Sketch Learning Environment with Diagnosis and Drawing Guidance from Rough Form to Detailed Contour Form

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Abstract. We developed a sketch learning environment with a diagnosis function and the ability to guide drawing from a rough form to detail a detailed contour form. We use a cup and a dish as motifs. When a learner uses the environment, the system first requires the learner to draw a circumscribed-rectangle of the motif's view on paper. Then, the system diagnoses the circumscribed-rectangle and advises the learner if it has errors. The system guides the learner from a rough form to a detailed contour form by repeatedly drawing circumscribed-rectangles. We evaluated the environment and confirmed a significant learning effect.

Keywords: Sketch, Learning environment, Painting, Drawing, Skill.

1 Introduction

There exist many systems and software that support drawing or painting on computers. For example, Baxter developed an excellent system called DAB that assists a user in painting on a virtual paper on a computer [1]. The user operates a stylus pen on a haptic interface as a brush, and the system paints colors using the virtual brush on the virtual paper. The motion and pressure of the virtual brush reflect those of the stylus pen.

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Z. Pan et al. (Eds.): Transactions on Edutainment III, LNCS 5940, pp. 129–140, 2009.

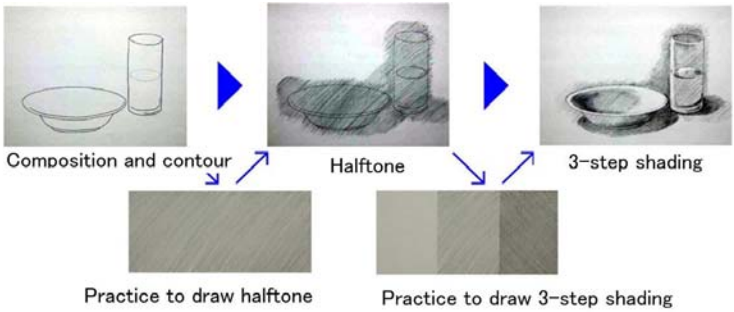


Fig. 1. Process for drawing a sketch. This process was proposed by a painter who teaches sketch drawing to novice learners, and therefore, it may not be used by all painting teachers.

Although DAB is an excellent system, it does not have a function for diagnosing the sketches by users. Therefore, novice learners cannot use DAB for self-learning. Learning support for drawing or painting is a task that differs from drawing support or painting support. Functions for diagnosis and advice are required for learning support. Our project was the first learning environment that could diagnose a learner's sketch and then provide advice.

We have previously developed various sketch learning support environments. Our environments are capable of diagnosing sketches drawn on real paper. This function is a unique feature of our environments, and it is important for learners, because drawing on a paper using a real pencil requires a different skill as compared to drawing on a virtual paper using a mouse or a stylus pen.

Our first sketch learning environment is described in [2-4]. This environment could diagnose a sketch drawn by a learner and provide adaptive advice for the correction of errors in the sketches. Figure 1 shows the process for drawing a sketch. The process comprises 3 stages, namely, (1) composition and contour, (2) halftone, and (3) 3-steps shading. This environment could successfully diagnose the learners' sketches after they completed each stage. However, because of this limitation, if a drawn sketch had many errors, the learner had to correct many errors at once or redraw the sketch. Some learners felt overburdened by this and occasionally, some lost the motivation to continue learning how to draw sketches.

To avoid these situations, we developed environments that could diagnose sketches while the learners were still drawing them. These environments were developed based on the cognitive process of a human being's interaction with objects. Human interactions with objects comprises three main stages, namely, recognition, selection (or decision), and action (Fig. 2). This process is explained for the task of drawing a sketch as follows.

In the recognition stage, a learner perceives objects as a motif of drawing, and recognizes them. If the learner recognizes, say, a dish, then he/she moves into the selection (or decision) stage as follows. The learner thinks how to draw the dish. Then, he/she decides to draw the edge of the dish first. The edge of the dish appears elliptical from his/her viewpoint. Then, he/she thinks how to draw the ellipse. He/she

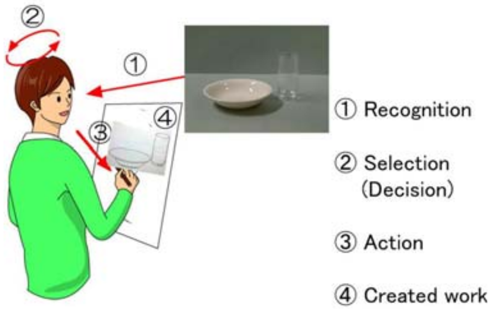


Fig. 2. Interaction between a learner and objects. The interaction comprises 3 stages, namely, (1) recognition, (2) selection (decision), and (3) action. A learner creates his/her work by repeating this process many times.

decides to divide it into two parts. He/she decides to draw the upper half of the ellipse first by moving his/her arm like a compass. Then, he/she decides to draw the lower half of the ellipse in the same manner after putting the paper upside down. Therefore in the selection (or decision) stage, the learner selects (or decides) appropriate actions that he/she will perform in the next stage. Finally, in the action stage, the learner acts in accordance with the actions that he/she selects (or decides) in the selection (or decision) stage.

Based on the human interaction process, we developed a sketch learning support environment that provides adaptive advice in real time. This environment comprises two subsystems - an area-dependent advice system and a hand and arm motion advice system.

The area-dependent advice system [5,7] is designed for supporting the recognition stage. It obtains the learner's drawing position data using the pen tablet. It identifies the area in the motif that the learner is drawing. The system offers advice according to the areas where the learner draws. The system originally has an abstract sketch area map. This map comprises small areas in a sketch. Each area is related to specific advice contained in the advice DB.

The hand and arm motion advice system [5,6] is designed for supporting the action stage. It obtains the learner's arm motion data when he/she installs 3D magnetic position sensors in his/her shoulder, elbow, and wrist. The system compares the learner's arm motion data with the teacher's correct data stored in the system. Specifically, the system compares speeds, arm orientations, and drawing areas by arm motions. If an error occurs, the system offers advice to the learner using the 3D arm model in real time.

The two systems were combined into one environment to support the selection (or decision) stage. The environment could determine where a learner was drawing, and simultaneously determine the hand and arm motion. Therefore, the environment could decide whether the hand and arm motion is appropriate for the area where the learner is drawing.

We evaluated the environment and confirmed the effect of advice. However, there remained two unsolved issues. One is that the area-dependent advice system provides advice on the detailed contour of the motifs from the beginning. However, this method is not appropriate for novice learners because it is not easy to draw detailed contour from the beginning. Furthermore, novice learners may acquire only a few drawing skills that cannot be applied to any other motifs. In other words, the area-dependent advice system could be effective for drawing support, but not for skill learning support in drawing. Therefore, it is necessary to resolve these issues.

The remainder of this paper is organized as follows. In chapter 2, we describe our new learning environment. In chapter 3, we explain an evaluation experiment. Finally, we present the conclusions in chapter 4.

2 Design of New Sketch Learning Environment

To resolve the abovementioned issues, we developed a new sketch learning environment that provides diagnosis and drawing support from a rough drawing to a detailed contour drawing. We use a cup and a dish as motifs. When a learner uses the environment, the environment first requires the learner to draw a circumscribed rectangle of the motifs' view. Then, the environment diagnoses the circumscribed rectangle and advises the learner of errors, if any. The environment guides the learner from a rough form to a detailed contour drawing by repeatedly drawing circumscribed rectangles. Our new learning environment can be used only in the composition and contour stage (Fig. 1), because its objective is to solve the issues in this stage.

2.1 Composition of Sketch Learning Environment

Figure 3 shows a composition of the sketch learning environment and a flow of the procedure. The environment comprises two databases (DBs) and a pen tablet. The DBs are the advice DB and the DB of the motifs' views and auxiliary lines.

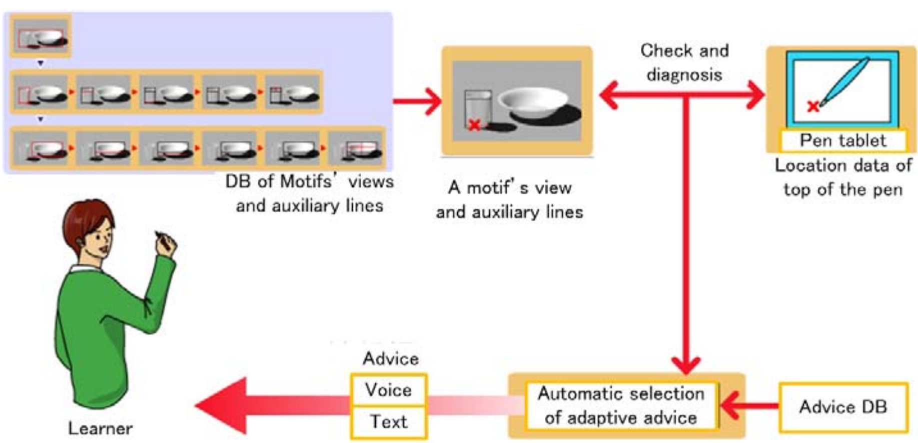


Fig. 3. Composition of sketch learning environment and a flow of the procedure. The environment comprises two DBs and a pen tablet. The DBs are the advice DB and the DB of the motifs' views and auxiliary lines.

2.2 Preparation

We used a dish and a cup as motifs. Advice data in the advice DB and data in the DB of motifs' views and auxiliary lines must correspond to the motifs. Therefore, the motifs are fixed. Learners cannot use their own motifs. Therefore, the environment is motif-dependent. However, the design of the learning environment and the methodology described in this paper can be applied to other motifs.

Motifs are kept on a table at a distance of 1 m from a learner. The comparative position between the dish and the cup is fixed in advance. A learner's viewpoint is also fixed in advance. Therefore, the learner must arrange his/her sitting height by changing the chair height at the beginning.

The learner uses a pen tablet called Intuos 3, 12x19 and a grip pen for Intuos 3 made by Wacom (left-hand side, Fig.4). The tablet's active area size is 12" x 19". The tablet can obtain location data of the grip pen by electromagnetic induction. We improved the grip pen of the tablet Intuos 3 (right-hand side, Fig.4) by attaching a pencil tip to it. The learner places a paper on the tablet, and draws a sketch using the improved grip pen by observing the motifs on the table.

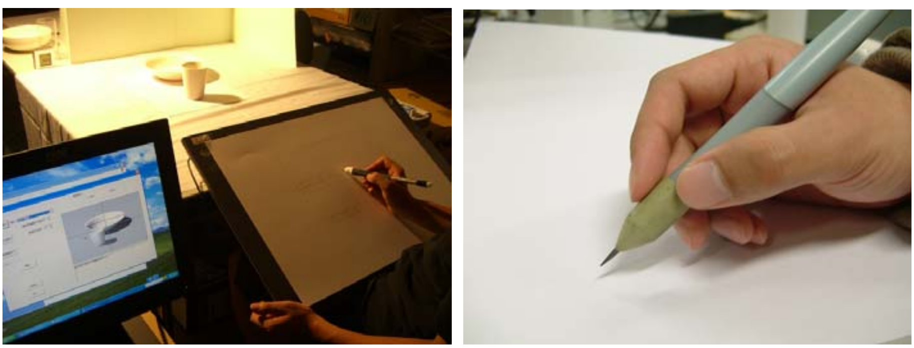


Fig. 4. The left-handed side shows a sketch being drawn on a paper on the tablet Intuos 3 using the improved grip pen by observing motifs on a table. Right-hand side shows the improved grip pen of the tablet Intuos 3. A pencil tip is attached to it.

2.3 Strategy for Learning Support

This environment is designed to resolve the issues in chapter 1. Therefore, the necessary objectives and functions that the environment must support are as follows.

(1) To support the learning of general drawing skills. It is desirable for a learner to learn more general drawing skills that are independent of the motifs.
(2) To support learning by reflection.
(3) To reduce modification load.

To achieve (1), we propose a method in which the environment requires a learner to draw circumscribed rectangles of motifs or parts of motifs at every drawing step. The circumscribed rectangle motif's view reflects not only the size and location but also the aspect ratio of the motif or a part of it. It is easy for a learner to determine the size, location and aspect ratio of motif's view by drawing a circumscribed rectangle.

To achieve (2) and (3), we propose a method in which the environment diagnoses a learner's drawing at every step, and provides advice if the drawing has errors. The learner can reflect on his/her drawing by checking at every step. In this manner, the modification load becomes minimal as well.

On the basis of the abovementioned discussion, the flow of the procedures of the learning environment is as follows. When a learner uses the environment, the environment first requires the learner to draw a circumscribed rectangle of the entire motif's view. Then, the environment diagnoses the circumscribed rectangle and advises the learner if it has errors. The environment guides the learner from a rough form to a detailed contour form by repeatedly drawing circumscribed rectangles (Fig. 5).

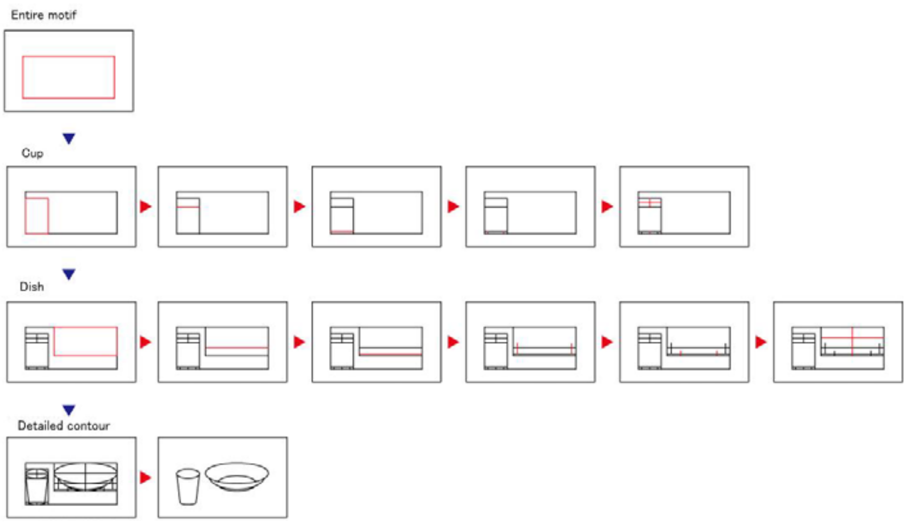


Fig. 5. Flow of guidance from a rough form of the entire motif view to a detailed contour form by repeatedly drawing circumscribed rectangles and auxiliary lines

2.4 GUI and Interaction between a Learner and the Environment

Figure 6 shows the GUI of the learning environment. It can show the motif CG in the DB of the motifs' views and auxiliary lines. A learner can select "Display motif CG" or "Do Not display motif CG" on the GUI. It is recommended that the motif CG is not displayed, since the learner can then draw a sketch by observing only the motif CG without observing the real motifs. The learner is strongly recommended to draw a sketch by recognizing a real motif in the real world. Otherwise, he/she cannot enhance his/her drawing skills. The ability to recognize a real motif and its projection on a paper is an important skill for drawing a sketch.

It is important to draw a sketch by considering the proportions of motifs. Here the proportion is the size ratio between the motifs and their aspect ratios. If a learner can recognize the proportion correctly, he/she can draw a sketch well. Therefore, the environment supports the drawing of auxiliary lines. First, the learner draws the circumscribed rectangle of the entire motif. At this stage, the learner can recognize and learn the entire motifs' proportions carefully.

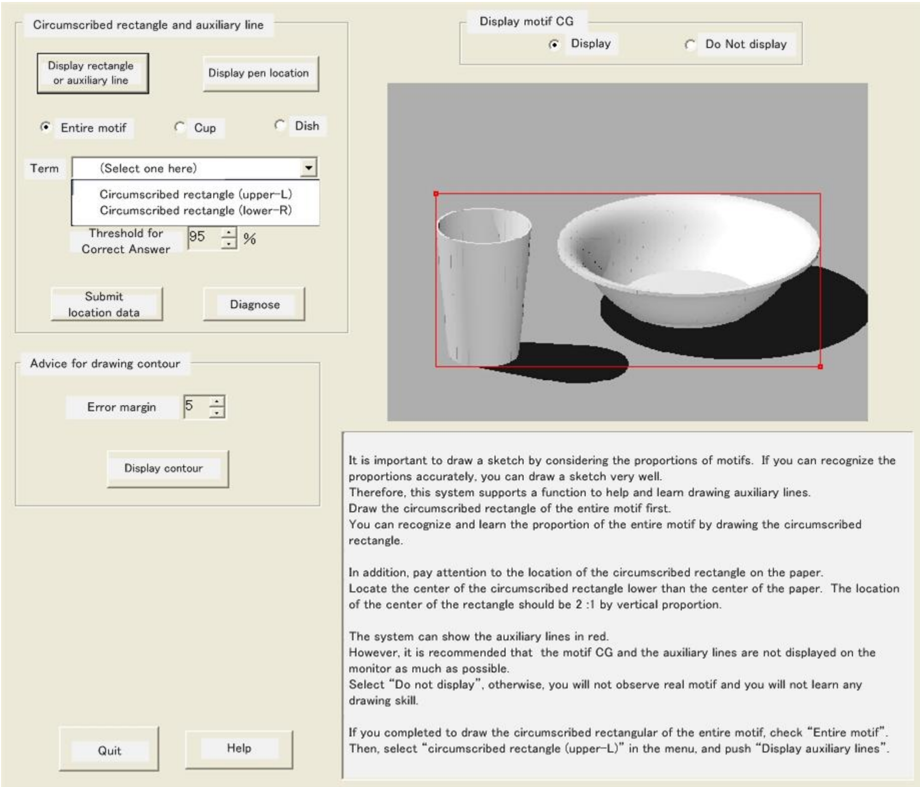


Fig. 6. GUI of the learning environment

At the same time, the environment advises the learner to focus on the location of the circumscribed rectangle drawn on a paper. The environment indicates to the learner that the center of the circumscribed rectangle should be located at a point lower than the center of the paper. In addition, it indicates that the location of the center of the rectangle should be 2:1 by vertical proportion.

The learner checks "Entire motif" at the upper left of the GUI. Then, the learner selects "circumscribed rectangle (upper-L)" in the menu, and selects "Display auxiliary lines." Then, the environment shows a circumscribed rectangle of the entire motif in red. If the learner understands what is to be drawn, he/she draws a circumscribed rectangle of the entire motif on the paper on the tablet. Then, the learner points to the upper-left vertex of the drawn circumscribed rectangle using the improved grip pen and clicks the "Submit location data" button. Similarly, the learner submits location data of the lower-right vertex as well.

The location data of the upper-left and lower-right vertices form a unique rectangle. Therefore, when the learner clicks the "Diagnose" button, the environment calculates the difference between the circumscribed rectangles of the input data and the data in the DB of motifs' views and auxiliary lines. If there is a difference between the two, the environment retrieves adaptive advice sentences from the advice DB and indicates the advice to the learner using voice and text messages.

Figure 7 shows all auxiliary lines. The number for each auxiliary line indicates the order of drawing and diagnosis.

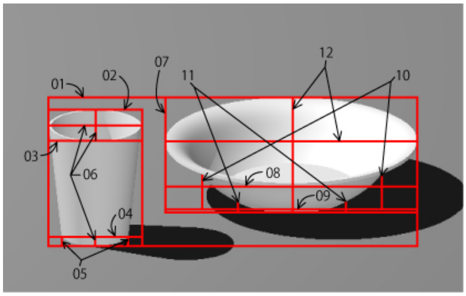


Fig. 7. All auxiliary lines. The numbers for each auxiliary line indicates the order of drawing and diagnosis.

3 Evaluation

We evaluated the learning environment by comparing an experimental group with a control group.

3.1 Goal of Evaluation Experiment

The goal of the evaluation experiment is to confirm the learning effect by the learning environment. In particular, it is necessary to determine whether the learned drawing skills are applicable to other dishes and cups.

3.2 Method of Evaluation Experiment

Figure 8 shows the flow of the evaluation experiment. 20 students from our university participated in this experiment. They were all novices. They were divided into two groups, namely, the experimental group and the control group, each comprising 10 students. The students in the experimental group used the learning environment; those in the control group did not use the learning environment but read instructions on paper. The same dishes and cups are used in the pre-test and in the training and learning stage; however, the layouts are different. The dimensions of the dishes and cups are different in the training and learning and the post-test stages. This is done to determine whether or not the subjects in the experimental group can learn general drawing skills using the learning environment.

In the training and learning stage, subjects in control group read instructions on paper. These instructions are the same as those provided by the learning environment to the experimental group. Therefore, the only difference between the experimental and control groups is that the former trains and learns interactively. The learning environment diagnoses and advises them on drawn auxiliary lines and contours step-by-step. However, the control group trains and learns without any such interaction.

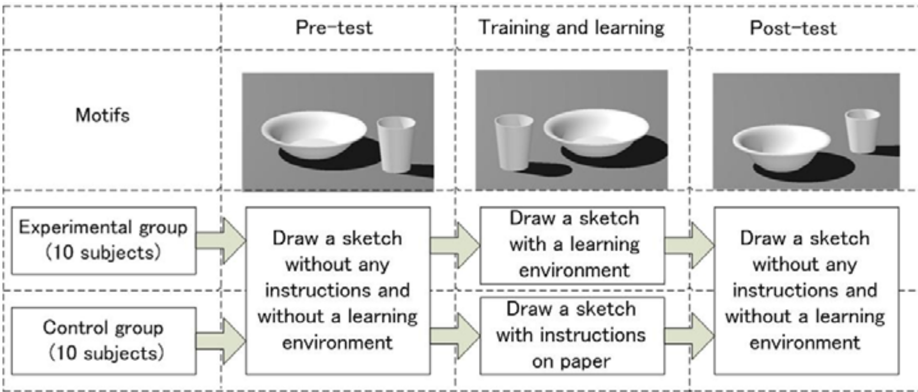
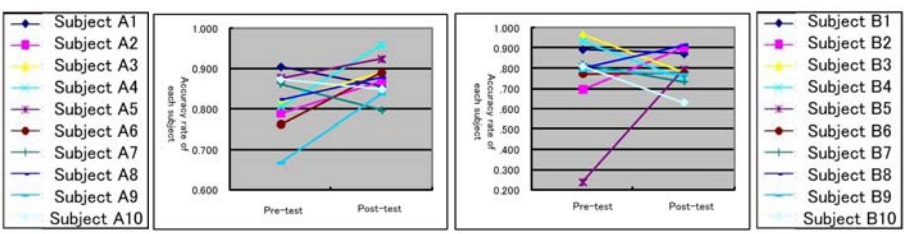


Fig. 8. Flow of evaluation experiment. The same dishes and cups are used in the pre-test and the training and learning stages. Different dishes and cups are used in the training and learning and the post-test stages.

3.3 Results

Figures 9 - 13 show a comparison of the learning performances between the experimental and control groups. In these figures 9 - 13, the horizontal axis indicates time, and the vertical axis indicates the accuracy rate of each subject. If the accuracy rate is increasing, it implies that a subject is exhibiting a learning effect. The accuracy rate is given as the ratio between the subject's drawing and the correct drawing. If the accuracy rate is equal to 1.0, it implies that a subject's drawing is perfectly accurate. Note that the accuracy rate does not imply the ratio of the number of subjects who draw correctly.

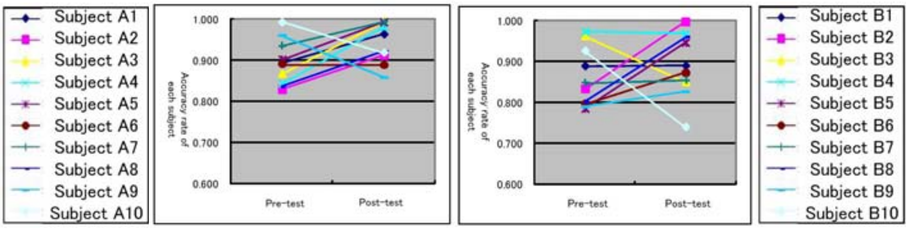
Figure 9 shows a comparison of the learning performances of the aspect ratio of circumscribed rectangles of entire motifs. The t-test results of learning performances are P = 0.056 in the experimental group and P = 0.774 in the control group. If P < 0.05, the result is significant. Therefore, the result of the experimental group is close to being significant.



(a) Experimental group (b) Control group

Fig. 9. Learning performance of the aspect ratio of circumscribed rectangle of entire motif

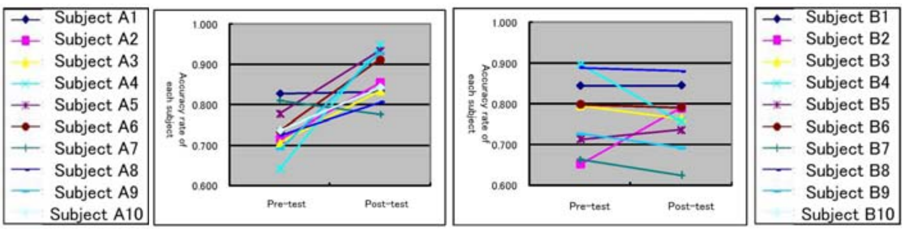
Figure 10 shows a comparison of the learning performances of the aspect ratio of circumscribed rectangles of cups. The t-test results of learning performances are P = 0.095 in the experimental group and P = 0.440 in the control group. If P < 0.05, the result is significant. Therefore, both results are not significant.



(a) Experimental group (b) Control group

Fig. 10. Learning performance of the aspect ratio of circumscribed rectangle of cups

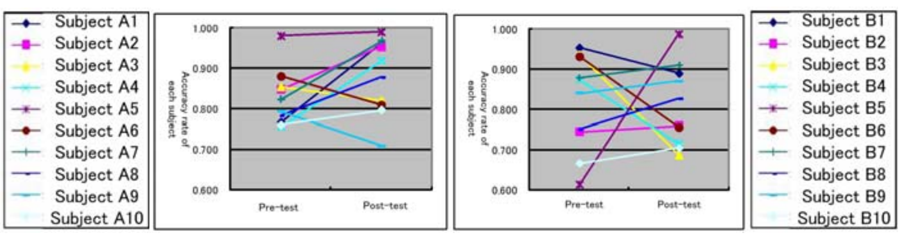
Figure 11 shows a comparison of the learning performances of the aspect ratio of circumscribed rectangles of dishes. The t-test results of learning performances are P = 0.003 in the experimental group and P = 0.428 in the control group. If P < 0.05, the result is significant. Therefore, the result of the experimental group is very significant.



(a) Experimental group (b) Control group

Fig. 11. Learning performance of the aspect ratio of circumscribed rectangle of dishes

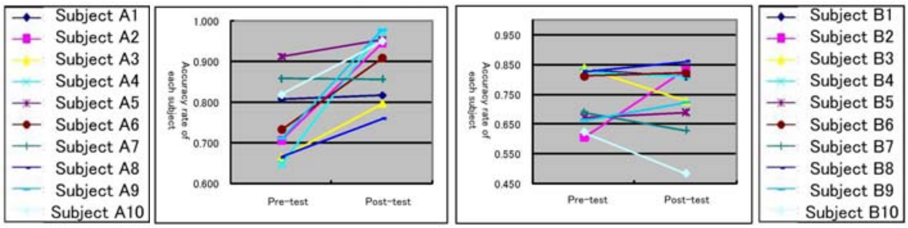
Figure 12 shows a comparison of the learning performances of the aspect ratio of circumscribed rectangles of ellipses of cups. The t-test results of learning performances are P = 0.106 in the experimental group and P = 0.884 in the control group. If P < 0.05, the result is significant. Therefore, both results are not significant.



(a) Experimental group (b) Control group

Fig. 12. Learning performance of the aspect ratio of circumscribed rectangles of ellipses of cups

Figure 13 shows a comparison of the learning performances of the aspect ratio of circumscribed rectangles of ellipses of dishes. The t-test results of learning performances are P = 0.003 in the experimental group and P = 0.996 in the control group. If P < 0.05, the result is significant. Therefore, the result of the experimental group is very significant.



(a) Experimental group (b) Control group

Fig. 13. Learning performance of the aspect ratio of circumscribed rectangles of ellipses of dishes

3.4 Discussion

The experimental results indicate that the learning environment is effective for learning how to draw accurate circumscribed rectangles of a dish and the ellipse of a dish. A significant learning effect could not be observed in drawing circumscribed rectangles of a cup and the ellipse of a cup. We consider why the results of the experiment exhibit such a difference.

We believe that the result comes from the facts that a dish is larger and it has a shape that differs significantly from a circumscribed rectangle. If a motif is large, it is probably difficult for learners to recognize the aspect ratio correctly since they cannot recognize the entire motif at once. In addition, if the motif has a shape that differs significantly from a circumscribed rectangle, it is probably difficult for learners to recognize the circumscribed rectangle since they have to mentally visualize the circumscribed rectangles.

4 Conclusion

In this paper, we first explained the background of our sketch learning support environment project, and then described the necessity of developing the new sketch learning environment with a diagnosis function and the ability to guide drawing guidance from a rough form to a detailed contour form. We use a cup and a dish as motifs. When a learner uses the environment, the system first requires the learner to draw a circumscribed rectangle of the motif's view on paper. Then, the system diagnoses the circumscribed rectangle and advises the learner if it has errors. The system guides the learner from a rough form to a detailed contour form by repeatedly drawing circumscribed rectangles.

Finally, we evaluated the environment, and confirmed a significant learning effect when learners draw dishes. However, we could not confirm a significant learning effect when learners draw cups. We believe that the result comes from the facts that the dish is larger and it has a shape that differs significantly from circumscribed rectangle.

We conclude that our learning environment is more effective when learners try to draw complicated motifs. In the future, we intend to apply the learning environment to more complicated motifs.

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