CS Unplugged with Assisted Digital Materials for Handicapped People at Schools

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Abstract: We report practice lessons in 'Computer Science Unplugged' (CS Unplugged) with assisted digital materials. CS Unplugged involves physical or group activities that lead students to computer science, and it is an excellent method of informatics education for beginners. However, such activities are not always easy for all students. Therefore, we designed various digital materials to assist students with such activities. We also adopted these to the lessons of CS Unplugged at a vocational training school for the disabled. As a result, we observed that the materials effectively assisted students with their lessons.

Keywords: Computer Science, computer science unplugged, informatics education

1 Introduction

Computer Science Unplugged (CS Unplugged) [1][2] is an excellent method of learning the basics of computer science. There are many junior/senior high schools and universities in Japan in which CS Unplugged has been used [3]. CS Unplugged has three outstanding features [4].

- It consists of active games (e.g., drawing/painting, magic tricks, and group learning).
- Each activity leads to students learning some concepts of computer science.
- None of the activities require computers.

The authors adopted CS Unplugged in the curriculum for a course at a vocational training school for people with disabilities in 2008 and tested and confirmed its learning effects. However, we noticed that kinesthetic activities might not be able to be exercised in class because of physical or communication problems.

This paper discusses a solution that is assisted by computers to CS Unplugged activities. The authors developed various digital materials to solve these problems. We report practice lessons and the effect of these materials.

2 Adoption of CS Unplugged in Vocational Training School for Handicapped People

2.1 CS Unplugged Content

One of the authors translated CS Unplugged into Japanese and had 'Informatics not using computers' published in 2007 [5, 6]. The book detailed 12 activities. Table 1 summarizes its contents.

Table 1 Informatics not using computers

Activity	Title	Activity's Content	Digital Materials
1	Count the Dots	*Binary Numbers*	✓
2	Color by Numbers	*Image Representation*	✓
3	You Can Say That Again!	*Text Compression*	
4	Card Flip Magic	*Error Detection & Correction*	✓
5	Twenty Guesses	*Information Theory*	
6	Battleships	*Searching Algorithms*	
7	Lightest and Heaviest	*Sorting Algorithms*	
8	Beat the Clock	*Sorting Networks*	✓
9	The Muddy City	*Minimal Spanning Trees*	
10	The Orange Game	*Routing and Deadlock in Networks*	✓
11	Treasure Hunt	*FiniteState Automata*	✓
12	Marching Orders	*Programming Language*	

For example, Activity 4 (Card Flip Magic) treats error correction by using parity bits. This lesson begins with a demonstration of a card magic trick by the teacher.

First, a student places many two-sided cards on a blackboard as a matrix of 5x5 squares. The teacher (magician) places more cards in a row and in a column while saying 'this is just to make it a bit harder'. Next, the teacher turns around, does not face the cards, and the student flips over one of the cards. Last, the teacher can hit the card, which the student flipped over, even though the teacher had been looking in the opposite direction. After the magic trick, the teacher lets students think about why he/she could hit the card, where additional cards should be placed, and other details. These questions lead to the concept of parity bits. If students notice or discover this concept by themselves, they gain greater educational benefits rather than just being taught by the teacher.

Thus, CS Unplugged is a learning method that raises students' motivation and attracts them to the world of computer science.

2.2 Adopting CS Unplugged to Vocational Training of Disabled Students

In 2008, we tried to adopt CS Unplugged in the curriculum for the 'OA System Course' of Kanagawa Vocational Training School for students with disabilities. This school was established with the aim of disabled people gaining social independence through vocational capabilities. Computer literacy was the most important skill they had to acquire.

The OA System Course, which is for physical disabilities, is a special course that grooms students to become computer programmers or systems engineers. Therefore,

the students have to study computer science and computer technology. The main content of vocational training, which is related to computer technology, is generally to teach how computer programs are made. Therefore, traditional learning content and learning methods were adopted for this course.

However, many of the students enrolled at this school so that they could be rehabilitated into society after difficulties they had after experiencing accidents or sickness. They wanted to make information processing their occupation, but they had no interest in programming and disliked thinking logically. Additionally, there was one student who was not able to sufficiently learn through the process of compulsory education due to long-term hospitalization and there was another who was not able to take notes due to physical reasons. Therefore, even a book for beginners was sufficiently obscure to decrease their motivation to learn. The conventional learning approach was not suitable for basic study of their future occupations.

Therefore, we decided to try to adopt CS Unplugged into the curriculum because it does not require assumed knowledge and it leads to the basics of computer science. Therefore, all students could learn about computer science without difficulties. We also expected that CS Unplugged might develop their logical thinking abilities.

There had been no instances where CS Unplugged had been adopted in any vocational training curricula. First, students seemed to be confused due to such a strange method of learning. However, they found CS Unplugged was an excellent learning method as they progressed through the curriculum. However, we confirmed that some features such as kinesthetic activities, physical movements, and communication skills in CS Unplugged became a serious issue for students with disabilities.

3 Issues and Achievements with CS Unplugged Practice at Vocational Training School for Students with Disabilities

3.1 Issues with CS Unplugged Practice for Disabled Students

We examined what kinds of issues existed when 'normal' activities were carried out. For example, students who had upper limb disorders could not understand activities such as 'coloring in with a pencil' or 'grabbing with their hands'. These difficult activities affected the movements of moving materials in Activity 1 (Count the Dots), Activity 10 (The Orange Game), and the work time for 'coloring in with a pencil' in Activity 2 (Color by Numbers).

Physical movements in Activity 8 (Beat the Clock) or in Activity 11 (Treasure Hunt) were dangerous for students who had lower limb disorders. Consequently, such students could not participate in these activities. One student who had communication problems found it difficult to practice cooperative activities such those in Activity 6 (Battleship) or Activity 10 (The Orange Game).

3.2 Development of Assisted Material for Handicapped Students

One of the authors developed six online materials, which were based on CS Unplugged (checked in fourth row of Table 1) to assist students with the activities.

The materials were uploaded to a Web site [7]. These materials were developed for personal use. There were three support patterns.

1. Replacing some actions (e.g., drawing/writing) by clicking with a pointing device.
2. Replacing group work with personal work
3. Simulating group work

The materials could be used repeatedly in the lesson or after it. Fig. 1 shows screen shots of the materials.

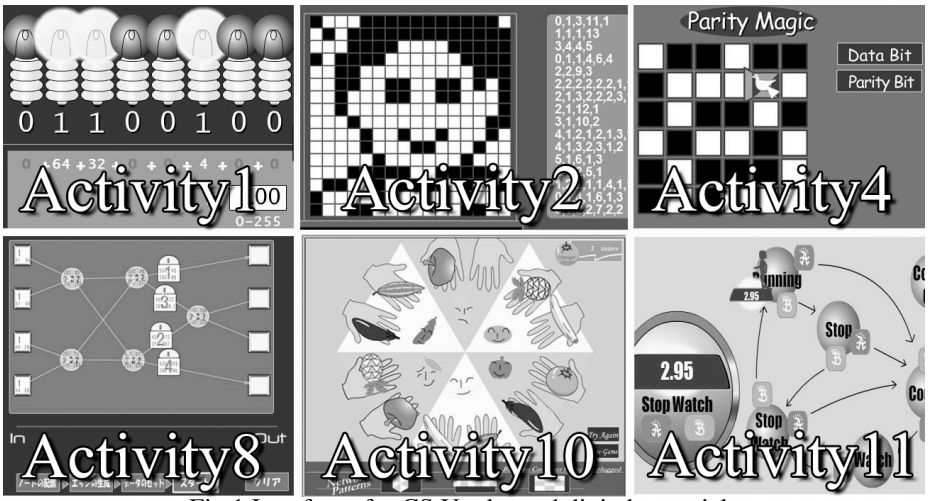

Fig.1 Interfaces for CS Unplugged digital materials

The virtual world could also be an assisted environment. One of the authors had previously participated in research on CS Unplugged for disabled people [8], which was executed in the 3D virtual world of Second Life. Students in the virtual world could move around freely and communicate with one another by transforming themselves to avatars. Therefore, it was possible to practice CS Unplugged activities in this virtual world.

4 Trials on digital material to provide learning support

4.1 Activity 2 (Color by Numbers)

This section introduces the lesson content for Activity 2 (Color by Numbers). This activity dealt with how images were digitalized to represent images on computers. A run length algorithm was used to digitize the images for this activity. Students could

learn the basics of digitalization and data representation of images throughout the work of coloring in dots in pencil, translating dots to numbers, and simulating communications. Our lesson plan involves seven steps.

Lesson plan:

1. The teacher urges students to notice the rules for the run length algorithm through a quiz game.
2. The students draw/paint an image on a card by coloring in small dots in pencil.
3. They translate/digitize the image to digital data with the run length algorithm.
4. Students exchange cards, which are written in digital data.
5. They color/encode the digital data that they received to dots. (Fig. 2)
6. They compare two images of the source and destination.
7. The teacher asks students how a computer stores data and what the important elements about network communication are.

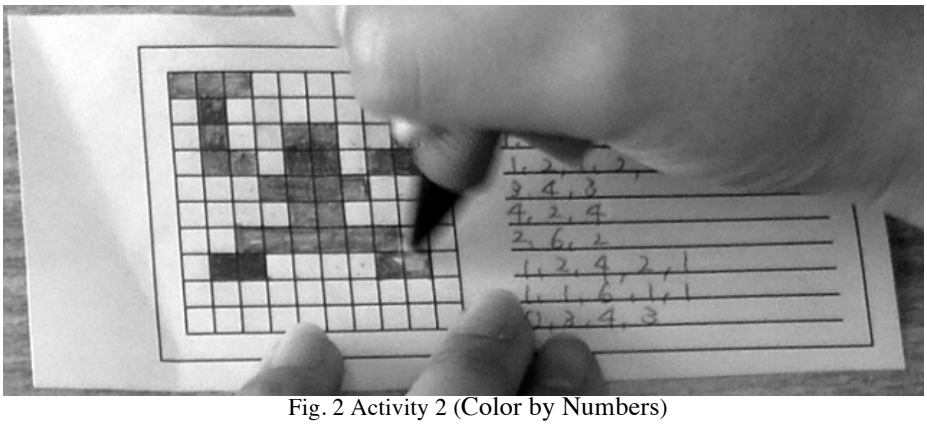

Fig. 2 Activity 2 (Color by Numbers)

Most of the students in the class lesson were surprised at the principles underlying digitization or the communication of digital data. It was important for students to understand such principles in this lesson by coloring in the dots. Coloring work was done twice. This work was important to establish the relationship between colors and numbers. However, coloring in dots in pencil is difficult for students who have upper limb disorders and erasing dots is actually more difficult than coloring them in. This caused such students to work inefficiently or lose concentration while learning.

We adopted digital materials based on Activity 2 in the lesson to solve these problems. These materials assisted students with manual coloring by enabling them to click with a mouse or use a track ball. These were used in lesson plans 2 and 5.

The functions of these digital materials are explained below.

The canvas consisted of many small square tiles. The default number for the tiles was 256 (16x16). The students could change the tiles by clicking with the mouse. Each tile had two states, one side was white and the other was black. If a white tile was clicked with a pointing device, it converted to black and if a black tile was clicked, it converted to white.

Fig. 3 is a photograph of a student who had a severe impairment to his upper extremities. His grip was so weak that he could not use a pencil or eraser. He usually used a ballpoint pen for writing that was fixed to his hand with special equipment. He operated the track ball as a pointing device to use the computer and had two special pieces of equipment fixed to each hand to attach the ballpoint pen to and to type on the keyboard with the pens.

Fig. 3 Student with impairment using upper clicked trackball with special equipment for drawing/painting

The student spent too much time when he drew in pencil by hand, and a trace protruded outside the frame. However, when he drew with the materials, he could reduce his working time. He was freed from having to worry about whether the trace had protruded outside the frame.

The student's four main comments were:

- I felt good as I did not want to color in the dots in free hand.
- I wondered why the numbers became a painting.
- I even enjoyed this lesson even though my drawing was poor.
- I understood the basics of digitization by using this learning material.

We found that the materials decreased the difference in working time between the student with upper limb disorders and other students. The student could also concentrate on his original studies without having to worry about whether the trace of the pen was outside the frame by using these materials.

4.2 Activity 10 (The Orange Game)

This section introduces the lesson for Activity 10 (The Orange Game). This activity dealt with the routing algorithm for a computer network. Students could learn about these concepts by delivering oranges (we used some actual fruit) as packets.

This activity was usually practiced in groups and students could note the importance of processing efficiency through working collaboratively. Therefore, all communication skills by the participants were important factors for problem solving.

Our lesson plan involved five steps.

Lesson plan:

1. A group of six students sits in a circle.
2. The teacher distributes fruit to students randomly and each student has two pieces of fruit. (Each student holds one piece of fruit with his/her other hand empty)
3. The teacher explains the rules of the game where students can only pass the fruit to both sides.
4. All students cooperate throughout the activity.
5. The teacher explains routing in a computer network after the game.

Fig. 4 Activity 10 (The Orange Game)

Group members in this activity had to pass the fruit to aim for the goal where all members were holding their own fruit. If any member thought that "I got my own fruit and I've finished", then the entire situation might not lead to a solution. It was important for each member to recognize the group status and share their method of delivering fruit to avoid such situations.

The conditions in classrooms at the vocational training school were as follows. The class for the lesson was divided into three groups. We observed the activities of all three groups. The first group evolved throughout the game by taking note of the time and counting the number of deliveries. The second group discussed how to obtain a better solution. However, the third group that was composed of three deaf students and three students with normal hearing did not communicate sufficiently and could not reach the goal even once. It was obvious that there was a lack of communication between the deaf students and those with normal hearing. We observed their efforts to communicate when they used gestures or writing. However, these were not sufficient to enable them to communicate effectively. This reduced their motivation and the activity was terminated without being completed. This meant they could not fully realize the importance of processing efficiency through collaborative work.

We predicted that if all member of the group attained a high level of ability in attaining a solution, then the whole group would reach the goal. We adopted digital materials based on Activity 10 in the lesson to develop personal abilities to solving this routing problem. The students played the orange game alone (Fig. 5) by using these materials. All the fruit had to be moved through individual thinking. Therefore, we expected individual abilities would increase. The fruit could only be placed on a neighboring player's hand in the same way as in the real game. The number of times fruit was received was counted. They could focus on learning objectives to simplify non-essential tasks, such as painting with colors.

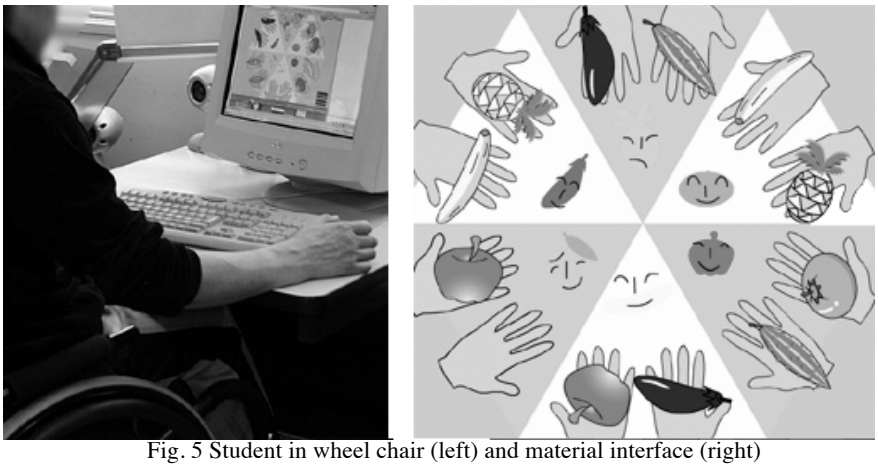

Fig. 5 Student in wheel chair (left) and material interface (right)

We taught an experimental lesson in another course at the vocational training school. First, the lesson began with the 'normal' orange game. Next, we made students use the materials. Last, the students played the 'normal' orange game again. Then, all groups were able to reach the goal.

Repeating the same games made some students get the knack of obtaining a solution. Moreover, we could see how students considered solving the problem by observing their computer displays. This enabled us to give appropriate advice to individual students.

The four main comments students made are below.

- I felt it was hard because I had to move the oranges only by thinking.
- I could do it well by myself but my group could not.
- I felt the difference between the flat screen of the personal computer and the actual three-dimensional sensation was odd.
- I understood I had been repeating useless movements by using these digital materials.

Three more tendencies were discovered.

- Two opposite opinions coexisted. "My group could not do it well but I could " and "It was hard to think only by myself on the materials".
- There were some opinions about the differences between the computer screen and the actual appearance of the fruit.
- There were many opinions that required the best solution to be indicated in the materials.

We could infer the relationship between personal ideas and group work, which was not evidenced in the group activity by observing the students using the materials. Moreover, we confirmed that students adopting personal learning with the materials led all of them to think more deeply about the run algorithm.

4.3 Activity 8 (Beat the Clock) in Second Life

This section introduces the experimental lesson for Activity 8 (Beat the Clock), which was practiced in a 3D virtual world. The students in this experiment had already practiced the 'normal' Activity 8 (Fig. 6).

Fig. 6 Activity 8 (Beat the Clock)

This activity dealt with parallel computing where students could learn about this concept by walking on a parallel sorting network marked on the floor. The network was constructed with various lines and nodes. This activity was usually practiced by six students who walked along the lines of the network comparing the numbers on cards that they held at each node. When the students reached the goal, they could see that six numbers were perfectly sorted in order. This surprised the students and aroused their intellectual curiosity.

This activity was dangerous for students who had lower limb disorders. Some students did not participate in the 'normal' activity to avoid accidents.

However, even disabled students could move around freely in the virtual world by walking, running, jumping, and flying. A large network had been constructed in Second Life (Fig. 7) in this research.

First, the students tried to carry out ‘Beat the Clock’ in Second Life. They were able to execute this without any feelings of danger. Six large cubes and one button had been prepared in this sorting network area. Each cube had a number written on its surface. When an avatar pushed the button, the cubes began to move along the network lines to compare the numbers. The avatars and their users (students) could watch the movements of the cubes. Some avatars flew into the sky and experienced a bird's-eye view of all the movements.

They could not look over all the movements in the 'normal' activity. However, they could recognize what they had done from all viewpoints in the 'virtual' activity. This meant that virtual activities had other effects that real activities did not.

Most students enjoyed the experience and said they would like to use it more. The students who could not practice in the real world appreciated this implementation. We confirmed that the digital environment could remove factors that prevented learning with CS Unplugged in this research.

Fig. 7 Activity 8 (Beat the Clock) in Second Life

5. Using digital materials in high school lessons

We recognized the effectiveness of the materials in alleviating physical problems when CS Unplugged was adopted for the practice lessons at the vocational training school. We also observed that the materials had effects other than assuaging their physical problems. Consequently, we used them in a high school lesson on a compulsory subject called 'Information'. We taught the lessons at Hadano-Sogo High School and observed the students.

5.1 Activity 2 (Color by Numbers)

We began to do 'normal' unplugged activities as we handed out paper and pens to the students. We found some students who concentrated on painting in dots or who spent too much time on painting in dots rather than coding data in the primary learning materials. Therefore, we taught other classes to use the digital materials where drawing/painting were alternated with clicking. As a result, these problems decreased and students focused on coding.

5.2 Activity 10 (Orange Game)

The lesson began with the 'normal' unplugged orange game, where the group was divided into two types of students, in which the first were directors and the second was directed. The directed students did not seem to think for themselves. Therefore, we made the students use the materials, where all students cooperated in all movements by group members. As a result, we found that all students began to think about the 'effective delivery of packets'.

5.3 Activity 8 (Beat the Clock)

We developed other digital materials (not Second Life) for Activity 8 (sorting network). We thought that there were two problems with this activity. The first was that there were some students who could not understand what this activity meant. The second was that students could not watch all movements and they did not understand what was happening.

We implemented a 'bird's-eye view' to solve these problems, where students could look down on the whole network. We also implemented 'changing the number of members, where they could increase/decrease the number (data). Students were able to think about the meaning of this activity and understand all movements by using the materials after the original activity.

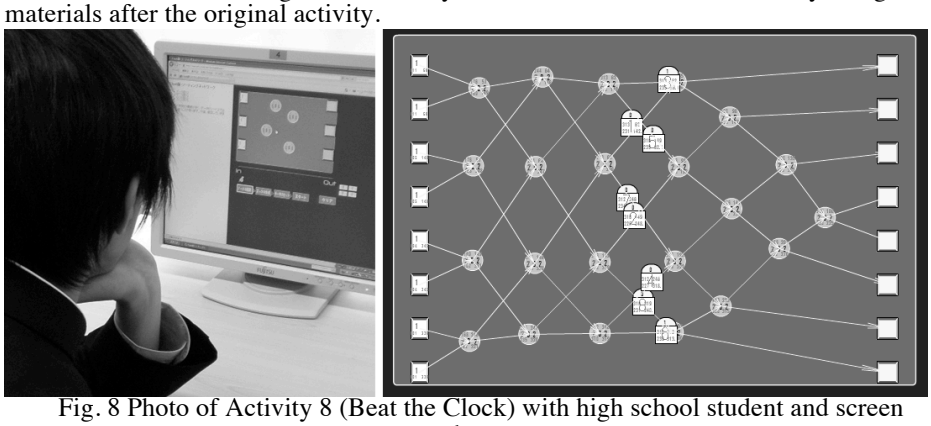

Fig. 8 Photo of Activity 8 (Beat the Clock) with high school student and screen shot

6. Conclusion

We tried to adopt CS Unplugged in the vocational training of disabled students and tried to support them by using digital teaching materials.

The students' learning attitudes were very positive in all activities and CS Unplugged was an appropriate learning method for vocational training for disabled students.

There were some activities in which disabled students could not participate thoroughly enough. However, handicapped people also have rights to experience excellent learning methods such as CS Unplugged. The digital materials supported them by giving them chances to gain a positive learning experience.

The students in general high-school education who used the digital materials developed by one of the authors, demonstrated three different effects to the students with disabilities.

- They could focus on learning objectives to simplify non-essential tasks, such as painting with colors.
- They could think about steps in the algorithm by trial and error alone.
- They could understand the activities by using the bird's-eye view of the entire activity.

We would like to develop digital teaching materials in the future that are more useful by listening to the opinions of numerous students and teachers.

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