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Description	

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*Manuscript

An Educational Framework for Creating VR Application through Groupwork

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Abstract

Virtual reality (VR) application creation is a comprehensive development process that requires a variety of skills: not only hardware and software knowledge but also aesthetic design and storytelling abilities. A groupwork-based project is a suitable approach for creating a VR application because the group members can utilize their full powers and knowledge of their special fields through collaboration.

Students learn best when they are actively involved in a process, such as in group discussion and field work. Such groupwork projects are also effective in improving their collaboration skills.

This paper introduces an educational framework for creating VR applications through groupwork, and highlights the advantages of this framework.

Keywords: Emerging Technology, Virtual Reality, Groupwork

1. Introduction

Human society is becoming increasingly complex, and it is difficult to solve multifaceted problems without a robust interdisciplinary approach. Interdisciplinary training is one way of overcoming the handicaps of specialization [1].

In the early years of the twenty-first century, the so-called *knowledge age* has become a reality after intense innovation in computer and communication technologies. In the knowledge age, the tertiary industries, known as service industries, are growing. From the point of view of the characteristics of service industries, it is necessary to adapt products flexibly to a client's demand [2].

JAIST (Japan Advanced Institute of Science and Technology) fosters the development of front-line researchers and experts in knowledge creation media who will act as pathfinders, enabling the knowledge creation society. JAIST also cultivates people rich in creative, executive, and critical abilities to become researchers and experts. We have taught our graduate students a method of knowledge creation for solving complex problems using groupwork-based projects focused on virtual reality (VR) applications.

1.1. About IVRC

The *IVRC* (International collegiate Virtual Reality Contest), organized by the *Virtual Reality Society of Japan*, is a technical contest incorporating robotics, virtual reality, and interactive technologies, that was established in Japan in 1993. Since 2004, IVRC has cooperated with a French virtual reality student competition, called *Laval Virtual*[1].

The main objective of this contest is to give participants a deeper understanding of, and make them familiarity with, interactive technologies, through activities such as planning interactive systems, making the devices, and improving the quality of system content. IVRC is not only a technical competition but also a novel educational framework designed to encourage participants to think, study, and create by themselves.

The competition usually starts in May and ends in November. There are five rounds, as outlined in Figure 1: Proposal submission; screening(early in June); oral presentation (late in June); preliminary contest (mid-September); and the finals (early in November).

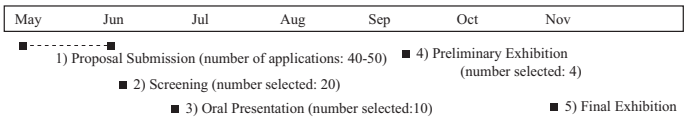

Figure 1: IVRC Schedule

The average acceptance rate at the final stage is four from more than forty applicants.

Since 2002, 17 works that were selected for the IVRC final stage have been accepted at SIGGRAPH Emerging Technology, as shown in Table 1. This has made the IVRC a prestigious technical competition in Japan. We have

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[1] http://www.laval-virtual.org/

participated in IVRC since 2003, and some of our work has been exhibited abroad, such as at SIGGRAPH and Laval Virtual.

Year	02	03	04	05	06	07	08	09
Number	1	1	2	3	3	2	2	3

Table 1: Number of IVRC works exhibited at SIGGRAPH

1.2. Related Works

It is widely accepted that groupwork skills are fundamental for all students, and some organizations have tried to incorporate groupwork into a curriculum [12, 14]. Farkas developed an advanced computer science course using group projects [9]. He pointed out that group projects are suitable for enhancing both the educational and social experience of students.

Susan Gold, Gorm Lai and Ian Schrieber founded The Global Game Jam (GGJ) [8] in 2008 as a rapid prototyping game development event that urges participants to think and work quickly, allowing them to experiment and innovate. The GGJ gives participants a chance to see the power of collaboration, allowing them to try new ideas and grow as developers, designers and artists. However, the theme of the game to be developed is given by the event organizers.

Fullerton et.al. published a very instructive book regarding game design, titled "Game Design Workshop" [10]. Their approach is exercise driven, and the exercises require neither programming skill nor visual art abilities, making it easy to start designing games.

Stansfield proposed an introductory course in VR [11] that incorporates multiple components of VR theory and practice, and provides an ideal environment for incorporating capstone elements that allow students to integrate various skills.

Our educational framework is designed to teach a method of knowledge creation for solving complex problems in a groupwork-based project that is centered around a VR application.

2. How we collaborate

This section describes how to create a VR application through groupwork.

2.1. Why groupwork ?

In general, teams are stronger when ideas are intermixed and integrated through collaboration, especially interdisciplinary teamwork.

Csikszentmihalyi says that people enter a *flow* state, in which, when they are involved in an activity, nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost for the sheer sake of doing it. He also describes the effectiveness of the *flow* experience as follows: *The self becomes complex as a result of experiencing flow. · · · When we choose a goal and invest ourselves in it to the limits of our concentration, whatever we do will be enjoyable. And once we have tasted this joy, we will redouble our efforts to taste it again. This is the way the self grows* [5].

We have observed that students learn best when they are actively involved in a process, such as in group discussion or field work. Groupwork is also effective in improving student collaboration skills. A variety of skills, including technical skills and design expertise, are required to create a VR application; therefore, we have applied a groupwork method [4] to create better VR applications and develop the students as people.

Table 2 shows the number of group members for each project introduced in this paper; the number in parenthesis indicates the number of members that have a technical background. The technical members mainly implemented the system software, made the interface devices, and constructed the final system. The non-technical members mainly created the story behind the VR application, created the movies, and designed the user experience.

Project Name	Number of members (Technical)
Ton^2	3(3)
Kyukon	8(3)
Interactive Fountain	6(4)
Landscape Bartender	5(2)
Spider Hero	8(5)

Table 2: Number of group members

2.2. Groupwork Process

The design process is one of the most important elements in content creation. In the design process, physical objects and user interfaces are often the most tangible, attractive and visible outcomes; however, the user experience plays a more important role than any of these. That is, experience design is essentially the practice of designing content, applications, and systems.

James Webb Young says that the production of an idea proceeds through the following five steps [3]:

1. Gather raw material
2. Digest the material
3. Put the issue out of your mind completely
4. Constantly think about it
5. Expose the idea to reality

He states, "an idea is nothing more nor less than a new combination of old elements." He also suggests that the second most important principle is the ability to see relationships between disparate things. His method is supported by reference [13], which describes group creativity. We have followed his method to produce ideas in groupwork projects with respect to VR applications.

The following subsection describes the process of groupwork, divided into three steps:

1. Divergent Thinking: put forward many ideas intensely
2. Convergent Thinking: unify and combine ideas
3. Idea Crystallization: feasibility study and embodiment of idea

2.3. Divergent Thinking

The first step in creating a VR application, as in other content design fields, is to put forward an idea intensely, as it occurs. In this step, it is very important to think up ideas freely without being shackled by stereotypical thinking and conventional methods.

We support the divergent thinking process by utilizing a BBS (Bulletin Board System) based on the concept of the *Idea-Marathon System (IMS)* [6]. *IMS* is a way of life that involves recording your own ideas at least once a day in a notebook. You can record any type of ideas, as long as they are original, regardless of the field or topic. The essential element of *IMS* is the continuous practice of putting forward ideas daily, whatever they may be.

For collaboration in groupwork, it is necessary to provide an environment for sharing ideas among group members. We found that a BBS is a suitable platform for sharing ideas because it allows a user to easily browse and comment on ideas at any time. Figure 2 shows a screen shot of our BBS. We have managed the BBS with the following considerations:

1) Indicate the number of replies and views :
This indicates the attention being paid to it, and the liveliness of each topic.

2) Topic updated most recently placed at the top :
This clarifies the current hottest topic. On the other hand, a topic with few replies is left out of the mainstream, and it may die out.

3) Negative comments are prohibited :
It is essential to establish a continuous flow of ideas, whatever they may be; A negative comment may discourage an idea holder and inflict harm on the community.

(a) BBS Configuration (b) Screen Shot

Figure 2: BBS based on IMS

With this customized BBS, the group members can describe their ideas, refer others to them, and reflect on and think about the ideas at any time. This concept development phase of the application design plays an important role in creating successful projects.

2.4. Convergent Thinking

Using divergent thinking, we obtain many ideas. In the next step, we unify and combine these many ideas into one idea.

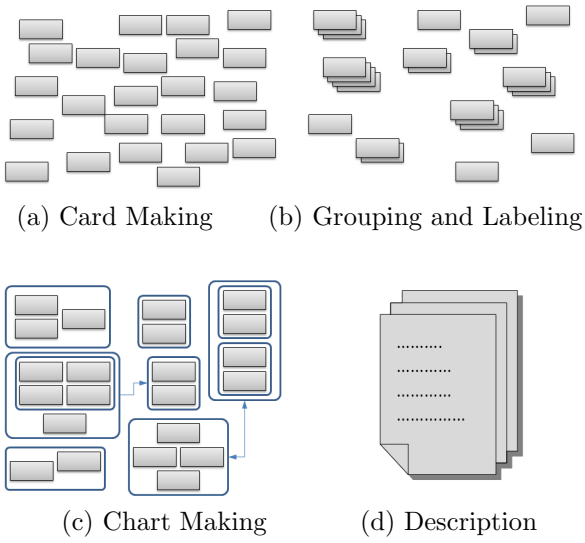
There are many ways of converging ideas, including the cross method and KJ method [16, 17]. We have applied a cooperative KJ method for merging the ideas produced. The KJ method consists of the following four steps, also illustrated in Figure 3:

(1) Card Making :
All ideas are written on individual cards.

(2) Grouping and labeling :
Cards that look as though they belong together should be grouped together, avoiding preconceptions. For each group, write a proper title and place it on top of its group. Repeat the group making, using new titles to create higher-level groups.

(3) Chart making :
Arrange the grouped cards on a large sheet in a spatial pattern considering their relations.

(4) Description :
Describe what the chart means, observing all the cards.



(a) Card Making (b) Grouping and Labeling

(c) Chart Making (d) Description

Figure 3: KJ Method

During the convergent thinking process, it is important to look at the entire picture. Prior to merging the

ideas, we hold face-to-face group discussions. Each idea is summarized on a one-page poster, and the posters are displayed on a wall so that the members can browse through them and look over the ideas, as shown in Figure 4 (a). In the group discussions, we exchange opinions and share the concrete visions of the proposed project.

(a) Idea Posters

(b) Group Discussion

Figure 4: Group Discussion

After the discussion, we merge the ideas. General digital tools are not necessarily suitable for this process, because it is difficult to repeatedly add comments and modify the layout simultaneously during a group discussion. Therefore, we use *Post-it Notes*^{TM} and a large sheet of paper, as shown in Figure 5. During this converging process, the participants think over how the end user will enjoy the target system; this makes the merged idea more sophisticated and gives it more depth.

2.5. Idea Crystallization

In this process, the converged ideas are screened through a feasibility study, and the selected idea is embodied.

It is important to design a system from the viewpoint of the end users, focusing on the quality of the user experience. That is, we design the user's experience into the target application: how a player feels using a system, what kind of pleasure and amazement a system provides, and so on. Here, we must pay attention to designing a system that is not technology oriented, but user oriented. VR application tends to emphasize technical fascination; however it is more important to focus on what the player experiences.

For example, in the *Landscape Bartender* project described in subsection 3.4, we started to design an application by scripting a short story and illustrating a concept image, as shown in Figure 6.

Figure 5: Convergent Thinking

Then, we storyboarded the user experience, as shown in Figure 7, to share the story behind the VR application among group members.

After finishing the experience design process, all we have to do is implement the system.

In agreement with Baker [7] and Paul [15], we think that our groupwork method helps students develop their creative and critical thinking abilities. Creative thinking is divergent, unconstrained, and imaginative; however critical thinking is convergent, constrained, and logical. Creative and critical thinking tend to be seen as a polar opposite thinking styles; however, good thinking needs both, and requires a balance between their contributions [22].

The small bar in a corner of a city. The bartender creates a small world in a cocktail glass to make the guest happy. You are the bartender - what kind of landscape will you make tonight?

Figure 6: Concept Design

Figure 7: Experience Design

3. What we made

This section introduces some representative projects. All movies related to our work are shared on the web [2].

3.1. Ton^2

Ton^2 is a body sensory style VR application that is implemented using an intuitive and robust interaction model, as shown in Figure 8. This application captures the player's motion as displacement values through distance sensors, and uses the data for its interaction model.

We revived a traditional Japanese game, called *Paper-Sumo*. Normally, the game is played on a board using paper and cardboard, but we have designed it to take place underwater. We used water as the medium, not just to make the game enjoyable, but also to let the players feel the pleasure of pressing water down. The movement of the sumo wrestlers are projected as 3D CGs on the floating screen; the movement of the wrestlers influenced by players pushing down on the surface on the water. In Ton^2, participants can play the game using only their intuition, no special techniques are required. This system was exhibited at SIGGRAPH 2005 [18].

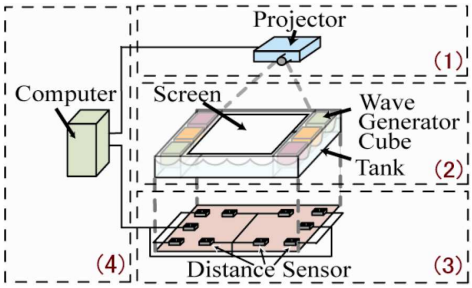
3.2. Kyukon

Traditional video sports games use buttons or sticks as user interfaces, but these are very unnatural interfaces for playing sports. Kyukon realizes a virtual pitching experience through a non-wearable interface. Our system allows control of the ball in a manner similar to that of a real pitcher. Wireless sensing technology and a strip screen constitute the non-wearable interface. There are no physical restrictions, so a user can pitch the ball freely.

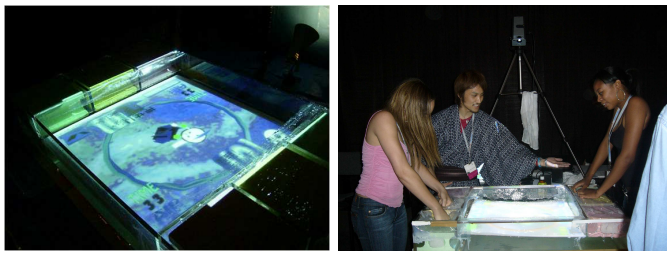
The strip screen smoothly connects a player to the virtual stadium projected on the screen. The mission is to strike out the batter. As the player throws the ball to at screen, and it passes through the screen smoothly. At the same time, the virtual ball is projected at the exact place the player threw the ball, which also reflects the speed and the rotation of the thrown ball. The player can also pitch a miracle ball with a particular rotation and speed.

Figure 9 illustrates the system configuration and shows a screen shot. This system was exhibited at Laval Virtual 2006, and was awarded a prize in the category of *Jeux Vidéo et Attractions*.

[2] http://jp.youtube.com/mytlab



(a) System Configuration



(b) User Experience

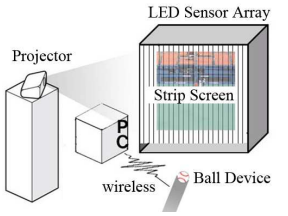
(1) Projector projects the image on the screen, which floats on the water. (2) Wave generator cube (WGC) generates waves from the pressing action of the player. There are three WGCs on each side of the tank. (3) Distance sensors are placed at the four corners of the screen, and six, one for each WGC, are set under the tank to obtain displacement data. (4) The computer that controls the system calculates the input data from the A/D conversion board.

Figure 8: Ton^2

3.3. Interactive Fountain

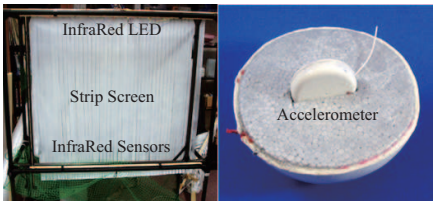
This project proposes a fountain as a novel display system that reacts to user's motions.

The system consists of seven fountain units, as shown in Figure 10; each unit has a PC-controlled water pump and nine full-color LED lights.



(a) System Configuration

(b) Screen Shot



(c) Installed Devices

(d) User Experience

The strip screen is made of white vinyl split into many strips. As the thrown ball passes through the strip screen, the screen gets a little distorted. The screen immediately re-forms and displays the virtual ball. A wireless accelerometer inside the ball detects (1) the time at which the ball is released from the hand and (2) the rotation of the ball. Optical sensors installed behind the strip screen detect the time and position of the ball reaching the screen.

Figure 9: Kyukon

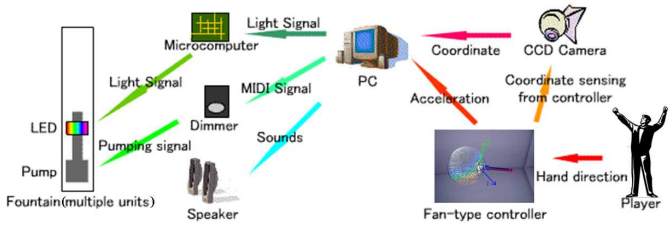
A player operates the fountains with a fan-type controller. The fountains instantly react to user motion by changing water jets, the illumination color of the water, and sound effects. As shown in Figure 10(b), a player's interaction can create effects like water being scattered by the wind in the world of SF movies and TV games, using real water. This system was exhibited as an invited work at Laval Virtual 2007.

3.4. Landscape Bartender

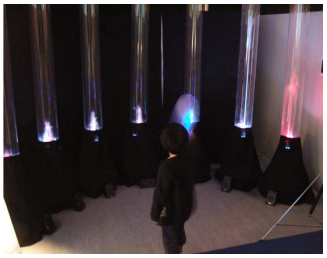
This project presents a system that generates landscapes using a cocktail analogy. With this system, users generate landscapes in the same manner as making a cocktail by combining "ingredients."

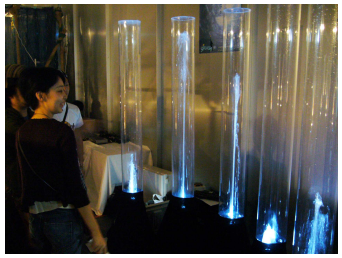
Each ingredient of the "landscape cocktail," i.e., each landscape element, is actually water contained in a separate bottle. The player picks a bottle containing the intended landscape element, such as a rock, plant, cloud, water, or sun, and pours a suitable amount of water into a shaker. The amount of water from each bottle determines the ratio of landscape elements. The terrain and the position of each element are changed by shaking the shaker. The terrain becomes rough if the controller is shaken vertically, and becomes smooth if it is shaken horizontally.

This system provides the enjoyment of creating one's own favorite scenery. Figure 11 illustrates the system con-



(a) System Configuration





(b) User Experience

This system consists of a PC, fan-type controller, CCD camera, seven speakers, two MIDI-controlled 4ch dimmer switches, and seven fountain units. Each metallic nozzle head is surrounded by nine full-color LEDs. The MIDI-controlled dimmer switches change the height of the water jets. The self-illuminated fan is used as the controller body. A wireless three-axis accelerometer is set on the controller handle. The system detects the position of the controller using a background image subtraction method. The detected position of light is used to select the fountain to be activated.

Figure 10: Interactive Fountain

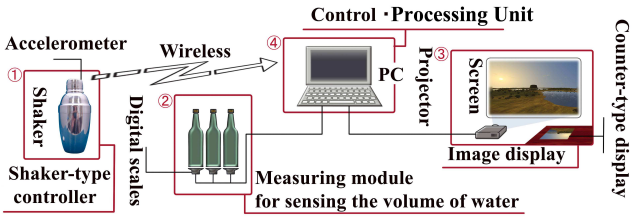
figuration, user experience, and sample scenes. This interactive system was exhibited as a New Tech Demo at SIGGRAPH 2008 [19].

3.5. Spider Hero

In this VR application, the user can jump from one building to another by using a web and swinging on it, like Spiderman™, the famous super hero [20].

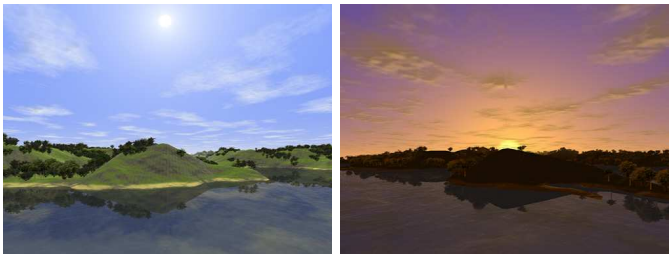
Wearing a web-shooter, which shoots a web, a user takes aim at a target building with this device. Next, when the user swings his arm in front, the web is launched and sticks to the target building on the screen. After the web sticks to the building, the user's arm is pulled in the direction of the target building by the pulling force feedback system, which gives a feeling of pulling the user directly and smoothly, as if he were attached to an elastic string, ultimately moving the user toward the target building.

This system was exhibited as an invited work at Laval Virtual 2010, and was awarded a prize in the category of *Interactive Art* at 15th Computer Graphics Contest for Students, Japan, 2010.



(a) System Configuration

(b) User Experience



(c) Sample Scenes

The system consists of four modules; 1) a shaker-type controller with a wireless accelerometer hidden inside the cap of the shaker. The acceleration data is used to change the terrain and the position of each element; 2) a measuring module for sensing the volume of water; 3) a counter-type image display unit; and 4) a PC.

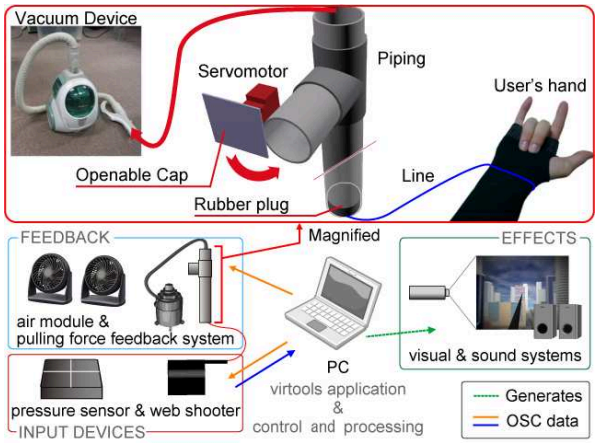
Figure 11: Landscape Bartender

4. Evaluation

This section describes the evaluation of our educational framework.

Table 3 shows feedback from the participants regarding the educational framework. There are 19 respondents for each questionnaire, using a 5-point scale, with a higher number representing a stronger response. This evaluation shows that most participants feel they developed as a person through the groupwork, and they recognize the framework as being worthwhile.

Table 4 and Table 5 give some objective evaluations of our framework. Table 4 shows the final rankings at IVRC from 2004 to 2008. This table omits the year2009, because the ranking regulations changed from 2009 onwards. This table shows that our project were very competitive with other overwhelmingly strong teams, such as UEC and Titech. In fact, only our teams archived a fourth place or higher in all five years.



(a) System Configuration

(b) Screen Shots

(b) User Experience

An air module gives the user the feeling of wind, and a pulling force feedback system gives the feeling of being pulled. This system connects the user's arm to an elastic line, and the line gives the user the sense of being pulled. The line is attached to a rubber plug, and a vacuum device provides the pulling force. A user can change the perspective by shifting their weight on the pressure sensor. The system also produces sound effects of the environment, the virtual city, and the wind.

Figure 12: Spider Hero

Table 5 shows the number of academic awards received for both the IVRC accomplishments and for individual member's research papers, including best paper awards. These results show that the education framework augmented the participants' research work. (In addition to these benchmarks, most participants found employment in leading companies in Japan, including Nintendo, Sony, Hitachi, Canon, Panasonic, and Ricoh. This also implies that their personalities were highly evaluated.)

Questionnaire	Average
Do you feel you have developed as a person ?	4.7
Was it a worthwhile experience to collaborate with others through groupwork ?	4.7
Do you think your experience in groupwork was useful after you went out into the world ?	4.3
Do you recommend this education framework to others ?	4.9
How well were you satisfied with this education framework ?	4.7

Table 3: Subjective Evaluation

Year	1st	2nd	3rd	4th
2004	UEC[3]	Titech[4]	**JAIST**	UEC+Tokyo
2005	Tsukuba	Titech	NAIST[5]	**JAIST**
2006	**JAIST**	UEC	**JAIST**	Tokyo
2007	UEC	ESCIN[6]+ ESIEA[7]	Tsukuba	Titech **JAIST**
2008	Tsukuba	Univ. Paris 8	KIT[8]	Osaka **JAIST** Tokyo

Table 4: Ranking in IVRC

Project Name	Number of Awards
Ton^2	3
Kyukon	3
Interactive Fountain	3
Landscape Bartender	5
Spider Hero	1

Table 5: Number of Academic Awards

The following are voluntary comments from participants about the educational framework:

This was a really precious time in my school days. I mastered the ability to direct projects through our groupwork, and my collaboration skills improved greatly. There were many conflicts among team members, however we succeeded in overcoming them. Collaborative skills are indispensable for surviving a tough life (member of the Ton^2 project)!

I learned the importance of being conscious of the customer point of view through designing a player's experience. That was my first experience in being given direct feedback from people, and I fully realized the difficulty of satisfying or pleasing customers (member of the Ton^2 project).

I realized that my creativity was really improved through the groupwork, especially while doing brainstorming (member of the Kyukon project).

My vision was widened by participating in the groupwork. The direct feedback and evaluation from the players stimulated my confidence. This is a great educational framework (member of the Interactive Fountain project).

I feel my overall ability improved after participating in the groupwork project. In the project, we had to plan a concrete idea, manage a limited budget, and realize the idea by the due date. This process is the same as in my business, and I recommend that our juniors join this educational framework (member of the Interactive Fountain project).

My experience in realizing an idea by integrating software and hardware skill is useful in my current job. I think the process of groupwork is also meaningful for developing a student's personality (member of the Landscape Bartender project).

Before I joined this educational framework, I always drew a boundary between what I could achieve and what I could not achieve in my mind. However, I was able to break this mental barrier by overcoming a lot of difficulties with my team members. I recognized my weak points through groupwork, and absorbed knowledge actively (member of the Landscape Bartender project).

The project period was a full experience in many ways. I had a great opportunity to increase my capacities for handling a project from beginning to end, and along the way I developed new skills (member of the Spider Hero project).

5. Analysis

This section analyzes the process of creating a VR application through groupwork, taking the Spider Hero project as an example.

5.1. Group Development

We conducted a questionnaire survey with the project members every month until the project concluded. We surveyed 13 dimensions of group development [25], and evaluated each of them on a four-point scale. The dimensions were as follows:

- A-1 Unity
- A-2 Self-direction
- A-3 Group climate
- A-4 Distribution of leadership
- A-5 Distribution of responsibility
- A-6 Problem solving
- A-7 Method of resolving disagreements with group
- A-8 Meets basic needs
- A-9 Variety of activities
- A-10 Depth of activity
- A-11 Leader-member rapport

[3]The University of Electro-Communications
[4]Tokyo Institute of Technology
[5]Nara Institute of Science and Technology
[6]Ecole Superieure de Creation Interactive Numerique
[7]Ecole Superieure de Informatique Electronique Automatique
[8]Kanazawa Institute of Technology

A-12 Role of the leader
A-13 Stability

Figure 13 shows the survey result, which show that the group developed month by month, and matured at the end of the period. In this example, the score of A-3 and A-5 has high value; therefore, we consider that the project members took responsibility and grappled with their own problem throughout the period. Figure 14 shows the average increasing ratio of group development by comparing two months. In this example, we observe that the group developed dramatically during two periods. In the first period, from May to June, the members were in the divergent thinking process, and the main objective of the project was determined. In the second period, from July to August, the members were concentrated on implementing the system, and they were strongly motivated by a wish to complete the project.

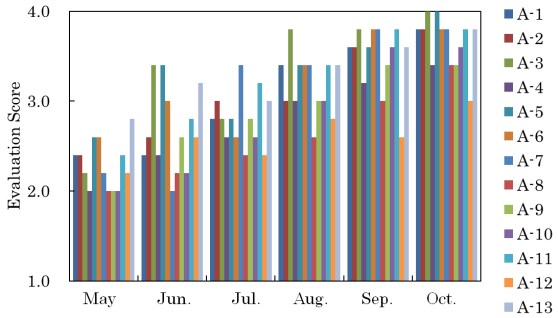


Figure 13: Group Development

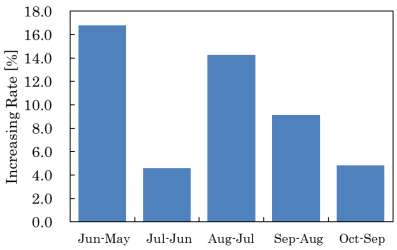


Figure 14: Group Development: Increasing Ratio

5.2. Individual Development

We also surveyed the following five dimensions of individual development, and each dimension was evaluated in four levels.

B-1 Relationships among others
B-2 Self-direction
B-3 Problem solving
B-4 Communication skill
B-5 Technical skill

Figure 15 shows the survey result, which shows that the individual also developed month by month, and matured at the end of the period. In this example, the score of B-1 and B-4 is high. All the members were in the phase of developing socially; therefore, we consider that this educational framework is also effective in improving their social skills. Figure 16 shows the average increasing ratio of individual development by comparing two months. The increasing ratio is very low in the last period, from September to October, because the system was almost completed and the members were developed by this time. As shown in this figure, a groupwork scheme works well for developing individuals.

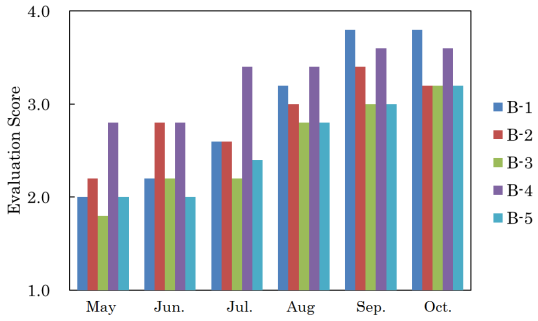


Figure 15: Individual Development

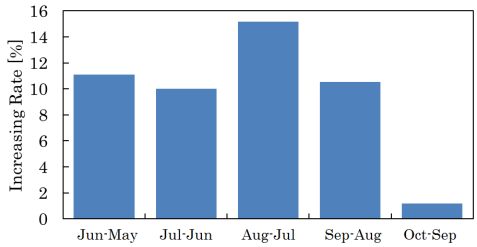


Figure 16: Individual Development: Increasing Ratio

6. Conclusion

We have outlined how groupwork helps effectively in designing and creating VR applications. Some of the outcomes of our groupwork have been evaluated.

VR application creation is a comprehensive development task, requiring a variety of skills that include not only sensing technology and computer graphics techniques, but also aesthetic design and storytelling. Therefore, a groupwork-based solution is suitable, because the group members can apply their full powers and special knowledge through collaboration.

In the future, we would like to adopt a method for conceptual synthesis in the design process and design space blending [21, 23, 24] to obtain highly creative ideas.

In summary, a groupwork scheme works well not only in creating a good VR application but also as a training framework for graduate students.

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