Practice of 21st Century Skills-Oriented Project-Based Learning: A Case for Developing Application Software

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Abstract
Rapid technological advances and globalization of the 21st century have caused a large change in people's way of life and how to think and learn. On the other hand, modern society has various complicated problems such as terrorism, conflict, refugee problems, poverty, and environmental issues. In the near future, children must face these problems. However, their educational system is employed the 20th system. Under the circumstances, MEXT which is Japanese ministry of education advocates the 21st century skills.

This study presents the 21st century skills-oriented project-based learning (PBL). We report the PBL design, educational practice, and the assessment. We gave 13 undergraduate students in their 20s a practical challenge that is to develop application software for checking the electricity usage in our university for half a year. All team members belonged to a faculty of social science and the same seminar. Through their self-assessment of the 21st century skills at the end of this project, we found that the learning environment of this project enabled all members to acquire "Critical Thinking, Problem Solving and Decision-making" and "Learning to learn/metacognition" in the 21st century skills. In addition, we confirmed that the experience of a role as a leader developed higher level 21st century skills with the comparison of the other members. On the other hand, we found that this PBL project was unsuitable to acquire "life and career skills" and some 21st century skills.

Keywords: 21st century skills, project-based learning, developing application software

Introduction

With the recent remarkable advance in technology, the technology is universal in our lives. Thereby, our lives have been changed greatly. People use technology for getting information, their communications, businesses, and the others. Technology makes progress day by day, and changes the impossible things to the possible ones. At the same time, globalization is also proceeding at a rapid pace. Rapid technological advances and globalization in the 21st century have made some significant changes in the way of our lives, our minds and our learnings. However, the current educational system has adopted a 20th century system.

On the other hand, modern society has various problems such as terrorism, conflict, refugee problems, poverty, and environmental issues. These are very complicated and international problems. It is necessary for children who deal with these problems to acquire skills such as flexibly corresponding, efficient communication, decent information handling, good collaboration, creativity, and all that.

Under the circumstances, the 21st century skills have been proposed. In this study, we did practice and assessment of the 21st century skills-oriented project-based learning. As a result, we found that the learning environment of this study enabled the project team to acquire some of the 21st century skills.

21st Century Skills

The 21st century skills is the concept that proposed by ATC21s (The Assessment and Teaching of 21st Century Skills). ATC21s is the international organization which was established by the educator of the world.

The 21st century skills are 10 skills, which are divided into 4 broad categories. The first category is “WAYS OF THINKING”. “Creativity and Innovation”, “Critical Thinking, Problem Solving and Decision-making”, and “Learning to learn/metacognition” are belong to the “WAYS OF THINKING”. The second category is “TOOLS FOR WORKING”. “Information Literacy/Research” and “Information and Communication Literacy” are belong to the “TOOLS FOR WORKING”. The third category is “WAYS OF WORKING”. “Communication” and “Collaboration/Teamwork” are belong to the “WAYS OF WORKING”. The fourth category is “WAYS OF LIVING IN THE WORLD”. “Citizenship—local and global”, “Life and career skills”, and “Personal and social responsibility—incl. cultural competence” are belong to “WAYS OF LIVING IN THE WORLD”.

These skills are recognized common skills to get through life in a world of ever-intensifying globalization. Currently, national governments have begun some efforts to shift to the education in order to foster the 21st century skills from the traditional old-century education.

Related Studies

Effectiveness of Project-Based Learning (PBL)

Project-Based Learning or Problem-Based Learning (PBL) is one of team learning methods which intended to resolve immediate problems.

According to S. Bell (2011), he said that "The outcome of PBL is greater understanding of a topic, deeper learning, higher-level reading, and increased motivation to learn." Additionally, as stated by B. Pearlman (2010), he said that "The New Tech network's experience is that students best work, produce, and construct knowledge through project-based learning (PBL)." These previous studies revealed that Project-Based Learning or Problem-Based Learning is effective for learning the 21st century skills.

Learning Environment

The learning environment has to be reconsidered because this is an important factor. Most of practical studies seeking to learn the 21st century skills for students are done in the part of the lectures or associated with acquisition of academic credits (Matsuzaki (2016), Nagamachi(2015)). In other words, most of the practical studies' learning environments are in the context of compulsory participation. There is room for research of learning environment which is not a part of the lectures or not associated with acquisition of academic credits, and seeking to learn the 21st century skills for like-minded student.

Difference from Related Studies

This study is a practical study seeking to learn the 21st century skills by Project-Based Learning. In addition, it is predicated on the ideas of previous studies. The different point from previous studies is that the learning environment is not a part of a lecture or not acquisition of academic credits, and not in the context of compulsory participation.

Overview of the Project in this Study

Backgrounds

The backgrounds of the project are the Great East Japan Earthquake on March 11, 2011. This is a seismic disaster caused by magnitude 9 quake and following tsunami. This seismic disaster caused a nuclear power station accident. In the result, the Japanese government at that time had no choice but to stop all nuclear power stations for providing assurance of safety. This causes rolling blackouts of some areas because it cannot supply the electricity.

From then on, there is increasing interest in electricity in Japan, and people became willing to conserve energy. The government enacted an ordinance to restrict the electricity usage for large-lot electricity users such as universities. Under this

circumstance, there are more universities to carry out visualization of their electricity usage as a part of saving on energy.

Goal

In this study, the goal of the project is to develop two smartphone applications (iOS for and Android OS) and a web application to visualize electricity usage of the university campus.

Project Duration

The project started in January 2014, and the applications for smartphones and website were released in July of that year. So that means the project implementation period was 6 months.

Members and Roles

The team was composed of 13 like-minded members. They were sophomores and juniors, whose majors are social science, in the same seminar. The project members were divided into 3 teams.

The first one is “Smartphone Team” which consisting of “iOS Section” and “Android OS Section”. The iOS version was written in Objective-C programming language and Android OS version were written in the Java programming language. “iOS Section” has 3 juniors and “Android OS Section” has a junior and 2 sophomores. So, “Smartphone Team” has 6 members in total.

The next one is “Web Team”. The web application was written in the PHP, Action Script 3.0, and other programming languages. “Web Team” has 2 juniors and a sophomore.

The last one is “Design Team”. “Design Team” designed all materials which were used in the application with Adobe Photoshop and Adobe Illustrator. “Design Team” has 2 junior and 2 sophomores.

In addition, each team has a leader in order to promote the project smoothly.

Flow of the Electricity Usage Data

Displayed data of smartphone and web applications is retrieved from the server of the university. Figure 1 shows the flow of the electricity usage data from measurement of the data to displaying the data in the application.

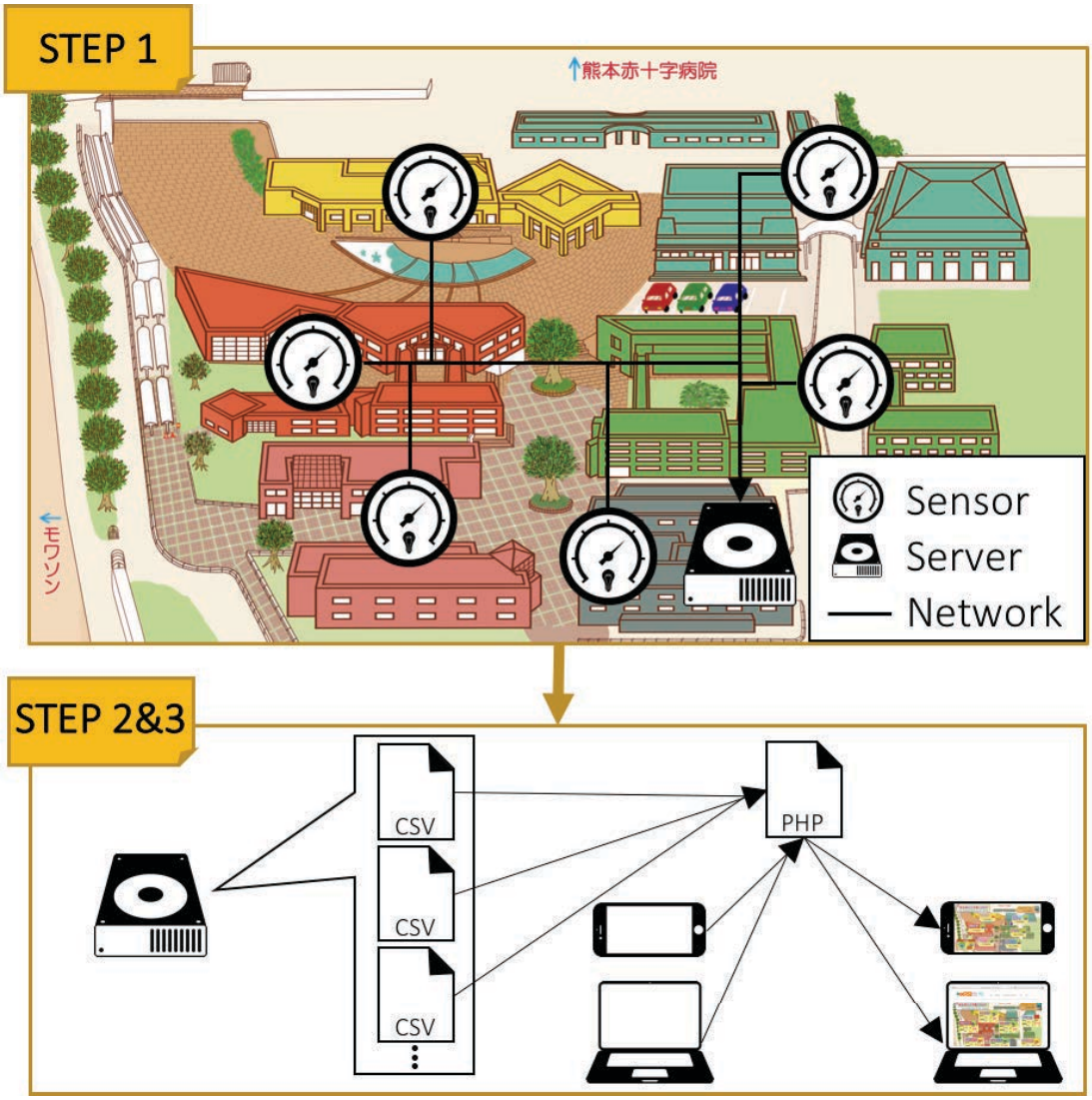

Figure 1: Flow of the electricity usage data

The flow of the data comprises 3 steps. The first step is measurement and accumulation. The data of electricity usage is measured by sensors attached to the distribution board in each building of the campus. The measured data stored in the server as a CSV format file via the campus network every half hour. The second step is processing. The CSV format file in the server is processed by the PHP program files on the same server. These PHP program files read the all of CSV data, and after that, tally up the electricity usage with each building. The last step is display. The smartphone and web applications access to the PHP program file to get the data for displaying. After that, applications show the data on the display screen.

Meanwhile, this data flow of was decided by the part of the project members, supervisor, staff of the university, and business operator for installing sensors and all that.

Process of the Project

Figure 2 shows relationship of people who get involved in the project. Basically, the project was carried out by the university students only. The supervisor only provides

advices to deliverables and give counsel when problems are caused, and he does not interfere as much as possible.

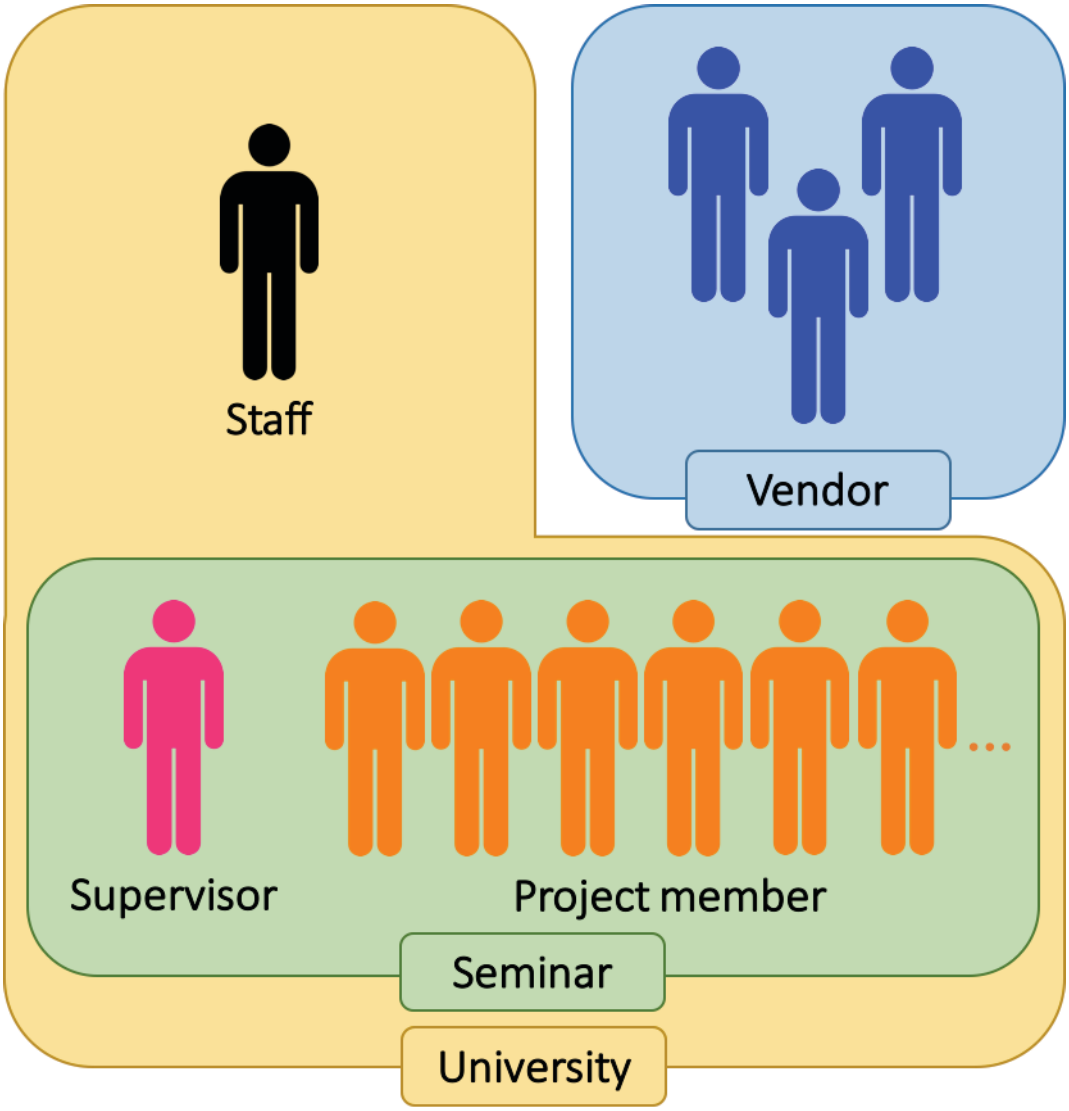

Figure 2: Relationship of people who involved in the project

The project was processed by the cycle of "regular meeting" and "team activities". The regular meeting is all-hands, 60 minutes, and it holds every week. The purposes of the regular meeting are decision-making and activity report. In the decision-making, members decided detailed specifications of the applications, interface design and all that. In the activity report, the leader of each team reported what they have done after last regular meeting, and what will they do by next meeting. In addition, other members give an opinion and ask a question for the report. The team activity was processed by each leader. The activity style was free, thus each team adopted their suitable styles, for example face to face meeting, using instant messaging and others. In addition, if the need comes, another small meeting was held by some teams.

Project Name

The project was called “e-PUK”. This name is a combination of “e” of “electricity” and “PUK” standing for “Prefectural University of Kumamoto”. This project name was also used for smartphone and web application name.

Outcomes of the Project

Developed Smartphone Application

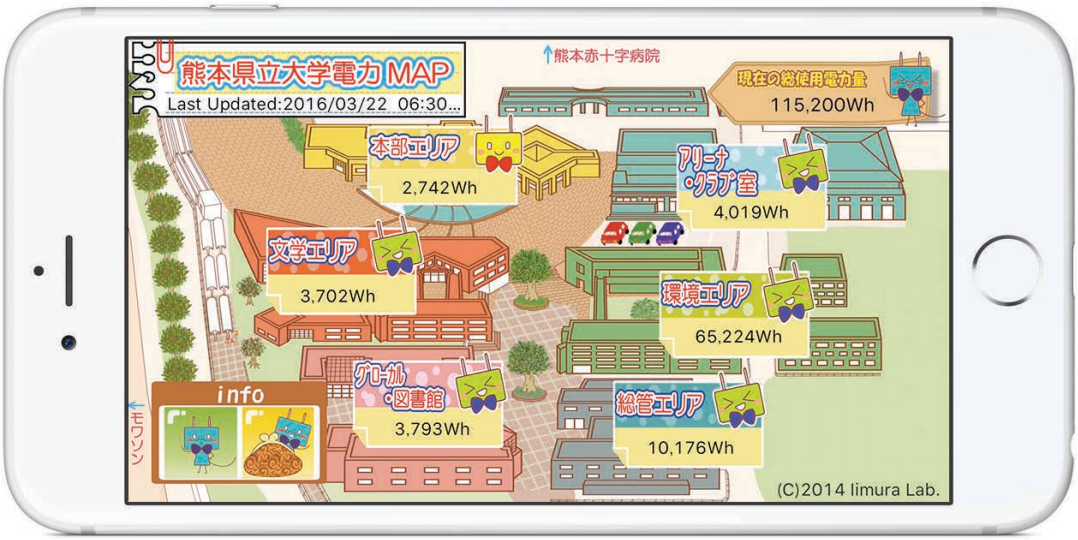

Figure 3: Screenshot of developed smartphone application

The developed application supported both iOS and Android OS, and these can be downloaded for free from each application store.

When the application user launches the application, the splash screen is displayed. After that, the total amount of electricity usage and the acquisition date and time of the data are displayed on the university map. In addition, the name, electricity usage, and character in each area are also displayed. There are 3 variations of the character, but details will be described below. When the user taps the character, the user can check more in-depth electricity usage of the area. Furthermore, when user taps “info” icon on the bottom-left corner of the screen, user can check electric power charge of each department and monthly conversion of electric power charge per student.

Developed Web Application

Figure 4: Screenshot of developed web application

The developed web application is embedded with the top page of "e-PUK Web" that is the website of the project. When the application user accesses the web site, the webpage and the application are loaded. After that, the total amount of electricity usage and the acquisition date and time of the data are displayed on the university map in a similar way as the smartphone application. The name, electricity usage and character in each area are also displayed. The difference from the smartphone application is that the web application shows each area's electric power charge and the ratio of electricity usage compared to the same day of the previous year.

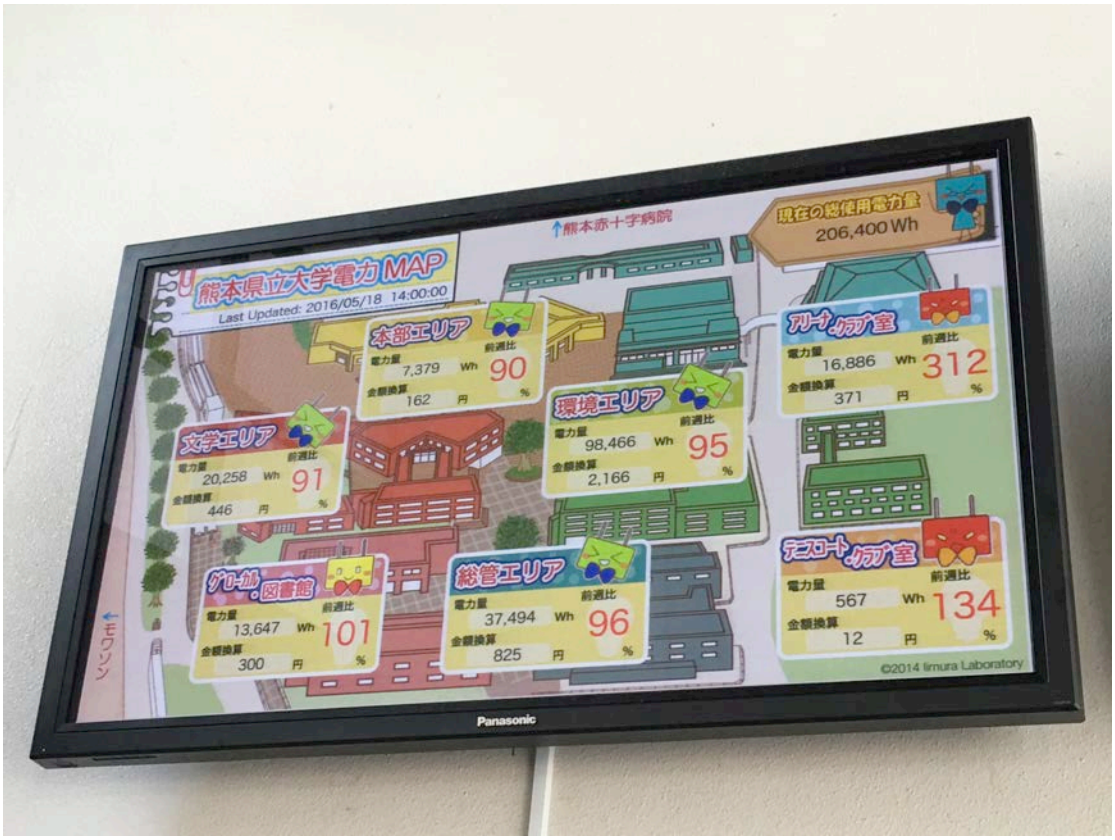

Figure 5: One of digital signage in the university

In addition, the web application is displayed on the digital signage in the university.

Design of Applications

The logo mark of the website, the icon of the smartphone application, a character, and campus map images which used in the applications were produced by the design team.

Figure 6: Original character "Denryokun"

The name of the character is "Denryokun", and this is original. This character has 3 type sign of emotion, and these are joyous, normal, and angry. These signs of emotion change depending on the ratio of electricity usage compared to the same day of the previous year. Specifically, the character’s expression is smile if the ratio is less than 100%, and the character’s expression is angry if the ratio is over 120% or over.

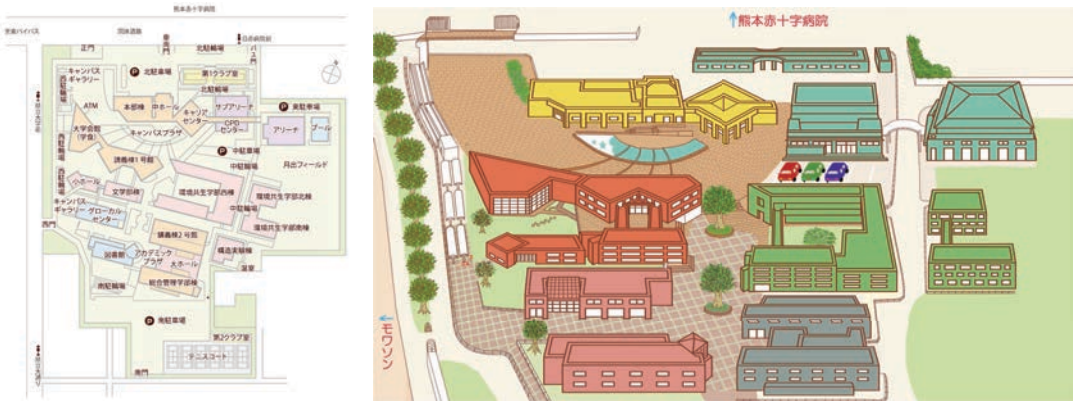

Figure 7: Existing map image (left) and new map image (right)

The map image which produced by design team is based on the existing map. It is optimized for the applications.

Media Coverage

Through this project, the project members had received media coverage. The total of 6 articles appeared in newspapers, web sites, and economic magazines.

Assessments and Considerations

Assessments Procedure

The assessment of the learning require multi-directional considerations. Yamada (2009) said that self-awareness is one of the educational outcomes. So that, it means that the self-awareness of the project members is the educational outcomes which are brought by the learning environment of this project.

In this study, "Knowledge building analytic framework" by M. Scadamalia et al. (2012) was adopted as the assessments. The project members performed self-assessments on each skills of the 21st century skills. Self-assessments were conducted based on the standard behavior or attitude regarding each skill's score. If a skill's score is closer to 1 point, this means the member learned the previous type skills. In reverse, if a skill's score is closer to 10 points, this means the member learned the 21st century type skills. The assessments were conducted in Japanese, and it was cited from "Assessment and teaching of 21st century skills (Japanese edition)".

The results of members' self-assessment evaluated from two different perspectives. First is the comparison results of the average scores of all members. Second is the comparison results of the average scores of leader group and non-leader group, and derive the result of statistical processing between leader group's score and non-leader group's score.

Results of the Assessments

Table 1: Average score of leader group and non-leader group

21st Century Skills	All members (*N* = 13)				(a) Leaders (*N* = 4)				(b) Non-Leaders (*N* = 9)				
	Average	SD	Max	Min	Average	SD	Max	Min	Average	SD	Max	Min	*p*-value
Creativity and Innovation	5.31	2.75	9	1	7.00	2.71	9	3	4.56	2.55	8	1	n. s.
Communication	5.85	2.88	10	1	8.50	1.29	10	7	4.67	2.60	9	1	*
Collaboration / Teamwork	5.85	2.91	10	1	7.75	0.96	9	7	5.00	3.12	10	1	***
Information Literacy / Research	5.15	2.41	9	1	6.75	2.63	9	3	4.44	2.07	7	1	***
Critical Thinking, Problem Solving and Decision-making	7.23	1.64	10	3	7.50	1.00	8	6	7.11	1.90	10	3	n. s.
Citizenship — local and global	5.15	2.23	9	1	6.75	1.71	9	5	4.44	2.13	8	1	**
ICT literacy	5.85	2.54	10	2	7.50	0.58	8	7	5.11	2.76	10	2	***
Life and career skills	4.38	1.89	8	2	4.25	1.26	6	3	4.44	2.19	8	2	n. s.
Learning to learn/meta-cognition	8.23	1.69	10	5	8.00	1.15	9	7	8.33	1.94	10	5	n. s.
Personal and social responsibility — incl. cultural competence	6.46	2.15	10	3	7.75	0.50	8	7	5.89	2.37	10	3	***
Total	5.95	2.51	10	1	7.18	1.77	10	3	5.40	2.60	10	1	**

*: p<0.01, **: p<0.05, ***: p<0.1, n. s.: not significant

Table 1 shows all members', leader group's and non-leader group's average score, standard deviation (SD), max score, minimum score, and p-value provided by t-test. In the column of p-value, the asterisks *, ** and *** indicate that the coefficients are statistically different from zero at the 1 ($p < 0.01$), 5 ($p < 0.05$), and 10 ($p < 0.1$) percent level, respectively. "n. s." means that there is no statistical significant.

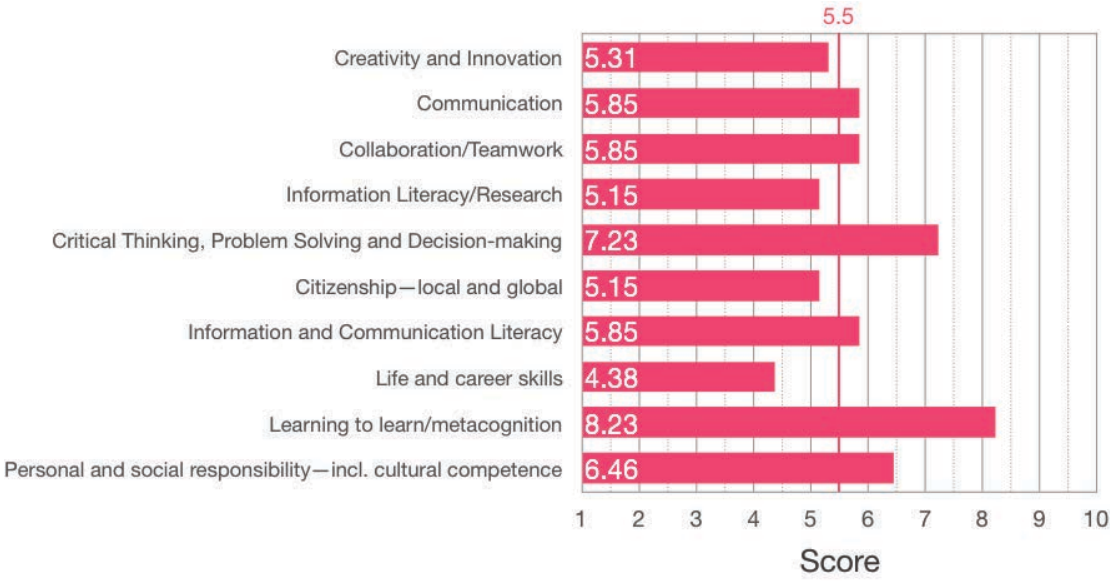

Figure 8: Average score of all members

Figure 8 shows the average score of all members. In the vertical axis of the graph, there are listed 10 skills of 21st century skills. In the horizontal axis of the graph, there are ten score values of 1 to 10. These numbers mean average scores of self assessments of each 21st century skills. In Addition, the score "1" means the type of skill is previous century type. In reverse, the score "10" means the type of skill is the 21st century type. According to this graph, the score of "Critical Thinking, Problem Solving and Decision-making" and "Learning to learn/metacognition" are higher than

that of other skills. On the other hand, the score of "Life and career skills" is lower than that of other skills.

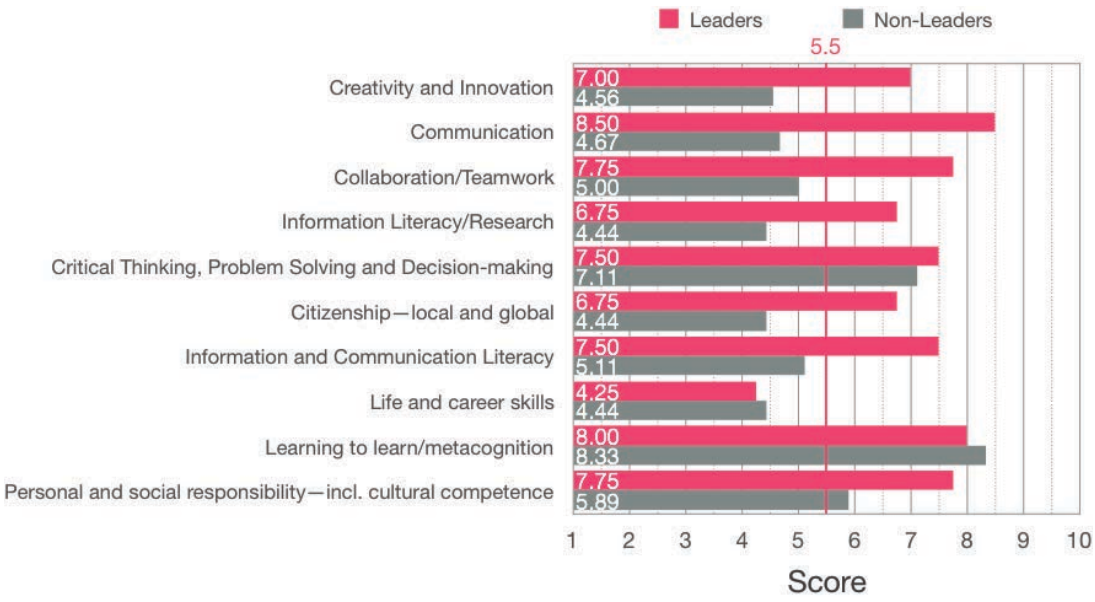

Figure 9: Average score of leader group and non-leader group

Figure 9 shows the average score of leader group and non-leader group. Leader group's average scores are pink bars, and non-leader group's average scores are gray bars. First, we focus on leader group's scores. The 7 skills, starting with "Communication" and "Learning to learn/metacognition" mark over 8 points, and "Creativity and Innovation", "Collaboration/Teamwork", "Critical Thinking, Problem Solving and Decision-making", "Information and Communication Literacy" and "Personal and social responsibility—incl. cultural competence" mark over 7 points. Next, we focus on non-leader group's scores. "Learning to learn/metacognition" mark over 8 points. In addition, "Critical Thinking, Problem Solving and Decision-making" is high score in both the groups, it marks over 7 points. However, other skills' scores mark under 5.5 points except for "Personal and social responsibility—incl. cultural competence".

When we focus on the column of p-value in table 1, there is statistical significant ($p < 0.01$) on "Communication" between leader group and non-leader group. On "Collaboration/Teamwork", there is statistical significant ($p < 0.05$). In addition, there are statistical significant ($p < 0.1$) on "Collaboration/Teamwork", "Information Literacy/Research", "Information and Communication Literacy" and "Personal and social responsibility—incl. cultural competence". On the other hand, there are no statistical significant on "Creativity and Innovation", "Critical Thinking, Problem Solving and Decision-making", "Life and career skills" and "Learning to learn/metacognition".

When we focus on row of all member's SD in table 1, the scores of "Critical Thinking, Problem Solving and Decision-making", "Life and career skills" and "Learning to learn/metacognition" are lower than other skills. When we compare SD scores of leader group and non-leader group, on the whole, leader's scores are lower than non-leader's scores.

Considerations

From all things considered, the project can be an opportunity to learn some of the 21st century skills for the members.

First, as to “Critical Thinking, Problem Solving and Decision-making” and “Learning to learn/metacognition”, there are no statistical significant between leader group and non-leader group, and mark high average score. Therefore, the member learns these 2 skills through the project.

Second, the 6 skills differ significantly between leader group and non-leader group. In addition, when we focus on the average scores of leader and non-leader, the average scores of leader’s 8 skills are higher than non-leader’s that, and most of the leader’s skills mark lower SD score than non-leaders. Therefore, it suggests a potential that the experiment of leader has a stable and good effect to learn the 21st century skills.

Third, as to “Creativity and Innovation”, there is no statistical significant between leader group and non-leader group. In addition, when we focus on the SD score, there is variability among the member. Therefore, as to this skill, it would appear that the learning level depends on the member’s role in the group.

Finally, as to “Life and career skills”, there is no statistical significant between leader group and non-leader group, and both groups mark low score. This means that the activity or theme of the project don’t have or less factor affecting for developing this skill.

Conclusions

In this study, we practiced the project-based learning in which the members developed the smartphone and the web application under the unenforceable learning environment, in order to let member learn the 21st century skills. In the result, the members learn the 21st century skills under the learning environment as an unenforceable project-based learning. Especially, as to “Critical Thinking, Problem Solving and Decision-making” and “Learning to learn/metacognition”, all member mark high score. In addition, compare the scores of leader group and non-leader group, it suggests a potential that experiment of leader have a good effect to learn the 21st century skills.

This study was conducted under the variety of restrictions. Therefore, there is room for additional studies when something of the project is changed. For example, the members were like-minded students in the same seminar in this study, it can’t be denied that the members started out with the right motivation. Moreover, it is believed that the results are related to the assignment of the project, the numbers of the project members and others. In the future, we will continue a practical study of learning the 21st century skills.

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