welfare (MHLW) revealed that 90% of the students at these centers are in grades 1 through 3 (**Fig. 1**).

Many large-scale after school care programs exist. The standard set forth by MHLW states that after school care programs can accommodate at most 40 students, but in reality, only half of the programs stay within this target. For example, there is a tendency for many after school cares to increase that number to more than 70. However, in many after school care programs, there are only two instructors or maybe three. Therefore, several instructors must instruct many children ten years or younger in these care programs. In addition, first graders who went to kindergarten/nursery school until March or second and third graders who are only 7–9 years old attend these programs together. They have the infant characteristic of "becoming independent while still dependent", and they still need the protection of adults.

#### 2.1.2 Role of After School Care Program

According to the after school care guidelines that are deter-

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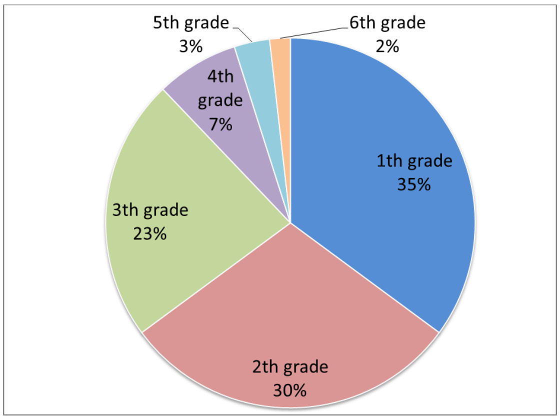


**Fig. 1** Situation by school grade.

**Table 1** Example care program schedule for weekdays.

| Time | Activities |
|---|---|
| 2:30 to 3:00 pm | Arrival/Free time |
| 3:00 to 3:45 pm | Study time |
| 3:35 to 4:15 pm | Eating snacks time |
| 4:15 to 6:00 pm | Free time |
| 4:30 to 6:00 pm | Departure time |

**Table 2** Example schedule for school holidays.

| Time | Activities |
|---|---|
| 8:00 to 9:00 am | Arrival /Free time |
| 9:00 to 10:00 am | Study time |
| 10:00 am to 12:00 pm | Free time |
| 12:00 to 1:00 pm | Lunch time |
| 1:00 to 2:00 pm | Nap time |
| 2:00 to 3:00 pm | Free time |
| 3:00 to 4:00 pm | Eating snacks time |
| 4:00 to 6:00 pm | Free time |
| 4:30 to 6:00 pm | Departure time |

mined by MHLW, the role of these after school care programs is to pursue the health care/safety management of the students, and training them to maintain a basic lifestyle. Furthermore, they aim (1) to cultivate the independence of the students' sociability, originality, and creativity through play, and (2) to fix the environment so that students can voluntarily perform learning activities and then provide them the necessary support.

#### 2.1.3 After School Care Schedule

Since after school care is a prominent part of the lives of many students, they may spend more time at these centers than at school. Students in different grades participate in many activities together, from doing their homework and eating snacks, to playing various games (e.g., cards, board games, or playground games) (**Table 1**, **Table 2**). The time for play occupies most of the schedules. In the free times, they play together. Then, the older students can teach the younger ones the proper ways when they participate in activities.

### 2.2 ICT and Education

The Ministry of Internal Affairs and Communications' (MIC) "Future School Promotion Project" and Ministry of Education, Culture, Sports, Science and Technology's (MEXT) "Learning Innovation Project" are examining the educational effect, and potential problems, to create a better ICT environment. The purpose is to try to design an operating policy which proves that a school with a specifically arranged advanced ICT environment can be successful at helping children learn and mature [3]. In the second education promotion basic plan explanation document from MEXT, we can find "a guarantee for the improvement of the quality of learning" and the "promotion of an evaluation and resultant inflection of the learning effect" through the use of ICT.

The preparation of appropriate ICT has been launched [4] and learning through the use of ICT has already started. We believe learning using ICT will increase more and more in the future.

### 2.3 Purpose of Proposed System

Students spend a lot of time in after school care and students in different grades participate in many activities together, as described in Section 2.1. Therefore, it is possible for them to learn by playing together. It is important for students to touch with ICT devices, as described in Section 2.2.

We consider it beneficial for students to learn by playing with ICT materials. Y. Harada and others created programming education for students after school [5]. We propose a learning support system using the Kinect. We believe the system can support the roles of after school care program (Section 2.1.3). In order for many students to learn Kuku multiplication using our system, the following are necessary:

- Its usage must be simple.
- Students can learn anything with empty hands.

## 3. Summary of Proposed System

Learning in classroom or self-study environments can be difficult. However, learning by playing games has been attracting attention as a way of relieving this difficulty [6]. Kinect motion capture was originally developed as an input device for playing games and is now also used in education [7].

Therefore, we believe that students can learn in a fun way by performing body actions that the proposed system then interprets, thus maintaining their motivation to increase their level of learning.

### 3.1 Learning through Body Movement

Elementary school students share many of the same characteristics: (1) They enjoy using expressive gestures and willingly perform actions, and (2) they enjoy imitating and repeating others, actions that they observe.

There are relationships between memorization and movement [8], [9]: (1) Children receive and memorize new things through their senses and their physical movement. (2) The right brain is connected directly with movement, and movement can therefore aid in memorizing words.

We feel that students will learn more effectively if they do so by moving their entire body. This is why we have developed a system in which students can learn the Kuku multiplication table by moving their body.

| × | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Line 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 2 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| 3 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| 4 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 5 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
| 6 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 |
| 7 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 |
| 8 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 |
| 9 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 |

9×1 = "kuichi gaku", 9×2 = "Kuni juuhachi" , 9×3 = "kusan nijuushichi",
9×4 = "kushi sanjuuroku", 9×5 = "kugo shijuugo", 9×6 = "kuroku gojuushi",
9×7 = "kushichi rokujuusan", 9×8 = "kuha shichijuuni", 9×9 = "kuku hachijuuichi"

**Fig. 2** Kuku table and easy-to-remember rhythms.

### 3.2 Learning Target: Kuku

At the beginning of mathematical learning in the Japanese educational system, students must perfectly memorize a multiplication table called "Kuku," which is the 9 × 9 multiplication table (**Fig. 2**). Students typically memorize Kuku by using wordplay and by creating easy-to-remember rhythms. However, a significant number of students have difficulty memorizing Kuku, and consequently, various games using cards or portable game consoles have been proposed to help with this [10]. Therefore, we propose a learning support system for Kuku that involves writing digits in the air. We are confident that this system can help students.

### 3.3 Using Kinect

There are various systems for writing characters (digits) in the air using gestures, for example, Kinect, Wii controllers, or similar systems [11], [12], [13]. These devices can also help students learn [14]. From our point of view, an ICT device which is intangible is advantageous for large number of students, such as what is found in after school cares. Kinect is a superior system because students can learn anything without having any devices and multiple students can learn at the same time using just one Kinect device. We, therefore, used Kinect as the basis of the proposed system.

### 3.4 Handwriting Character Recognition

Kinect enables a computer to recognize the poses and gestures of a learner. In our expansion of the Kinect, the computer recognizes the characters written in the air by the learner. It identifies the stroke information of the air-written characters, and then a handwriting recognition engine outputs the corresponding character codes.

### 3.5 System Overview

The proposed system configuration consists of a Kinect device, a personal computer, a projector, and a screen (**Fig. 3**).

The process flow of the proposed system is as follows.

1. A question appears on the screen.

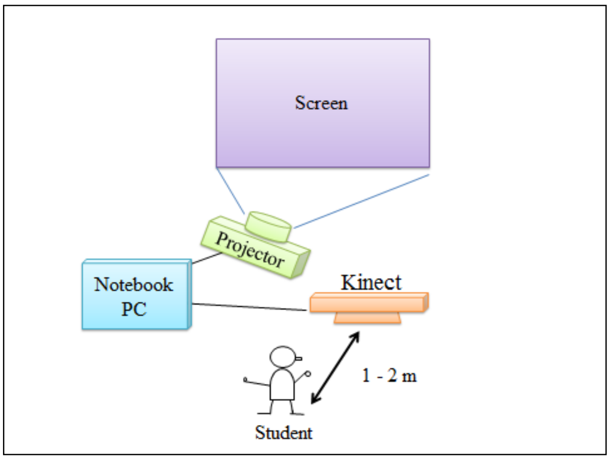


**Fig. 3** Configuration of proposed system.

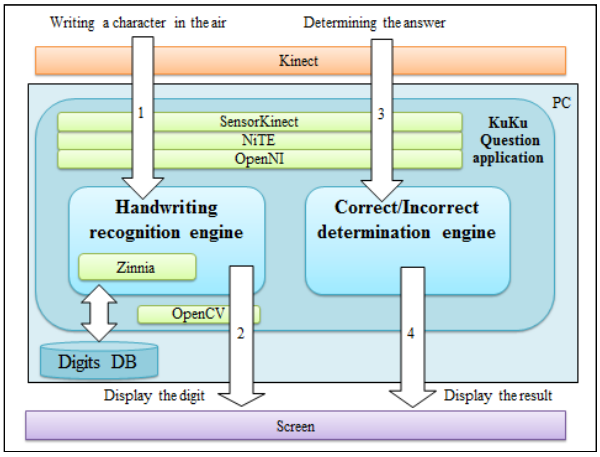


**Fig. 4** Software architecture.

2. The student writes the digits of the answer in the air.
3. The Kinect captures the student's movements and sends this information to the PC.
4. The PC (Kuku question application) returns the result.
5. The result appears on the screen.

The proposed system uses the following software [15], [16], [17], [18].

- OpenNI: framework for 3D sensing
- NiTE 3D: computer vision middleware
- SensorKinect: sensor module device driver for the Kinect
- OpenCV: image display functionality
- Zinnia: handwriting recognition engine

A diagram of the Kuku question application is shown in **Fig. 4**.

This application consists of a handwriting recognition engine and an engine that determines whether an answer is correct or incorrect. The process flow of this application is as follows.

1. The handwriting recognition engine obtains the stroke information of the character.
2. The handwriting recognition engine returns the corresponding character codes.
3. The correct/incorrect determination engine recognizes when the student has finished writing an answer and processes the information.
4. The correct/incorrect determination engine returns the student's correct or incorrect result.

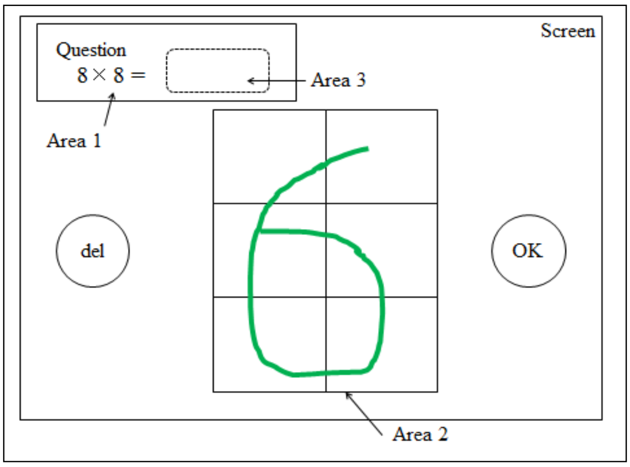


**Fig. 5** User interface.

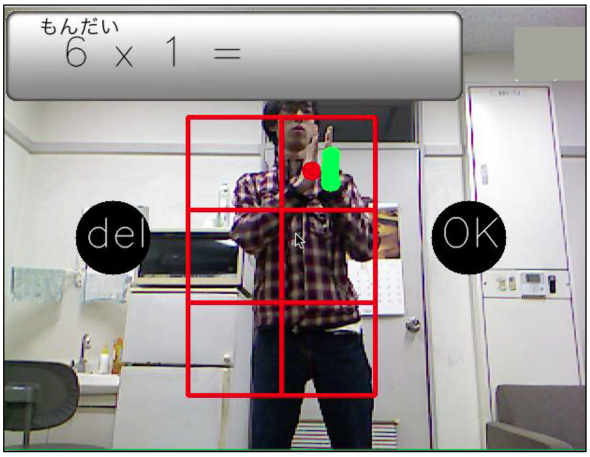


**Fig. 6** Starting character input.

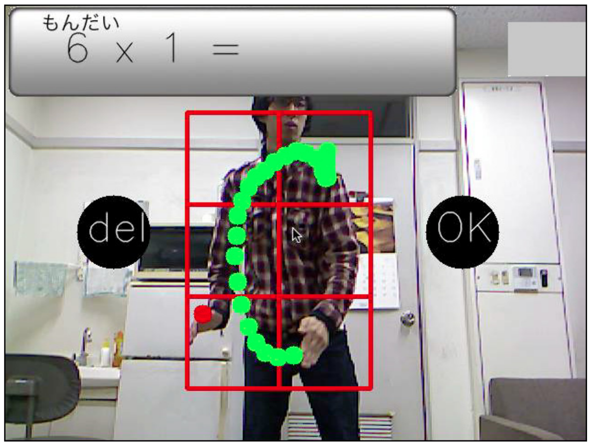


**Fig. 7** Writing characters.

```
(character
        (value 6)
        (width 2)
        (height 3)
        (strokes
                ((2 1)(1 1))
                ((1 1)(1 2))
                ((1 2)(1 3))
                ((1 3)(2 3))
                ((2 3)(2 2))
                ((2 2)(1 2))
        )
)
```

**Fig. 8** Example: S-expression of “6”.

### 3.6 User Interface

The proposed user interface (**Fig. 5**) consists of three areas: Area 1 displays the question, Area 2 consists of six sections for drawing the digit strokes, and Area 3 displays the digit written by the student. The student can erase a digit by sending a delete message to the system by keeping his/her left hand in the “del” area for a preconfigured amount of time. If the student is finished with the answer, an “OK” message can also be sent in the same manner with his/her right hand.

We have kept the number of rules to a minimum in order to make the proposed system easy enough for young students to use.

The student writes a digit in the air to answer. We chose this method for ease of learning. A set of gestures is defined to inform the computer of the controls. The student puts his/her palms together when starting the character input (**Fig. 6**) and writes a character with the right hand to input it into the system (**Fig. 7**). The student stops moving the arm for longer than the threshold time (2.5 seconds) to end the character input.

### 3.7 Handwriting Recognition Engine

This engine uses Zinnia, a support vector machine (SVM) system, to receive the digit strokes as a sequence of coordinate data (x, y) and to output characters sorted by the SVM. The current system uses one coordinate data for a digit. It requires training digit data in a database (DB) (digit DB in Fig. 4). The training data are written in S-expression form (**Fig. 8**).

### 3.8 System Usage

The process flow of learning Kuku with our system is as follows.

1. The student chooses a question method.

   We prepared three question methods.

   (1) Random:
   The system randomly outputs questions from the Kuku table.

   (2) Random for a specified line:
   The student chooses a line from the Kuku table.
   When he/she chooses line 2, the system randomly displays Kuku questions “$2 \times n$ [n: $1 - 9$]” for the nine numbers.

   (3) Ascending order for a specified line:
   The student chooses a line.
   When he/she chooses line 2, the system displays Kuku questions “$2 \times n$” (n is from 1 to 9) sequentially.

2. The student writes the answer in the air.

The student writes each digit of the answer (Fig. 6, Fig. 7). If the displayed digit is different from the digit that the student wants to input, he/she sends a “del” message to the system.

3. If the answer is what the student wants, he/she sends an “OK” message to the system (**Fig. 9**).

The proposed system then displays the student’s correct or incorrect result (**Fig. 10**).

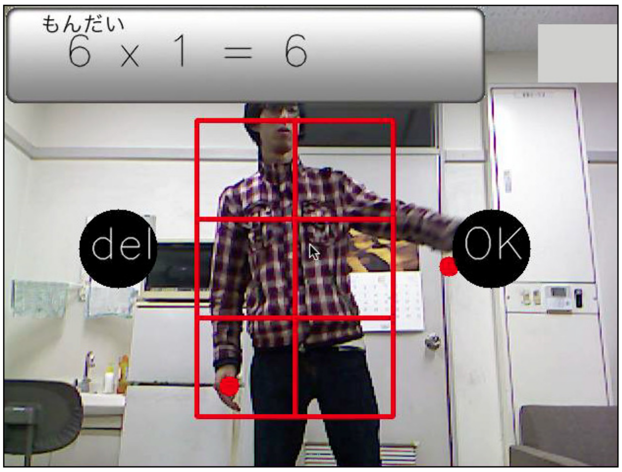


Fig. 9 Sending "OK" message.

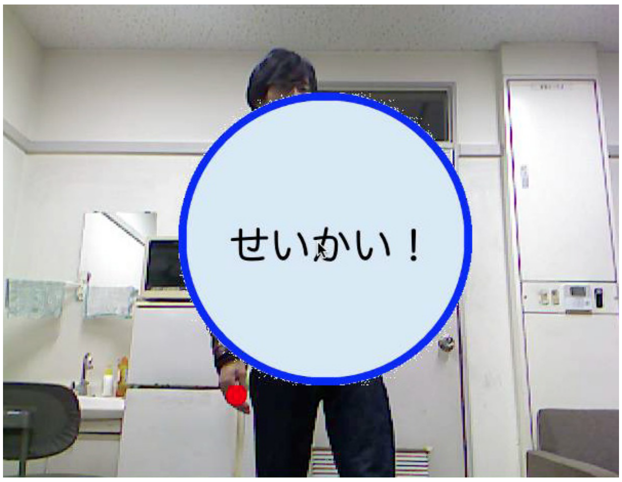


Fig. 10 Displaying correct result.

## 4. Experiments and Evaluation

We reviewed the proposed system on students from a public after school care center for 1.5 hours. The students then answered a questionnaire.

### 4.1 Participants in Experiment

There were 70 students at the center, and 42 of them used the system. There were three instructors at the center, and two of them supported us. The details of the participants are listed in **Table 3**. The third grade students had already learned Kuku at their school. The second grade students had not yet learned Kuku but were going to start in two months.

### 4.2 Experimental Scene

We divided the students into two groups, with equal numbers of students from each grade. Each group evaluated the system. Before this experiment, we taught them the rules for using our proposed system and the students then practiced. One by one they tackled each individual problem, and the other group members watched as each student took their turn. Each student answered from one to five questions. Then, we began the evaluation using the third graders, who took turns using the system.

The students gave their advice to the one currently tackling the problem. Those who had already memorized Kuku answered the question by themselves, and students who had not yet memorized Kuku gave answers suggested by their group members.

**Table 3** Breakdown of students who evaluated system.

| Grade \ Gender | Male | Female | Total (grade) |
|---|---|---|---|
| First | 8 | 8 | 16 |
| Second | 7 | 13 | 20 |
| Third | 3 | 3 | 6 |
| Total | 18 | 24 | |

Fig. 11 Evaluation scene.

An evaluation scene is shown in **Fig. 11**. The student using the system wrote a digit for the answer in the air while his/her group members watched.

When a student tackling a problem did not know what to do, the other members of the same group who had already tackled it instructed him/her how to proceed.

When a student successfully answered a question, he/she was highly pleased with the other group members.

### 4.3 Person and Digit Recognition

Our system was able to recognize most of the students, however, there was a scene where it sometimes could not recognize a student. When the student's clothes, both their top and bottom, were similar in color, our system had difficulty recognizing the person. When the contrast of a shirt and the pants of the student was clearer, our system sometimes recognized his/her waist to be his/her hand.

The after school care's students were novices for our system, so the probability that they were able to definitely input a digit into the system was around 70%. Therefore, students using this system several times can definitely input a digit by more than 90%. However, the students who were not able to definitely input a digit had to concentrate using our system, but their motivation did not decrease. Even if they exceeded the number of acceptable attempts, they still wanted to continue.

### 4.4 Questionnaire Results

#### 4.4.1 Students

Of the 42 students who evaluated the proposed system, 72%

**Table 4** Questionnaire results about body movement and using ICT.

| Question | Grade | Answers: Yes | No | Neither |
|---|---|---|---|---|
| Do you like moving your body? | First N=9 | 9 | 0 | 0 |
| | Second N=17 | 16 | 1 | 0 |
| | Third N=6 | 4 | 0 | 2 |
| Do you like computers? | First N=9 | 8 | 0 | 1 |
| | Second N=17 | 12 | 3 | 2 |
| | Third N=6 | 5 | 0 | 1 |
| Have you used a smartphone? | First N=9 | 2 | 7 | |
| | Second N=16 | 10 | 6 | |
| | Third N=6 | 5 | 1 | |
| Have you used a tablet PC? | First N=9 | 2 | 7 | |
| | Second N=15 | 8 | 7 | |
| | Third N=6 | 1 | 5 | |
| Have you used game consoles such as the Wii or Xbox? | First N=9 | 5 | 4 | |
| | Second N=17 | 10 | 7 | |
| | Third N=6 | 6 | 0 | |
| Have you used Nintendo DS? | First N=8 | 3 | 5 | |
| | Second N=17 | 10 | 7 | |
| | Third N=6 | 6 | 0 | |

answered the questionnaire (**Table 4**–**Table 8**).

The results indicated that 91% of the students liked physical activities where they can move their body, and 78% like using computers. The percentages of students who had used a smartphone or a tablet PC were 55% and 37%, respectively. The percentages of students who had used game systems such as Wii/Xbox and Nintendo DS [19] were 66% and 61%, and therefore, many students had used ICT devices for playing games at home (**Fig. 12**). We asked the students who had used ICT what they used it for (**Fig. 13**). They were able to select more than one answer to this question. They indicated that they used ICT devices for study and research as well as for games.

The favorite activities for students to do at the after school care center are listed in Table 5. The students were able to select more than one answer to this question. Static play refers to play that takes place while the students are seated, for example, playing cards or board games, or doing origami. Dynamic play refers to

**Table 5** Questionnaire results about what students like doing at after care centers.

| | Grade | Answers: Static play | Dynamic play | Homework | Reading |
|---|---|---|---|---|---|
| What do you like doing at the center? | First | 8 | 8 | 7 | 5 |
| | Second | 10 | 14 | 6 | 7 |
| | Third | 5 | 6 | 6 | 6 |
| | Total | 23 | 28 | 19 | 18 |

**Table 6** No. of students who had practiced Kuku.

| | Grade | Answers: Yes | No |
|---|---|---|---|
| Have you practiced Kuku? | First N=9 | 6 | 3 |
| | Second N=17 | 14 | 3 |
| | Third N=6 | 6 | 0 |

**Table 7** Students' opinions of this system.

| Grade | Answers: Interesting | Uninteresting | Neither |
|---|---|---|---|
| First N=8 | 7 | 1 | 0 |
| Second N=16 | 12 | 3 | 1 |
| Third N=6 | 5 | 0 | 1 |

**Table 8** Students' interest in recommending this system to their friends.

| | Grade | Answers: Yes | No | Neither |
|---|---|---|---|---|
| Do you want to recommend this system to friends? | First N=7 | 4 | 0 | 3 |
| | Second N=16 | 12 | 1 | 3 |
| | Third N=6 | 4 | 0 | 2 |

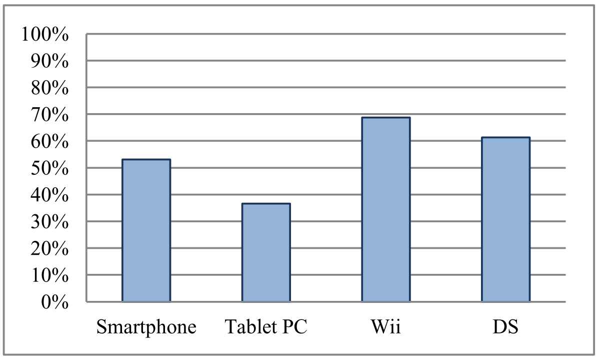


**Fig. 12** Experience using ICT devices.

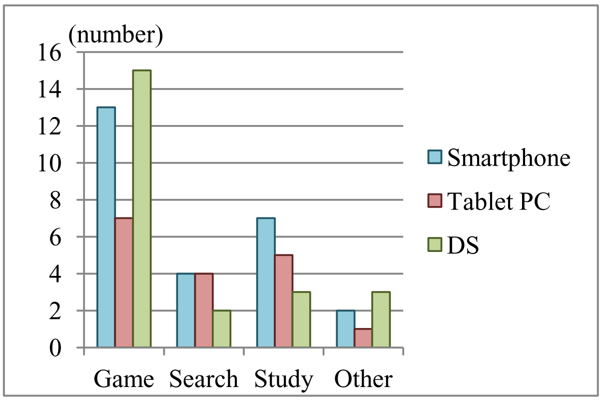


**Fig. 13** Purpose of using ICT devices.

physically active play that involves moving the body, for example, dancing, playing soccer or dodge ball, or playing with a kendama toy. The students liked dynamic play the most, and they liked any kind of play more than they liked studying (doing homework or reading).

The number of students who had practiced Kuku before are summarized in Table 6. The third grade students practiced at their schools and homes. The other students practiced at home or at a cram school.

The questionnaire results for this system are presented in Table 7 and Table 8.

The results indicated that 80% of the students were interested in this system. The students who used ICT games (Wii/DS) enjoyed this system (89%). Therefore, it may be that this system is just as interesting for students to use as for playing ICT games.

The students who had practiced the multiplication table were interested in this system more: among the students who had practiced Kuku, 90% of students were interested in this system, and among the students who had not practiced Kuku, 75% of students were interested. Therefore, the students who had practiced Kuku were able to enjoy this system more than those who had not practiced. However, students can try this system happily whether or not it is focused on a subject that they have practiced or not. This may be because students challenged this system while the other students in a group taught them how.

The results indicated that 69% of the students wanted to recommend this system to their friends. Among the students who were interested in this system, 80% of them wanted to recommend it to their friends.

The students who answered "yes" added comments such as:

- "I enjoy challenging activities where I can move my body."
- "I can practice Kuku happily using this system."
- "It is very easy to practice Kuku using this system."
- "I can play a lot."
- "I want to tell my friends that I had fun doing it, and I want to do it again next time."
- "I want to practice Kuku with my friends."

We evaluated the system and found that it is useful for students to enjoy learning Kuku. Their statements were sufficient for us to evaluate and tweak the system to make it more attractive and practical.

#### 4.4.2 Instructors

There were two instructors who participated in the experiment. We also asked them some questions.

■ We asked about play time at their center. The answers are as follows.

- The group play time is longer than personal play time.
- They think that it is very important that the students teach each other during play. When the students play in a group, they instruct the older students to become leaders as much as possible, but an instructor sometimes becomes the leader when it is difficult for the older students.

■ We asked of this experiment. The answers are as follows:

- The students enjoyed the experiment.
- Even if one's turn was over, they did not want to take the place of the next student, because they wanted to try it more and more.
- The students who had already tried it taught a student who was trying to use it.
- It matched the passage of time when using ICT materials.

■ They wanted to use this system as assistance to learning when it is improved.

■ We asked the following, "This system would be better if we improved what? Choose items from among the following (Nothing, Setting, Operability, Increased recognition, No. of kinds of problems, Other)." The answers were:

- "Increased recognition"
  One of them said the following. The body recognition needed to be almost 100%. Therefore, the digit recognition can be lower. The students can definitely enjoy it when they play in a group even if they cannot input a digit at first.
- "Setting of the system"
  It was desirable for it to be as easily prepared as possible. Another said "No. of kinds of problems" needed improvement, so that students from every grade could enjoy it.
- "No. of kinds of problems"
  There should be addition and, subtraction problems so all school years could enjoy it. Furthermore, the students can enjoy the alphabet.

■ We asked whether they recommend this system to other instructors as a tool cultivating the independence of children and their sociability, and as a tool for acquiring the power that children need to voluntarily perform learning activities when it is improved. They answered that they did, and items needing improvement were the "Increased recognition," "Setting," and "Operability."

■ We asked whether they think that this system helps students develop independence, sociability, and originality through play. They agreed it. One of them said that the students taught each other, and therefore this system helped to improve the students' sociability. Another said that it is important that the students try it in a group.

■ We asked whether they think this system helps you set up an environment where students can voluntarily perform learning activities and give the necessary support. They agreed. They said that the students will have an increased interest in learning while playing with this system, because this is similar to a game.

From this questionnaire, we understood the following things:

- The students were able to enjoy this system.
- They taught each other.
- There were students who could not do operations/ inputs as expected, but they continued challenging it.
- It is thought that this system helps students develop independence, sociability, and originality through play, and helped to fix the environment in which students could voluntarily perform learning activities and give necessary support.

## 5. Summary and Future Tasks

After school care centers are a place for students whose parents are working or unable to be at home after they finish school. They spend a lot of time there and grow up with their friends. The mission of after school care programs is to cultivate the independence of students' sociability, originality, and creativity through play, and fixing an environment so that students can voluntarily perform learning activities and give the necessary support. We believe our proposed and implemented learning support system can help with this mission. This system uses the Kinect motion capture combined with handwritten character recognition software. It recognizes digits written in the air through the physical motions of students learning Kuku.

We tested and evaluated the system using students in an after school care program and concluded that the proposed system, with its actions involving moving the body, was effective for maintaining the students' motivation to further their studies. The evaluation results indicated that students from grades 1 through 3 were interested in learning Kuku using the proposed system, and they wanted to recommend the system to their friends. Therefore, we concluded that the proposed system can support student learning in after school care programs. Additionally, we researched this system using instructors. We concluded this system needs some improvement, but can assist in students' growth in after school care programs.

Our future tasks are twofold: (1) we shall refine the implemented system based on the experimental results and student feedback; for example, the body and digit recognition must be improved, the gestures for starting and ending the writing of a character should be easier than the current gestures, and we will use the system in after school care center again to check these refinements. (2) Although we used the scenario of learning Kuku in this study, in the future we intend to apply the proposed system to learning addition, subtraction, division, and the letters of the English alphabet.

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