Web-based Collaborative and Practical Education for 3D-CAD and Roadway Design

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Abstract: In this paper, a collaborative distributed education method is proposed. This method combines traditional lecture in classroom with asynchronous dispersed information exchange system supported by web technology. An experiment lecture with this method has been done in order to practice roadway design using LDT/Civil, software products based on 3D-CAD. This training is about not only how to use the software, but to create new ideas, to establish models and to finish drawings for roadway design. Teachers can discuss with students about their design works on web pages, and can check the procedure that students experienced in their homework. This enables civil engineering, roadway design and CAD experts to take part in practical, real world education. In this way, the quality and the efficiency of educational activities are improved greatly compared to traditional method.

***Keywords*:** collaborative education, 3D-CAD, roadway design, web technology, asynchronous distributed system.

1. INTRODUCTION

It's a long time for educationists to reform education by using IT, such as distance learning on the Internet, computer aided instruction (CAI) system and so on. As well known, it is very important for design curriculums to cultivate students' creativity. In this paper, authors developed a new collaborative education system to encourage students to do their own works in the course Roadway Design by using CAD software. The class consists of two major parts: a web-based asynchronous distributed system and traditional synchronous get-together lectures in classroom.

In recent years, our researches have been focused on the application of three-dimensional CAD on civil engineering practices [1~3] and how to use web technologies to support the bridge construction [4,5] and teaching of Bridge History [6]. This paper described some research results conducted in Roadway Design and 3D-CAD at the Graduate School of Science and Technology, Kumamoto University, Japan. The first objective of the pilot education is to teach students basic CAD knowledge. The second one is to let them learn some special skills in roadway design through discussion among students, teachers and engineering experts by web pages. The last one, the most importantly, is to activate students' creativity.

In this paper, firstly, current education about civil design, CAD teaching, and software packages used are introduced. Secondly, the importance of change from traditional education mainly focused on teaching knowledge to new education style that pays more attention to elevate students' abilities of imagination and creativity is emphasized. Then, the pilot course is elaborated and its result is verified.

2. CURRENT EDUCATION SITUATION OF CAD IN CIVIL ENGINEERING

Being a part of CALS/EC (Continuous Acquisition and Life-cycle Support/Electronic), CAD has been approved as measure output by Geographical Survey Institute and Japanese Ministry of Land, Infrastructure and Transport. It has been recognized as proven technology to achieve major objectives of the initiatives. Industry has begun to seek students who have been well trained in CAD technology and expected universities to make students equip the technology as a tool to solve engineering problems and decision-making process.

In the research, authors used a set of software products, Autodesk Land Desktop (LDT) and Autodesk Civil Design (Civil). These two software products can be used not only as CAD drafting, but also used as design creation. In other words, they meet all civil engineering design needs, including investigation, design, drawing and so on. Civil is the extension of LDT to expand the design creation capability by adding advanced three-dimensional design functions. With the models built in Land Desktop, it is possible to do various special designs in different fields, such as hydrographic calculation and so on. The software is also well prepared to design roadways, such as cross-sections, profiles and horizontal alignments needed by Japan Highway, Ministry of Land, Infrastructure and Transport and so on. Furthermore, using these capabilities, the parametrical or graphical design can be carried out

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within the software. Students can produce graphical three-dimensional models on his computer screen. They can get the result of design simulation no matter when and how they design the project in LDT.

At present, the usage of software for actual roadway design is uncommon, but it is forecasted that LDT/Civil will become its de-facto standard. Consequently, it is the best choice for students in civil engineering to learn CAD application. Although CAD is taught for undergraduates here and there, LDT teaching for undergraduate or graduate students in Roadway Design is only maiden attempt. Through this practice, we did not hope to train CAD operators, but let students accumulate experience for future work and cultivate their engineering thinking ability and creativity for new ideas.

3. NEW TEACHING STYLE

3.1 Four Steps of Knowledge Transference

Fig.1 shows the four steps of getting knowledge. The left of horizontal axis stands concrete knowledge based on engineering practices. The right part is abstract, common scientific knowledge. In his book *What's Clinical Knowledge* [7], Nakamura divides medical knowledge into clinical one and fundamental one similarly. The left refers to knowledge necessary to intrinsic place, whereas the right refers to scientific knowledge learned in mathematics, physics, chemical classes, and so forth at university. Vertical axis stands for students gaining knowledge actively or passively.

In Fig.1, step A represents knowledge generalization from intrinsic place through experiment or observation. Such as in learning English, this step corresponds to learn by hearing and reading. So it is the process of passive input. Step B represents the process that students learn existent knowledge actively. It includes the most of study in their university life. In order to contribute their knowledge afterwards, they must understand, absorb and master it. In step C, the key is comprehension of acquired knowledge. They should put their fragment knowledge in order. In step D, students should practice how to use the knowledge for the future. In this process, the main way is to exercise by simulation. So the skill is also called knowledge gained by ones' actual practice and experience. During this period, they will learn new knowledge that is relative to real work. In order to master some skills, they must learn and exercise again and again actively.

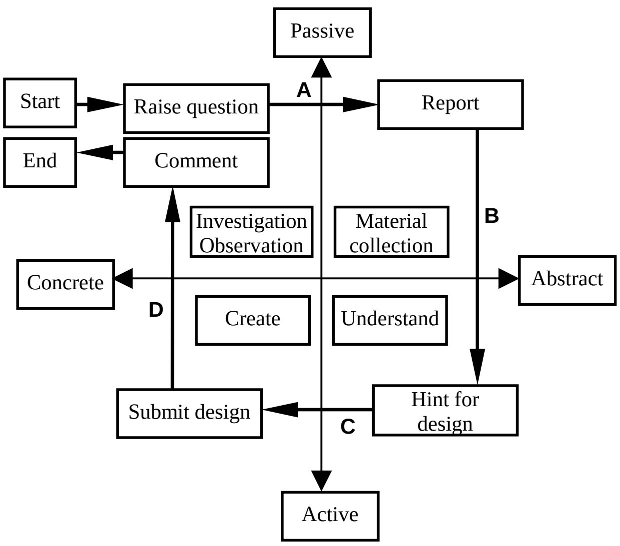


Fig.1. Four steps for getting knowledge

Although this kind of chart is also introduced in [8] as knowledge creation in an organization, authors reconstruct it as the process of individual knowledge gaining. The flow of knowledge as shown in Fig.1 is introduced afterwards.

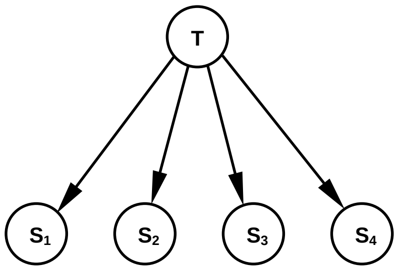
Authors extract characters in the following four steps. University courses can be categorized to any one of these:

- *Inductive type:* to study from practice by such as experiments or investigations. The majority of experiments and investigation are involved in this category;
- *Deductive type:* to derive general knowledge from existing particular science and technology. It includes normal courses at the university;
- *Creative type*: to suppose some condition to simulate practical work conditions and let students decide parameters. Furthermore, to design the object such as in design curriculums; and
- *Training type:* to train students' skill of doing something such as drawing, model making, etc. It also involves using CAD software to model something in computer and so on.

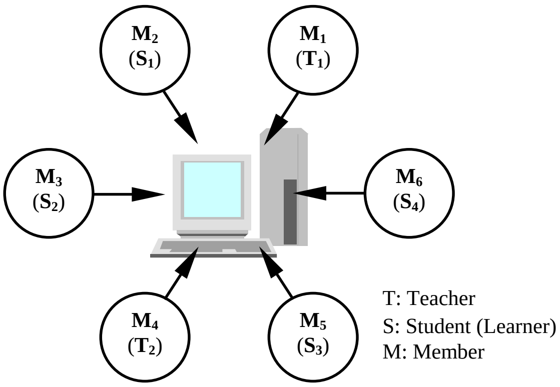
3.2 Experimental Collaborative Teaching

When several people (a team) doing something, they can come together in one place. In this situation, we call it synchronous gathering type ("gathering type" for short, the same below). On the contrary, if team members are distributed in different places, they will do their own work separately. In this situation, we call it asynchronous distributed type ("distributed type" for short, the same below). Isolated members can communicate in some ways, such as Internet, to form a virtual team.

Fig.2 a) shows the gathering style in traditional education activities. One teacher instructs his knowledge to many students. So its cost is low. The education level that students received are almost fair. Moreover, if the teacher



a) Gathering type (knowledge type)



b) Distributed type (knowledge + technology + idea type)

Fig.2. Compare of two education types
(The relationship between teachers and students)

works conscientiously and students study hard, they can finish this process smoothly. Students can learn not only knowledge but also some of teacher's idea or view of life.

Students, however, must take their notes and get materials from teacher. In order to do this, the teacher has to write a lot on the blackboard and distribute printing materials largely. Usually, students misunderstand that if they glance at these materials, they can master the knowledge well. Moreover, because the class duration is limited, individual problem is difficult to be solved effectively. These small questions, however, perhaps are the origin of knowledge. Excellent design often depends on selection of some parameters in different viewpoint. So in order to cultivate students' creativity, it is very important that students themselves have to get new ideas not only from the teacher, but also from other classmates. Moreover other students couldn't share the instruction of the teacher to individual student in traditional method. Especially, Japanese students couldn't understand the importance of this approach. Compared with students in foreign countries, they can scarcely raise excellent questions or make ingenious comments. They are trained by the style of learning by heart, so there is no atmosphere to stimulate students' creativity.

In the distributed education, teachers and students form a team. So it is possible that lessons are taught through a central web server. As shown in Fig.2 b), certain team member (M_i) can sometimes act as teacher (T_j), sometimes as student (S_K). There is no problem even existing several teachers. They can consider problem in the position of student. Meanwhile information can be shared by all of others through BBS (Bulletin Board System). Moreover, information sent to the central web server, including documents and comments, instantly shared by all students. They can print it anytime and anywhere if they want.

In the collaborative education, authors propose to combine the gathering type with the distributing type mentioned above. Merits of both two methods should be expedited. During step B and step D of Fig.1, if students can study by themselves, teachers should let them do so. More than half of the courses in university should be taught in this way, such as use of software and project curriculums. Students can study by themselves in their own space and free time. If someone has question, he can post it on the BBS. Although he couldn't get its answer immediately, it was possible for the rest of team to solve his problem later. During that period of time, he can also consider his own question carefully. So comparing with traditional education, he can have a deep understanding of his question.

When all the team members get together, they can discuss or comment on their works. At the same time, team members from the industry can pass on their expertise and experience to students. The teacher can correct their mistakes and assign new homework to students according to each one of students' levels of understanding. For industry experts, they consider more about how students achieved in practice. Usually they tend to evaluate students absolutely. Even so, it is necessary for education to supply more experts in order to give students more practical knowledge. For distributed type, if industry experts can understand students' levels clearly, great achievement can be acquired through one or two gathering lectures.

Invited as part-time teachers, the industry experts from enterprises can be divided as two kinds. The first kind is one who lives not too far away, so he can come to the campus every week. The second kind is one who lives very far, so he can only give students concentrative lecture in a couple of days. It is obvious for the former, however, that he has the burden of much time; while for the latter, perhaps they only carry out their obligation, because there is not enough time for students to understand the knowledge at intervals. With the change of social structure, it is necessary for universities to invite more experts from industry as instructors. It is expected that this will become one of criteria to evaluate the level of universities.

In order to solve the problem existed above, authors proposed the system that uses both synchronous gathering education and asynchronous distributed education.

Moreover, all the information posted on BBS should be connected with the content of course, including the dialogue among relevant people. If it is necessary, its history should be linked in the next version for reference.

3.3 Purpose of Three-dimensional Roadway Design Practice

The process to solve practical problems is similar to the flow of Fig.1. First of all, topics should be assigned to students. It is the raising of question. The second quadrant is corresponding to investigation of question itself and observation on construction sites. Students find the best answer for the question in the first quadrant. Then in the forth quadrant, in order to express their ideas clearly, they must calculate all the parameters by using some concrete analysis tools. Finally in the third quadrant, the plan should be drawn on paper to submit their idea. For roadway design, it refers to CAD drawings. After all of these, works of student will be reviewed. Consequently, comprehension to their questions will be deepened further through all the above four quadrants.

Four quadrants in roadway design can also be divided into four stages shown in Fig.3:

a) *Observation:* the process to conceptualize vague ideas;
b) *Expression:* In order to let others understand his idea, designer should present documents for more discussion. Its form can be various from language to models;
c) *Selection of parameters:* The process of fixing the details; and
d) *Drawing of plan:* The process of drawing idea into paper according design data.

As shown in Fig.3, in civil engineering, the most of design process is drawing of plan with CAD software. With software like LDT/Civil, most of the decision of design parameters can also be evaluated and chosen finally. So in the future, both step C and D are to be completely finished with the advancement of CAD software packages, such as LDT mentioned in this paper. In conception of design, these two parts can be excluded from design duration or only treated as the after treatment.

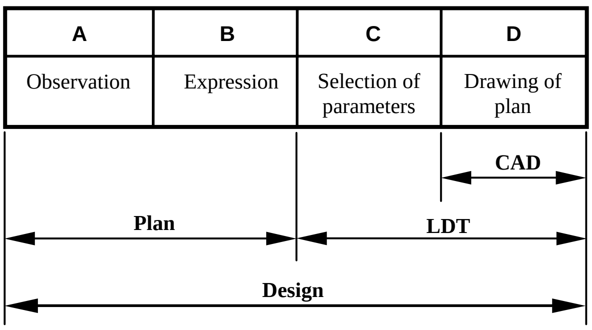


Fig.3. Four Stages of Design

Based on above analysis, the aim of our lecture is not only to train students' CAD skill according to step C and D, but also to find out how students formed their idea in the past, such as brainstorm or flash of wit. So, all inspection of the whole process in which idea is refined from step A to D is needed.

4. ABOUT THE COURSE

4.1 Course Schedule

The Roadway Design course was prepared for first year graduate students in Graduate School of Science and Technology, Kumamoto University, Japan. The number of students was 15 and the whole class hour was 12×90 minutes. The schedule is as following table. Fig.4 shows snapshot of the workshop driven by an industry expert.

All the teaching materials were prepared in PowerPoint files and uploaded to the central web server. This web page can be accessed on the Internet. So, it is unnecessary for students to present at classroom. They can use it no matter when and where they need.

All the instruction information is also posted to the web page. Through BBS, team members can share all the

TABLE 1. SCHEDULE

Lesson	Date (2001-2002)	Content
1	15th, Oct.	Orientation
2	22nd, Oct.	AutoCAD introduction (1)
3	29th, Oct.	AutoCAD introduction (2)
4	5th, Nov.	AutoCAD introduction (3)
5	12th, Nov.	Outline of road line design and roadway design
6	19th, Nov.	Theory of road line design
7	26th, Nov.	Existing ground preparation in LDT
8	26th, Nov.	Alignment design in LDT
9	10th, Dec.	Horizontal and longitudinal alignment design in LDT
10	10th, Dec.	Sectional template preparation in LDT/Civil
11	21st, Jan.	Cross section design in LDT/Civil; Calculation of earthwork.
12	21st, Jan.	Comment

Fig.4. Practice snapshot

information. Meanwhile the information is also notified to relevant people by email.

4.2 The Structure of Our Web Pages

The web pages consist of the following four features.

a) Teaching material:

All the teaching materials were in PowerPoint form. The exercise of CAD software was also available here. Users could browse or download them freely.

b) Collection of works: (Fig.5)

This was the place where various files were uploaded, including text documents and CAD drawings. Reports submitted by students were also stored here. Authorized person could upload files, while these files could be downloaded freely.

c) BBS: (Fig.6)

This was the place for discussion. Here, teachers and students communicated with each other equally to solve problems. The common questions were all stored in the database as FAQ (Frequently Asked Questions) for reference afterwards.

d) Relevant people: (Fig.7)

In the course, there were 7 instructors and 15 students. Instructors consisted of 2 teachers, 3 industry experts in three-dimensional CAD and roadway design, and 2 teaching assistants. In this web page, the information of all people related to this course was presented, including their names, affiliation, email address and portraits. This supplied not only convenience for them to contact with each other, but more importantly atmosphere as a real-world classroom although it was virtual one.

4.3 Example of Question and Answer in BBS

The following is an example of one question and its answers posted on BBS. About the page numbers mentioned, please refer to the References 9.

Question about curve fitting

[Q1] (Student A):

When input the data of curve 1 in page 174, the fitting pattern of its end point should be pattern B. Why the fitting pattern of start point of curve 2 becomes A in page 175?

[A1] (Teaching Assistant A):

Because curve 1 and curve 2 are counter-curves each other, so in my opinion, the fitting patterns of both the end point of curve 1 and the start point of curve 2 should be pattern B.

[Q2] (Student A):

So is it a printing error?

[A2] (Teacher F):

About this question, I want to express my opinion. Generally, the setting of counter-curves should be at the end point, not at the start point. The fitting pattern of the

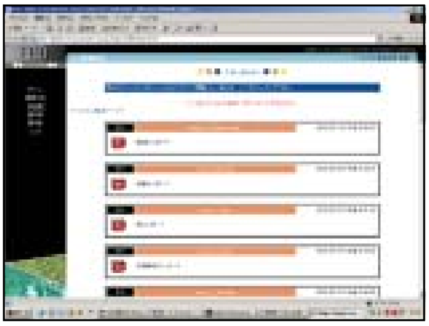


Fig.5. Collection of works

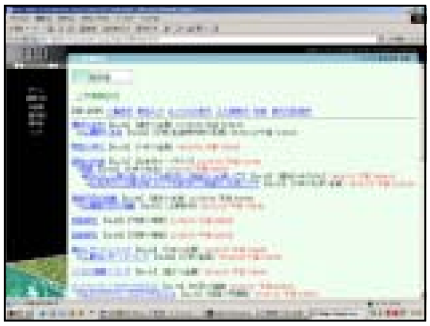


Fig.6. BBS

Fig.7. Relevant people

second curve, therefore, should be set in the first curve. Software products are also designed in this way. In software Civil, if the fitting pattern is A (there is no counter-curve existed), the “Detail Information” button will be unavailable. On the contrary, if that button is available, it messages that there is counter-curves here! So you can push that button and the dialog about next curve will appear. You can set the details in this dialog.

[A2 p.s.] (Teacher F):

About your question, if the fitting pattern of start point of curve 2 in the textbook was printed as B, not A, it should be easier to understand. So, if the textbook is revised, I think this printing error should be corrected.

4.4 About Works and Problems

4.4.1 Works

In research, we chose terrain modeling to train students for minimum amount of earthwork in roadway design [9]. All the works are asked to upload directly in DWG format. After the last review lesson, every student was asked to submit two-page report in A4 size. These DOC files were uploaded onto the web server and shared among all the members. Before deadline, students can revise their designs by referring other’s works. However, in order to share the information, all the reports must be submitted punctually. That is to say, the fairness of electronic submission should be guaranteed.

The following is the works of two certain students.

The work shown in Fig.8 and Fig.9 is one of normal results of design. The designer is a student who had studied Landscape Design and Civil History. He had experience to make physical landscape models, so he understood the process of Fig.3 very well. This student wrote his impression as this. “Although there are so many places to be modified during the design, it is very interesting when this drawing is finished. At that moment, I have strong feeling of success.” “However, I cannot image what the real road is from my drawings because I am lacking of the ability of reading drawings. Perhaps it is more interesting to choose real roads around campus as topics.” So for this kind of students, it is necessary to do exercises building computer graphics from blueprints. Three dimensional roadway design models could have been constructed in computer graphics if there were two more months to spare, or if they had the experience of doing some CG researches about dam or bridge.

The works shown in Fig.10 and Fig.11 are made by the student from architecture department. He had experience to take part in some projects of bridge design. In his design, there was a pair of hairpin curves in the middle of the proposed roadway alignment. This was an unusual idea.

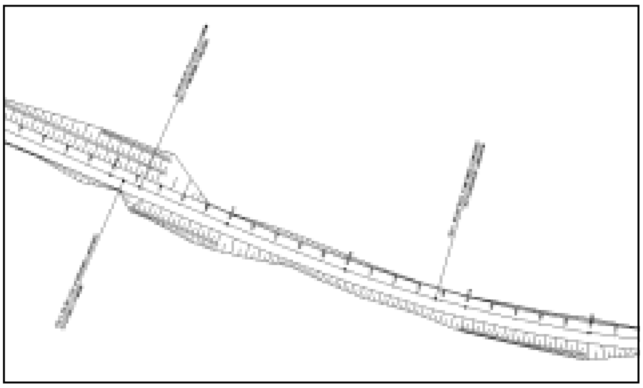


Fig.8. Works 1 (plan drawing)

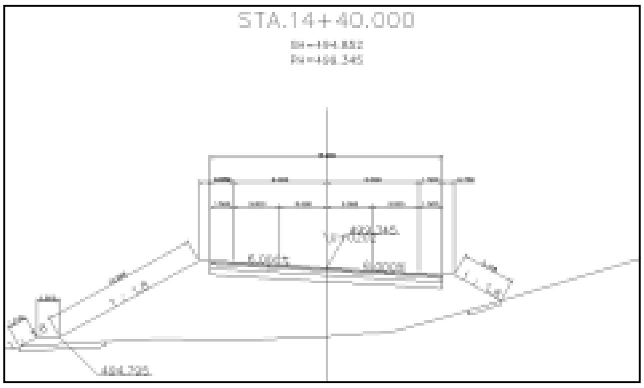


Fig.9. Works 1 (cross-section drawing)

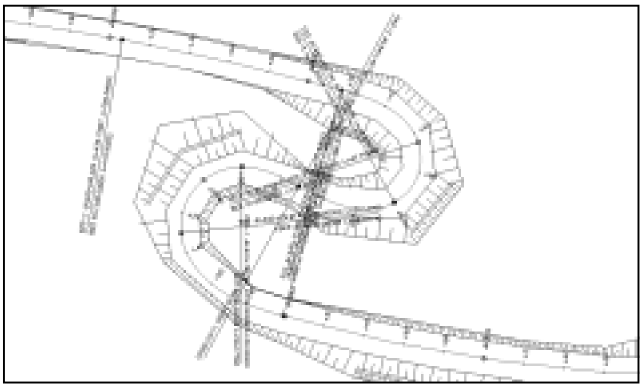


Fig.10. Works 2 (plan drawing)

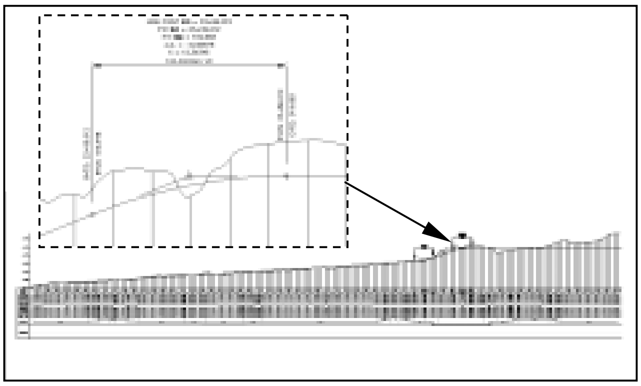


Fig.11. Works 2 (longitudinal-section drawing)

The student said that because he chose an unusual shape of roadway, the most difficult thing was to make plan drawing and the slope in longitudinal section drawing. Although it was not a too heavy work, he said that it was still unanticipated to do so.

4.4.2 Student's Impression

On the whole, impression from students was good. Especially, those students who were familiar with CAD said they benefited a lot from this course. They emphasized that they had learned practical skill from this course. "In the past, we had no knowledge about the software as LDT, so it is very helpful to be familiar with this kind of software." "This software is very easy to master." "I have never studied so carefully like in this course up to now." "As a student in civil engineering, I must learn how to use computer effectively to deal with real business issues." They even encouraged us to offer this course continuously.

Some students, however, criticized that our attempt prefers software to design. "There are a few classmates who didn't consider how to calculate parameters. They made blind parameters. So their design is not strict." One student wrote in his report.

Some students suggested that although this exercise was free design, the theme should be limited much strictly. For example, total amount of earthwork in the 20 meters area should have a maximum limitation. In this way, students can understand the design more deeply.

Concept making is usually weakness for students. They are unwilling to spend more time on writing their report. They misunderstood that the design of a project was only drawing it. So, it is necessary to emphasize its importance and supply them incentive atmosphere.

Even if the teacher wants to express his purpose clearly, perhaps he cannot do so in fact. For example, one student commented in his report as this. "I didn't know through this course what I should learn at first. But at the end of lesson, I understood what the main point is and how I should consider it. This is also very interesting." In a word, some students understood the main point that is described in Chapter 2 and Chapter 3, but some did not. So more effort should be put into the lecture.

For students who have not taken CAD education, limited time to exercise CAD couldn't expect great effect. They hope to extend span to one year. So in distributed system, if they want to spend much time positively in order to master the software, they can do it voluntarily. However, for the majority of students, they are not used to this kind of education. They felt time is enough because they are used to traditional method; that is to say, scribbling their reports only before deadline. In order to solve this problem, we asked students to submit their reports in the middle and at the end in twice. In this way, the pressure can be eliminated little by little.

The goal of our course prefers to cultivate creativity of students, rather than work out a practical design plan. Even though students' design results are unable to be implemented, teachers should also give them much praise. Commendation from both teacher and expert is needed.

According to the experience of this year, authors plan to improve the lecture in the schedule as the following.

Scheme 1: CAD should be taught to graduate students in the first semester of the first year. AutoCAD is first choice for practice.

Scheme 2: LDT should be practiced in the second semester of the first year.

① In the first half of semester, curve setting should be exercised over and over again by hand for following practice.

② Similarly to the practice of this year, up to the two third of the whole duration, first exercise should be finished and first review should be held. The direction will be adjusted according situation.

③ In second exercise, some real-world project terrain models that are completed will be supplied to students for simulating. In this way, students can access real project site or spot. Consequently, they can design more actually.

4.5 Summary

4.5.1 Consideration

In submitted designs, it is unavoidable that there is so many questions existed. This is because students decided the parameters by themselves according to the road grade and the standard speed. Although there was only a little hint in the reference material, some students even made very good design by referring to many reference books. Being the overall design, cross section drawings and longitude section drawings are considered as educational achievements. Moreover, this kind of experience is irreplaceable to improve students' ability for the future work.

As mentioned above, LDT and Civil are software products to support the whole lifecycle of civil design, including survey, design and drawing. In this experiment, the lecture was forced to given as the web system was set up. So it is inevitable for students to spend a lot of time to practice those softwares. Frankly, the road design itself was paid less attention. But students said that through the deciding of parameters, they touched with real design. In this way, they understood the their meaning. With this knowledge, it will be easier for students to operate the design software in their future work.

Because of the limitation of time, two-dimensional drawings, including cross section drawings, longitude section drawings and expansion drawings in normal direction, were expected to be the experimental achievements. The three-dimensional CG was only hoped to get in passing. But in fact, the result demonstrated that it is possible to train CG skill in this way. So in the future, students' design will be possible to be submitted in three-dimensional CG form.

4.5.2 Comment from An Industry Instructor (Mr. Fukuchi)

AutoCAD LDT R2 is a software product equipped with powerful functions to support design. Comparing with AutoCAD LT, which is the two-dimensional subset of AutoCAD and the standard software used in civil engineering, AutoCAD LDT R2 demands the operators more design knowledge and skill. In this practice, more than half of students are new to CAD. But nobody dropped out. Moreover, they even criticize the textbook for misprinting. Some opposing arguments were also raised against teachers. They showed very active attitude to study. This should thank to the using of web BBS, which is not only real time but also makes it possible to let several instructors take part in the education activities.

In recent year, it became more and more for university to invite some instructors who have experience in real work, especially in the area of engineering design with software. But its purpose should focus on the process of design itself and the decision of parameters, not only on the usage of CAD software.

In the future, it can be predicted that IT technology will impact civil engineering on design and construction management. Consequently, high education should be reformed to meet this need. Using the collaborative distributed education system, one lecture can be completed by several teachers. In this way, the problem of lack of talents can be overcome. Even in remote place, the best instructors can also be available for education.

4.5.3 Comment from An Industry Instructor (Mr. Ueno)

I think it is a good arrangement to divide the lecture into two parts: the first half and the second half. My main work was to instruct students for road design and three-dimensional CAD operating. This year, our work mainly focused on the flow of road design (layout plan, longitude section and cross section) and how to decide the earthwork parameters. In the end, all the achievements were satisfied very well. But it was not sure that only within two class periods, whether students could understand the contents well or not. In next practice, it is planned to add the vehicle speed as design condition to make the design to be more actual.

It is very convenient to use the web pages to give students instruction because it cannot be affected by time and place. To be honest, I am often away from home or company. So it is my only choice to use mobile telephone and portable computer to answer students' question. The traditional educational activities are limited in fixed time and the potential resource cannot be utilized effectively. With the collaborative distributed education system, the lecture limitation can be eliminated completely. The number of teachers can be unlimited in theory. For instructors, their talents can be exploited. The education cost can be decreased greatly.

By the way, it is valuable experience for our industry instructors to know what the modern students are concerning and how they are thinking.

5. CONCLUSION

In this research, collaborative education, which combines asynchronous and distributed method with synchronous and gathering method, is introduced. Pilot practical education on the course Roadway Design has been done among graduate students in Graduate School of Science and Technology, Kumamoto University, Japan.

Asynchronous and distributed collaboration system was prepared for the research. By using this website, seven teachers and fifteen students formed a collaborative team. They could solve various problems about how to set reasonable design parameters and to use the software of LDT/Civil in roadway design. With communication through the web site, it was not necessary for industry experts to often show up at university. Only in the place of job could they answer students' question in web page remotely.

Synchronous and gathering method refers to the traditional education. At the beginning of whole lecture, all the teachers met students, explained syllabus of course and assigned exercises. After students exercised a period of time, comments were made on every student regarding their works. Remote experts only needed to present one or two times at university. In this way, students can receive instruction from experts that have rich experience in both engineering and software.

Web pages cannot only display questions and their answer, but also introduce works, notify some issues and so on. So the collaborative education is suitable for three-dimensional CAD education. In the future, we plan to extend students' number to 50 and open the class to junior of undergraduate students. Furthermore, it can be considered to apply this method to distance education and continuing education.

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