New Methodology of Information Education with "Computer Science Unplugged"

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Abstract. We introduced "Computer Science Unplugged" to our classes in junior and senior high schools. "Unplugged" is an education method of computer science without students using a computer at all. For our classes, we developed original teaching materials and methods for Unplugged. As a result, the students could learn the topics of computer science with interest by using Unplugged. They enjoyed the games in Unplugged and thought about the topics deeply at the same time. We confirmed that students enhanced their motivations, thinking abilities and imaginations

1 Introduction

Information education became common area in Japan by the revision of curriculum guidelines in primary and secondary education in 2002 and 2003. However, lots of students only learn how to use computers and application software such as word processor, spreadsheet or presentation in schools. Some teachers do not teach the computer science because they regard computer science as so difficult for students in junior and senior high school.

However students could be familiar with computer science because they are familiar with mobile phones or video games which include computers in their daily life. On the other hand, it is difficult for students to understand individual topic in computer science such as searching or sorting because they cannot find importance of these things in their daily life.

To solve problems mentioned above, we introduce "Computer Science Unplugged"[1][2][3] (called "Unplugged" hereafter) which is the education method of computer science without students using a computer at all to classes in schools.

Unplugged provides sophisticated teaching materials and they are suitable for children of a range of ages. Students can enjoy the activities with them and can learn typical computer science topics actively, therefore they become interested in computer science. The project "Unplugged" was initiated by Tim Bell(University of Canterbury, New Zealand) et al. He decided to make the

teaching methods and materials about ten years ago because he wanted to show the fascinating aspect of computer science for his five-year-old child.

They published first textbook[4] in 1998 and now provide the textbook on the Internet[1]. Korean[5] and Japanese[2] versions were also published.

We developed original teaching materials for Unplugged and conducted lessons at schools. As a result, we confirmed that students could learn the computer science topics with interest by using Unplugged. In this paper, we report our lessons and their outcomes.

2 Textbook: "Computer Science Unplugged"

Table 1. Contents of the Textbook

Chapter	Title	Sub title	Ages
1	Count the Dots	Binary Numbers	7 and up
2	Colour by Numbers	Image Representation	7 and up
3	You Can Say That Again!	Text Compression	9 and up
4	Card Flip Magic	Error Detection & Correction	9 and up
5	Twenty Guesses	Information Theory	9 and up
6	Battleships	Searching Algorithms	9 and up
7	Lightest and Heaviest	Sorting Algorithms	8 and up
8	Beat the Clock	Sorting Networks	8 and up
9	The Muddy City	Minimal Spanning Trees	9 and up
10	The Orange Game	Routing and Deadlock in Networks	9 and up
11	Treasure Hunt	Finite-State Automata	9 and up
12	Marching Orders	Programming Languages	7 and up

2.1 Contents of The Textbook

The Unplugged textbook contains 12 chapters(Table 1). Each chapter involves the important topic in computer science. In ordinary circumstances, they are too difficult for children. However even elementary school students can understand them because the textbook provides well-thought explanations and fun activities.

2.2 Example of The Contents

In chapter 4, they use "Card Flip Magic" to show how to detect and correct an error(Fig.1). We label a girl as Student A and a boy as Student B in the figure. For this demonstration they use flat magnetic cards that have a different colour on each side.

The procedure of "Card Flip Magic" is following.

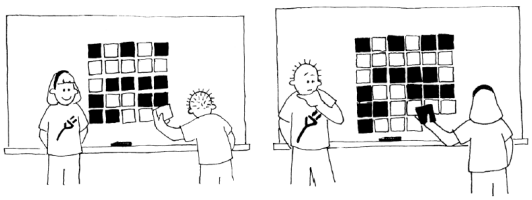


Fig. 1. Card Flip Magic

1. Student B lays out the cards in a 5 × 5 square with a random mixture of sides showing.
2. Student A says "just to make it a bit harder" and adds another row and column casually.
3. Student B flips over one card while Student A covers her eyes.
4. Student A points out the card which is flipped.

The trick of this magic is a one-bit parity. The cards that Student A added are the key to the trick. Student A must choose the extra cards to ensure that there is an even number of coloured cards in each row and column. The row and column containing the changed card will have an odd number of coloured cards and this will identify the changed card.

Students join this activity without any explanation about the parity bits. Therefore they try to find the trick of the magic eagerly and want to be magicians.

A teacher explain the trick and the parity bits after most of the students find the trick. After that, they learn "ISBN" and "bar-code" as real-life examples of the check digits. They also calculate ISBNs of books. In closing, the teacher explains the needs of error detection and collection by showing another examples in daily life, e.g. banking.

As described above, by using this method, students can learn topics in computer science without computers. It is difficult for students to have an interest in the parity bits and understand the essence of them only with textbooks and oral explanations. Students might forget the word: "parity bits" even if they learn it by using Unplugged. However they will remember the essence: "errors can detect with data for checking" because they had hands-on activities.

In similar way, students can learn various topics in computer science with hands-on activities by using this textbook.

2.3 Significances of Unplugged

(1) "Games" in every learning
Students can learn through "play" therefore they become interested in the topics. Some topics are difficult for students but they can enjoy them.

(2) Trial-and-error with real things
There are lots of hands-on activities with cards, scale and weights, balls and so on and they stimulate thoughts of students. Students can habituate themselves to think logically through trial-and-error.

(3) Learning in a group
There are lots of activities in a group. Students are expected to think deeply because these activities affect one another. They would also be good practices to communicate with others.

(4) Without circumstance
In most cases, students can start their activities with worksheets on the textbook. Teachers can make original teaching materials(Fig.2) at a moderate price if they need. They do not have to use the computer classroom and they can learn in the regular classroom or out of the classroom.

Fig. 2. Original teaching materials packed in small cases

3 Our Lessons at Schools

In this section, we introduce lessons which we conducted at one junior high school and two senior high school.

3.1 Lessons at Iinan junior high school

At Iinan junior high school (Matsusaka city, Mie prefecture, Japan), in the subject of "technology and home economics", one of the authors had been conducting the classes with Unplugged for 2 periods: from January through March 2007 and from April through September 2007.

The aim of these lessons were to enhance students' motivations, thinking abilities and imaginations by using Unplugged. The teacher also expected his students to increase their communication abilities through games in Unplugged.

The purpose of these lessons is not to teach technical knowledge of computer science but to give opportunities that the students think about the essences and the fundamental principles of computer science. This policy meets the purpose of "technology and home economics": "developing abilities of innovation and creation in real life". By using Unplugged, the students enjoy learning these things and their abilities will grow.

Overview of His Classes

At first period: from January through March 2007, the teacher had been conducting 10 hours of classes for 3rd grade students(16 students × 4 classes, elective). He taught all chapters of Unplugged textbook. At second period: from April through September 2007, he had been conducting 9 hours of classes for 3rd grade students(12 students × 4 classes, mandatory). Based on his experience in the first period, he selected 8 chapters of the textbook.

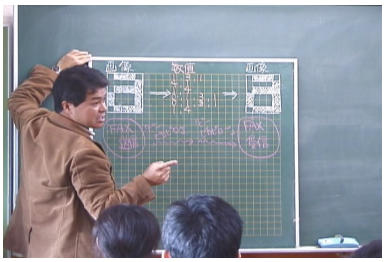
Table 2. Curriculum for junior high school A(second period)

Chapter	Subject
2	Image Representation
3	Text Compression
4	Error Detection & Correction
1	Binary Numbers
6	Searching Algorithms
8	Sorting Networks
10	Routing and Deadlock in Networks
9	Minimal Spanning Trees
11	Finite-State Automata

Fig.3(a) is the scenery of the class of "Colour by numbers" which is the teaching material to explain of image representation. In Fig.3(b), the students are using the scale and the weights to learn sorting algorithms. These materials was made by the teacher.

In Fig.3(c), the students are playing the game "Battleships" to learn searching algorithms. Each students is guessing where her/his partner's ship is. This activity demonstrates three different search methods: linear searching, binary searching and hashing by using different sheets.

In Fig.3(d), the students are playing "The Orange Game" to learn routing and deadlock in networks. There are two oranges with each student's name except for one student. The teacher distributes the oranges randomly to the students in the circle. Each student has two oranges except for one student who has only one. The students pass the oranges around until each student gets the



(a) "Colour by numbers" to learn image representation

(b) Scale and weights to learn sorting

(c) "Battleships" to learn searching

(d) "The Orange Game" to learn routing

Fig. 3. Class scenery at Iinan junior high school

oranges labelled with their name. Students will find that if they are "greedy" (hold onto their own oranges as soon as they get them) then the group might not be able to attain its goal. In this activity, they experience "deadlock" and realize the needs for strategy.

Evaluation of The Students

We have conducted enquiries over the students in second period classes to evaluate the lessons with Unplugged. In Table 3, results of questions "Was the lesson fun?" for each class are shown. We could see that most of the students enjoyed each class. Especially, over 60% of the students evaluated that "The Orange Game"(Routing and Deadlock in Networks) and "Treasure Hunt"(Finite-State Automata) is "Fun(4)" regardless of their difficulty. With respect to this result, we could confirm Unplugged was effective for the students to have an interest in computer science and understand the essence of them. Some students answered "Not fun" for some lessons. They answered that "It is too difficult to understand" in their free description. We must improve the methods for those topics and select topics carefully for next period.

In the free description enquiry, we could find lots of answers to confirm that we had achieved the desired objective of the classes: enhancing students' motivations, thinking abilities and imaginations (Fig.4). With respect to this result,

Table 3. Result of multiple choice enquiry: Was the lesson fun?(%)

Chapter	Title	4	3	2	1
2	Colour by Numbers	55.3	38.8	5.8	0.0
3	You Can Say That Again!	39.1	45.7	15.2	0.0
4	Card Flip Magic	34.0	48.9	17.0	0.0
1	Count the Dots	41.7	43.8	12.5	2.1
6	Battleships	56.5	41.3	2.2	0.0
8	Beat the Clock	46.8	40.4	8.5	4.3
10	The Orange Game	67.4	28.3	4.3	0.0
9	The Muddy City	39.1	47.8	13.0	0.0
11	Treasure Hunt	62.9	31.4	5.7	0.0

4:Fun,3:Relatively fun,2:Relatively not fun,1:Not fun

we think that Unplugged would be an innovative teaching material. We also observed that students got practical knowledge by connecting Unplugged activities and using computers in their daily life. Unplugged would break the wall between computer science and using computer in real life.

Answers relate to motivation

— It was fun. I'd like to do it again.
— I'm interested in "Sending Secret Messages". I'd like solve other problems like this.
— Studying with classmates is more fun than just hearing teacher's explanations.
— I understood how to compress and decompress data.
I'll remember it when I use computers from now.

Answers relate to thinking ability

— It was difficult but fun. I've thought much.
— I've thought more than usual. It was difficult but I felt fulfilled after done it.
— I found a pleasure to think and could enhance my thinking ability.
— I think that it was hard to learn it alone because I had to think much.
It's fun to cooperate with classmates.

Answers relate to imagination

— It's great that bar-codes have lots of meaning.
— I'm happy to find its regularity.
— I'm impressed because I didn't know computers send pictures using numbers.

Fig. 4. Some representative answers from the free description

3.2 Lessons at Shouyou High School

At Shouyou high school (Yokohama city, Kanagawa prefecture, Japan), in the subject of "Information B" that is for the scientific understanding of the functions and mechanism of a computer, one of the authors had been conducting

the classes with Unplugged for 2nd grade students(33 students) from January through March 2007. The teacher taught chapter 6: "Searching Algorithms" for 65 minutes, chapter 7: "Sorting Algorithms" and chapter 9: "Sorting Networks for 35 minutes.

To mix Unplugged activities with normal classes, she had to prepare for the activities to finish them at short times. In addition, she added deeper contents for senior high school students to acquire their interests.

In the lesson to learn searching, she named the introductory activity "Marriage Meeting Game". This broke the ice in the class and the activities after that run smoothly(Fig.5).

Fig. 5. "Marriage Meeting Game"

In the enquiry after learning searching, representative answers of the students are "I can understand need of searching(97%)" and "I can understand that there are various kinds of algorithms(91%)". We think that they could understand the characteristic of each searching algorithm in spite of limited time.

In the enquiry after learning sorting with balance and weights, representative answers of the students are "I can understand how to calculate of the maximum number of swapping data in selection sort(97%)" and "I can understand that there are various kinds of algorithms(94%)". As well as searching, we think they could understand the characteristic of each sorting algorithm.

The result of the question "Which do you like classes with computer or Unplugged?" was "Unplugged(60%)", "With computer(7%)" and "Both(33%)". As a result, we could confirm that Unplugged produced the students' motivations. In the free description enquiry, we could find lots of positive answers: "It's good for brain activation", "It's impressive", "It's fun", "Studying with classmates is good" and "You(teacher) looks fun too."

In these lessons, we could confirm the learning with hands-on activities and without using a computer is effective for information education. There were some students who are not interested in or not good at using computers. However, even

Fig. 6. "Battleships" at Shouyou High School

such students felt fun, understood the mechanisms and had good impressions in the Unplugged classes.

3.3 Lessons at Osaka Gakuin Daigaku Senior High School

At Osaka Gakuin Daigaku senior high school (Suita city, Osaka prefecture, Japan), in the subject of programming, one of the authors who usually teaches at a university had been conducting the classes for 3rd grade students in senior high school(10 students) from April through December 2007. He introduced Unplugged as materials for introductions of programming exercises. He used "Kid Fax" in chapter 2, "Card Flip Magic" in chapter 4, "Battleships" in chapter 6 and "Treasure Hunt" in chapter 11.

"Card Flip Magic"
In November 2007, the teacher conducted the class to teach "Error Detection & Correction" for 100 minutes. Fig.4 shows the lesson plan of the class. In the beginning of the class, he used "Card Flip Magic"

Table 4. Lesson plan to learn "Error Detection & Correction"

1. Teacher and students play "Card Flip Magic".
2. Students play "Telephone Game".
3. Students execute a sample program and confirm that an error can detect by parity checking.
4. Teacher explains ISBN and students calculate ISBN checksums.
5. Students make programs to calculate ISBN checksums.

"Telephone Game" is not included in the textbook. However we think it is important for the students to realize the needs of error collection in real communication. Therefore the teacher made original work sheets for the game.

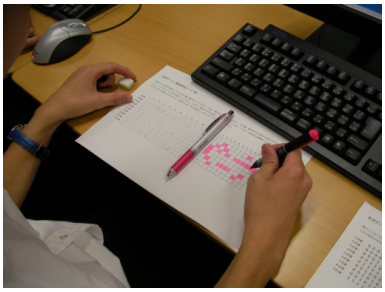
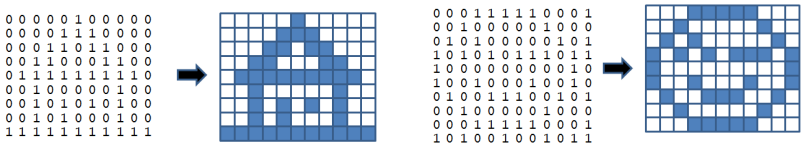


Fig. 7. Drawing a bitmapped image in "Telephone Game"

The procedure of "Telephone Game" are listed below:

1. The teacher hands the first sheets on which 11×9 matrix of numbers(0 or 1) are written to the first student of each team. This matrix represents a bitmapped image(Fig.8) .
2. The first student tells the matrix to the next student. The next student writes the matrix on his sheet. The teacher gives the instruction that the chance to tell the matrix is only once.
3. The student who had the matrix tells it to the next student. When he has the matrix with parity bits, he can fix it if needed.
4. Last student converts numbers that he heard to a bitmapped image.

Ten students were divided into 3 groups(Group A: 3 students,Group B: 3 students, Group C: 4 students). In the first trial, they used the data without parity bits(Fig.8(a)). In the second trial, they used the data with parity(Fig.8(b)) and passed the data in reverse order.



(a) no parity (b) with parity

Fig. 8. Data for "Telephone Game"

Table 5 shows the results of the "Telephone Game". Two teams succeed in second trial with parity bits and another team had only one fault. There was a possibility that learning in first trial effected influence second trial. However we could see the effect of the party bits on "Telephone Game".

It appeared also in the enquiry after learning that asked in result of the enquiries that "Did you understand "Parity check"?" (Tab. 6). We could confirm that the students realized the needs of data checking with parity bits.

Table 5. Result of "Telephone Game"

Team	1st trial	2nd trail
A	failed(19 faults)	failed(1 fault)
B	failed(6 faults)	succeed
C	failed(2 faults)	succeed

Table 6. Result of multiple choice enquiry: Did you understand "Parity check"?

Answer	# of students
Understand	6
Almost understand	3
Hardly understand	1
Not understand	0

Effect by Using Unplugged

After the class period ended, we have conducted enquiries that the students freely selected the topics in which they were interested from the list of 11 topics in the programming classes (nine of the students answered). As a result, the most popular theme is "Telephone Game": 7 students (78%) selected that. Moreover, 6 students selected "Battleships" and "Drawing and Redrawing Maps". "Drawing and Redrawing Maps" is the activity expanded upon "Treasure Hunt". In the activity, the students made their own state transition diagrams and translated them to the programs; then they exchanged their programs and redrew the other student's map. In contrast, number of students who selected the basic programing topics were three. With respect to this result, we could observe that Unplugged caught students' interest and it gave good effects for programming learning.

On the other hand, there was no student who selected "Searching Program" which related to "Battleships". We guessed that the reason was that "Searching Program" was too complex to understand for the students while "Battleships" was easy. We have to develop the teaching materials and methods fill the gap between programming education and Unplugged.

4 Conclusion

We reported the outline of "Computer Science Unplugged": the education method of computer science without students using a computer and results of our lessons with Unplugged in junior and senior high schools.

We could confirm Unplugged was effective for the students because it has the practical teaching materials with various games and hands-on activities. Unplugged includes advanced topics, e.g. "Data Compression", "Searching and Sorting","Amount of Information" and "Finite-State Automata" which are usu-

ally taught at universities. However the students could learn these topics with interest.

Another effect of Unplugged is that we can give a chance to think for students through these activities. In our classes, there were some students who do not like to think. However they had motivations to learn and thought deeply in Unplugged class.

Unplugged provides 12 or 20 sophisticated teaching materials now and the range of the adjustment of the materials is wide. In our classes, we made original materials included communication channel for "Error Detection & Correction". In this way, we will develop new teaching materials to generalize Unplugged.

There are relating researches. Kinesthetic Learning Activities[6] and Non-Programming Resources for an Introduction to CS[7] show the methods for studying computer science by using teaching tools. In the workshops for high school teachers held at Carnegie Mellon University, the session of Unplugged took place as "Featured Topic". We would like to cooperate with these activities.

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