Journal for Geometry and Graphics
Volume 3 (1999), No. 1, 99–109

Evaluation of Objective Test Using a Pair of Orthographic Projections for Descriptive Geometry Education

Kazuhiko Takeyama[1] , **Ryoji Maeguchi**[1] , **Kokichi Chibana**[2], **Katsuyuki Yoshida**[3]

[1] *Department of Architecture, Faculty of Engineering, Setsunan University*
Neyagawa, Osaka 572-8508, Japan
emails: take@arc.Setsunan.ac.jp, mae@arc.Setsunan.ac.jp

[2] *Department of Architecture, Faculty of Science and Engineering, Kinki University*
Higashiosaka, Osaka 577-8052, Japan
email: chibana@arch.kindai.ac.jp

[3] *Department of Architectural Engineering, Graduate School of Engineering, Osaka University*
Toyonaka, Osaka 560-0043, Japan
email: a61369@center.osaka-u.ac.jp

Abstract. This paper shows the results of tests that evaluate the effects of the education in orthographic projection. One of them is the "Objective Test" that was developed at Osaka University in 1994. The others are traditional pencil-and-paper tests. We have applied these two kinds of tests to students at Setsunan University from 1995 to 1997. The contents of the education at Setsunan University are different from those of Osaka University. The lectures and workshops at Setsunan University were carried out by pencil-and-paper, while those of Osaka University were carried out by 2D CAD. The results of the objective test have been very stable for three years. Two points to be improved are found out in the process of teaching. The objective test is useful for improving the education in Descriptive Geometry at the Setsunan University. The results of other courses related to Descriptive Geometry as workshops of architectural drawings are also discussed in this paper.

Key Words: Descriptive Geometry education

MSC 1994: 51N05

1. Introduction

In 1994, one of the authors began to teach orthographic projection by a CAD system at Osaka University. Then he evaluated the effects of the education by five typical problems.

ISSN 1433-8157/$ 2.50

Each problem has five possible solutions which must be marked with "O" or "X". This test is called *"Objective Test on Orthographic Projection"* (hereafter referred to as OTO). On the other hand, the education in Descriptive Geometry at Setsunan University consists of lectures and exercises. The effects of the education are evaluated by pencil-and-paper tests. They are called *"Descriptive Test on Orthographic Projection"* (hereafter referred to as DTO) and *"Descriptive Test on Perspective Projection"* including shades and shadows (hereafter referred to as DTP). In 1995, we applied the OTO to the students of Setsunan University in addition to the DTO. The results were presented at the 7th ICECGDG (Takeyama et al. 1996 [2]). In this paper, the results of the tests that we have applied to the students and the correlation among the results of the tests and the grades of the architectural drawings are discussed.

2. Tests and drawings

2.1. Tests

Tests used in this paper are OTO, DTO, DTP, and the *Mental Cutting Test* (hereafter referred to as MCT). The MCT has been developed for the college entrance examination in the United States. It was applied to students at many universities in Japan (Suzuki et al. 1992, [1]). It is used as a comparative test in this paper. DTO is shown in Appendix A and OTO is shown in Appendix B.

2.2. Architectural drawings

At Setsunan University, one studio work of architectural drawings is assigned to the students of the 2nd academic year and another to those of the 3rd academic year. The former is called *"Architectural Design No. 1"* (hereafter referred to as AD1) and the latter *"Architectural Design No. 2"* (hereafter referred to as AD2). The contents of AD1 are four copies of blueprint and two designs of small buildings. Two of the copies are drawings of Japanese wooden houses and the rest of the copies are of reinforced concrete buildings. The contents of AD2 are six drawings of architectural designs as kindergarten, library, museum, civic center and so on. The total number of points attainable at AD1 and AD2 is 100, each.

2.3. Students

86, 87 and 99 students who entered the Department of Architecture, Setsunan University, in 1995, 1996 and 1997, respectively, answered to all tests and submitted all drawings.

2.4. Implementation of the tests

The OTO has been applied to the students in October of the first academic year. The MCT was also applied in October 1995 and 1996. In 1997, it was applied in April and in October. The former is referred to as 1997-1 and the latter as 1997-2. The DTO has been applied to the students in September of the first academic year and the DTP also in February in the same academic year.

3. Results and discussions

3.1. Distribution of students' scores

The frequency distributions of students' scores are shown in Fig. 1. Mean values and standard deviations of DTO, DTP, AD1, and AD2 are also shown in Table 1.

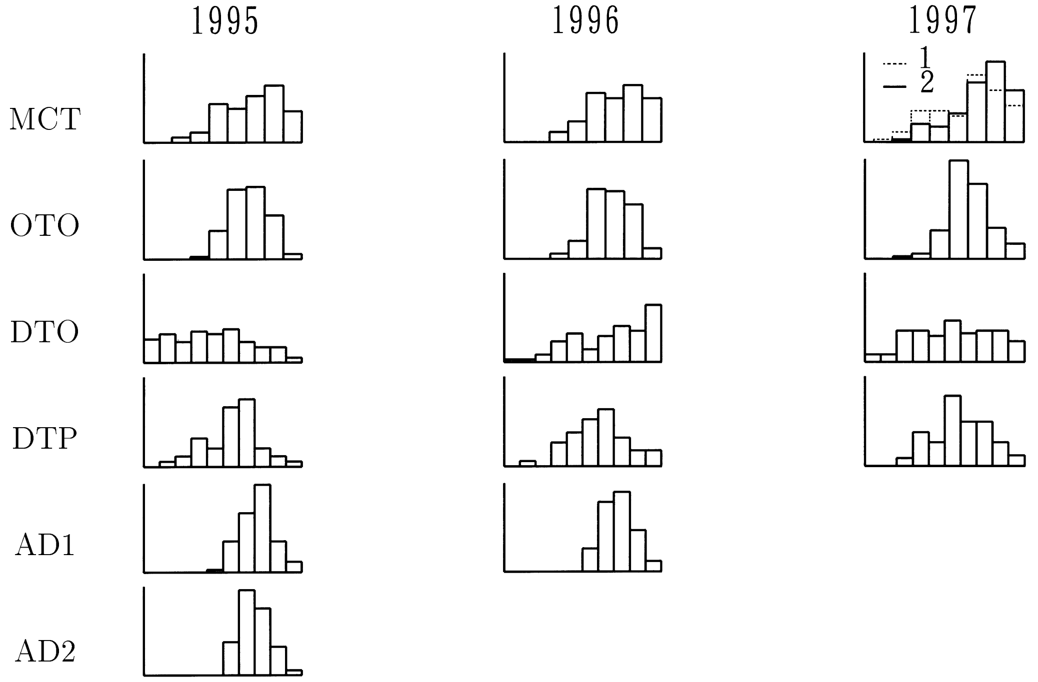


Figure 1: Frequency distributions of students' scores

		1995	1996	1997
DTO	*mean value*	45.2	68.8	58.0
	stand. dev.	24.6	23.5	24.5
DTP	*mean value*	55.8	63.1	62.4
	stand. dev.	16.8	17.9	17.2
AD1	*mean value*	73.0	74.1	—
	stand. dev.	10.4	9.9	—
AD2	*mean value*	71.6	—	—
	stand. dev.	9.6	—	—

Table 1: Mean values and standard deviations of DTO, DTP, AD1, and AD2

3.1.1. MCT and OTO

The frequency distributions of MCT are incline to the high score. The skewness of the distributions range from -0.84 to -0.35 and the kurtosises range from 2.22 to 3.01. There are significant differences among the mean values except for 1996 and 1997-2. Especially the difference between 1997-1 and 1997-2 is obvious.

On the other hand, the frequency distributions of OTO are approximately normal ones. There is no significant difference of the mean values at Setsunan University through three years. So, the scores of the OTO are very stable.

3.1.2. DTO and DTP

The frequency distributions of DTO are approximately flat. The kurtosises of the distributions range from 2.05 to 2.28. It is obvious that there are differencies among the mean values. But, the standard deviations have almost been the same during these three years.

Though the frequency distributions of DTP are approximately normal distributions, the standard deviations are almost the same like DTO. As the mean value of 1995 is lower than that of other years, DTP is not stable.

As shown in Appendix A, DTO applied in one year is different from one applied in the other year. It may affect the differences among the mean values. Of course, there are fluctuations every year in the grading standards.

3.1.3. AD1 and AD2

There are two data sets on AD1 and only one data set on AD2, because the former is the course for sophomores and the latter for juniors. The frequency distributions of student's scores of AD1 and AD2 are almost normal distribution. The mean values are ranging between 70 and 75. As these courses are workshops, there are a few students who get points below 60.

problem no.	1995	1996	1997-1	1997-2
1	89.5	92.0	93.9	97.0
2	73.3	66.7	66.7	66.7
3	98.8	100.0	98.0	100.0
4	87.2	81.6	75.8	80.8
5	86.1	88.5	87.9	88.9
6	86.1	82.8	82.8	89.9
7	76.7	78.1	75.8	78.8
8	94.2	94.3	86.9	83.8
9	39.5	42.5	40.4	53.5
10	80.2	85.1	77.8	82.8
11	84.9	90.8	82.8	91.9
12	69.8	78.2	63.6	71.7
13	50.0	48.3	39.4	56.6
14	52.3	62.1	53.5	54.6
15	80.2	83.9	74.8	81.8
16	62.8	64.4	57.6	79.8
17	63.9	78.2	60.6	74.8
18	72.1	83.9	70.7	77.8
19	64.0	66.7	62.6	77.8
20	74.4	85.1	77.8	84.9
21	66.3	74.7	53.5	74.8
22	66.3	66.7	60.6	77.8
23	40.7	36.8	35.4	40.4
24	46.5	46.0	43.4	50.5
25	45.4	51.7	32.3	43.4
mean value	70.0	73.1	66.2	74.4
stand. dev.	18.2	17.3	21.3	18.5
r 1995	1	0.951	0.968	0.920
r 1996		1	0.942	0.922
r 1997-1			1	0.935
r 1997-2				1

Table 2: Correct answer rates, mean values, standard deviations of MCT and correlation coefficients "r" among the correct answer rates of each year

3.2. Correct answer rate

The *"correct answer rate"* is defined by the following formula:

$$\textit{correct answer rate}\ \ (\%) = 100 * Nc/Na$$

Nc: number of students who get correct answer to the problem
Na: number of students who solve all problems

The correct answer rates are shown in Tables 2 and 3. The correlation coefficients among data sets are also shown in Tables 2 and 3.

problem no.	*solution no.*	1994	1995	1996	1997
1	1	89.9	83.7	79.3	79.8
	2	86.5	72.1	71.3	78.8
	3	94.4	82.6	85.1	87.9
	4	96.6	86.0	86.2	95.0
	5	87.6	67.4	77.0	62.6
2	1	88.8	70.9	70.1	71.7
	2	89.9	47.7	59.8	67.7
	3	86.5	44.2	50.6	51.5
	4	75.3	50.0	60.9	61.6
	5	85.4	65.1	77.0	66.7
3	1	89.9	79.1	72.4	69.7
	2	77.5	70.9	64.4	57.6
	3	85.4	53.5	50.6	53.5
	4	97.8	67.4	72.4	74.7
	5	80.9	41.9	49.5	47.5
4	1	34.1	33.7	37.9	36.4
	2	85.4	62.8	67.8	54.5
	3	54.5	58.1	64.4	64.6
	4	67.0	82.6	82.8	73.7
	5	76.1	59.3	59.8	52.5
5	1	67.4	86.0	80.0	72.7
	2	78.7	89.5	96.6	87.9
	3	88.6	80.2	73.6	65.7
	4	70.8	67.4	49.4	85.9
	5	92.1	94.2	89.7	85.9
mean value		81.1	67.9	69.2	66.6
stand. dev.		13.9	16.0	14.2	14.4
r	1994	1	0.404	0.456	0.540
	1995		1	0.896	0.807
	1996			1	0.905
	1997				1

Table 3: Correct answer rates, mean values, standard deviations of OTO and correlation coefficients *"r"* among the correct answer rates of each year

3.2.1. MCT

The maximum correct answer rate is 100 % at problem no. 3 in 1996 and 1997-2, and the minimum one is 32.3 % at problem no. 25 in 1997-1. The correct answer rates are below 60 % at the problems no. 9, no. 13, no. 23, no. 24, and no. 25.

The maximum correlation coefficient is 0.968 between 1995 and 1997-1, and the minimum one is 0.920 between 1995 and 1997-2. There are high correlations among data sets of every years. It means that the shapes of the graph of the correct answer rates are very stable.

tests/drawing	*year*	OTO	DTO	DTP	AD1	AD2
MCT	1995	0.179	0.273	0.115	-0.095	-0.076
	1996	0.196	0.422	0.211	0.085	—
	1997-1	0.257	0.310	0.286	—	—
	1997-2	0.286	0.351	0.219	—	—
OTO	1995		0.241	0.116	0.140	0.082
	1996		0.226	0.207	0.082	—
	1997		0.296	0.331	—	—
DTO	1995			0.282	0.317	0.258
	1996			0.333	0.397	—
	1997			0.250	—	—
DTP	1995				0.347	0.294
	1996				0.434	—
AD1	1995					0.588

Table 4: Correlation coefficients among tests/drawings

3.2.2. OTO

The maximum correct answer rate at Setsunan University is 96.6 % at solution 2 of problem no. 5 in 1996, and the minimum one is 33.7 % at solution 1 of problem no. 4 in 1995. The correct answer rates are below 60 % through three years at solution 3 of problem no. 2, solution 3 of problem no. 3, solution 5 of problem no. 3, solution 1 of problem no. 4 and solution 5 of problem no. 4.

The maximum correlation coefficient at Setsunan University is 0.905 between 1996 and 1997, and the minimum one is 0.807 between 1995 and 1997. There are high correlations among data sets of every years. It means that the shapes of the graph of the correct answer rates are very stable.

The correlation coefficients between each of 1995, 1996, 1997 (Setsunan University) and 1994 (Osaka University) are not so high. Though both values of the correct answer rate at Setsunan University and at Osaka University are below 40 % at solution 1 of problem no. 4, the values of Setsunan University are obviously lower at solution 2 of problem no. 2, solution 3 of problem no. 2, solution 3 of problem no. 3, solution 5 of problem no. 3, solution 5 of problem no. 4 than those of Osaka University. This may show that the contents of the Descriptive Geometry courses are different between these two universities.

3.3. Correlation coefficient among tests/drawings

The correlation coefficients between each two tests/drawings are shown in Table 4. It is known that there is a correlation between two if the correlation coefficient is 0.2 or more. There is a fairly high correlation between AD1 and AD2. But, there is no correlation among MCT, OTO, AD1 and AD2. One reason may be that AD1 is applied to students one year after MCT and OTO, and AD2 is applied two years after. Some students who get low score on MCT and/or OTO may try to raise their score. In fact, there is an example of the student who gets the lowest score on DTO and gets the highest score (the full point) on DTP. As

MCT and OTO are applied simultaneously, the lowness of the correlation coefficient indicates that both tests evaluate different spatial abilities of the students.

3.4. Relation between DTO and OTO

DTO		N	OTO				
			1	2	3	4	5
1995	1	23	4.4	2.8	3.3	3.2	4.1
		63	3.8	2.8	3.1	2.9	4.2
	2	62	4.0	2.8	3.1	3.1	4.3
		24	3.8	2.8	3.3	2.7	3.8
	3	21	4.3	2.7	3.2	3.0	4.2
		65	3.8	2.8	3.1	3.0	4.2
	4	14	3.6	2.4	2.9	2.7	4.4
		72	4.0	2.9	3.2	3.0	4.1
	5	16	4.3	3.2	3.6	2.9	4.6
		70	3.8	2.7	3.0	3.0	4.1
1996	1	50	4.1	3.3	3.2	3.3	4.1
		37	3.8	3.0	2.9	2.8	3.6
	2	64	4.1	3.3	3.2	3.2	4.1
		23	3.8	2.9	2.7	2.8	3.5
	3	42	4.2	3.2	3.1	3.5	4.0
		45	3.8	3.1	3.0	2.8	3.8
	4	28	4.0	2.9	3.1	3.3	4.0
		59	4.0	3.3	3.1	3.1	3.9
	5	30	4.3	3.3	3.3	3.6	4.1
		57	3.8	3.1	3.0	2.9	3.8
1997	1	55	4.2	3.4	3.1	3.0	3.8
		44	3.9	2.9	2.9	2.6	3.3
	2	58	4.1	3.2	3.1	2.8	3.6
		41	3.9	3.2	2.9	2.9	3.5
	3	45	4.2	3.3	3.2	2.9	3.9
		54	3.9	3.1	2.9	2.8	3.3
	4	47	4.3	3.3	3.0	3.0	3.7
		52	3.8	3.0	3.0	2.6	3.4
	5	35	4.5	3.5	3.4	3.1	3.8
		64	3.8	3.0	2.8	2.7	3.5
	6	20	4.5	4.1	3.0	2.8	3.7
		79	3.9	3.0	3.0	2.8	3.5

N: number of students
upper line: students who get mean score or more
lower line: students who do not get mean score

Table 5: Numbers of students of two groups on scores of DTO and mean score of each group on each problem of OTO

The students are classified into two groups for each problem of DTO. The first is the group of students who get mean score or more, and the second is the group of students who do not get mean score. Numbers of students of each group are shown in Table 5. The mean scores of each problem of OTO for each group are also shown in Table 5.

	MCT	OTO	DTO	DTP	AD1	AD2
MCT	57.0	34.9	31.4	33.7	31.4	29.1
OTO		54.7	30.2	32.6	30.2	25.6
DTO			46.5	31.4	31.4	29.1
DTP				55.8	38.4	36.0
AD1					57.0	39.5
AD2						46.5

Table 6: Percentages of students who achieved mean score or more in two tests

With 5 % significant level, there is a significant difference between the mean scores of two groups on each solution in each problem except for problem no. 2 of OTO. It asks for the intersection point of a straight line and a given triangle and for the hidden part of the straight line (see Fig. 3). So, only solution 4 is "O" and all other solutions are "X". To avoid misunderstanding, the students at Setsunan University are only taught to intersect a straight line and a transparent plane. This is the main reason for the effect described above and the first point to be improved. One more point is that there are many students who mark two or more "O" to the solutions of Problem no. 2. It will be our future work to improve teaching intersections to the students at Setsunan University.

3.5. Relation among tests/drawings

The percentages of students who get mean score or more on each test/drawing are shown on diagonal of Table 6. Other values in Table 6 show the percentages of students who get mean score or more on both two tests/drawings indicated by column and row. So, Table 6 means that half or more students who get mean score or more on one test/drawing get mean score or more on another test/drawing. There are 8 % of students who get mean score or more on all tests/drawings and there are almost the same numbers of students who get scores below mean on all tests/drawings.

4. Conclusion

An objective test to check the students' understanding of orthographic projections and the traditional pencil-and-paper tests have been applied to the students of Setsunan University for three years. The scores are statistically analyzed. The obtained results are as follows.

1. The scores of the OTO and the shape of the graph of correct answer rates are very stable when the students are taught Descriptive Geometry by same way every years.
2. Two points must be improved in the education of Descriptive Geometry at Setsunan University. Such objective test is useful for instructors to find out the points to be improved in the education of Descriptive Geometry.
3. There is almost no correlation among each of tests/drawings. But, half or more students who get mean score or more on one test/drawing get mean score or more on another test/drawing.
4. As concluding remarks of this paper, these results show that such objective test like OTO is useful. How to teach the two points above described and how to develop new objective test to evaluate spatial ability of students are in our future works.

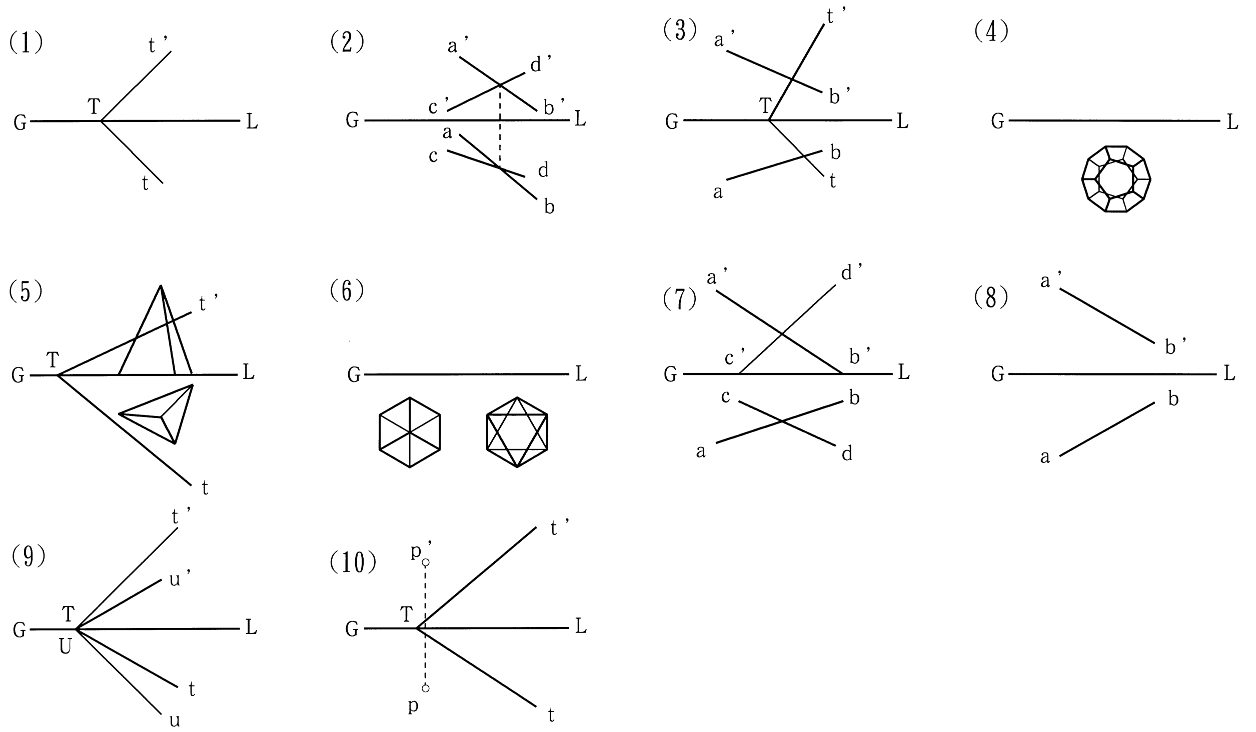


Figure 2: Problems of DTO

References

[1] K. Suzuki, K. Shiina, K. Makino, T. Saito, T. Jingu, N. Tsutsumi, K. Shibata, H. Maki, E. Tsutsumi, H. Isoda: *Evaluation of Students' Spatial Abilities by a Mental Cutting Test.* Proc. 5th ICECGDG, Melbourne, Australia, 277–281 (1992).

[2] K. Takeyama, R. Maeguchi, K. Chibana, K. Yoshida: *Development and Evaluation of Objective Test using a pair of Orthographic Projections to measure Spatial Visualization Ability.* Proc. 7th ICECGDG, Cracow, Poland, 584–588 (1996).

Appendix A: Problems of DTO

(1) Draw the trace of a plane parallel to a given plane in a given distance.

(2) Draw the trace of the plane that is determined by two intersecting straight lines.

(3) Draw the point of intersection P of plane T and line segment AB and show the true length of AP.

(4) Draw the elevation from the given plan of a regular dodecahedron.

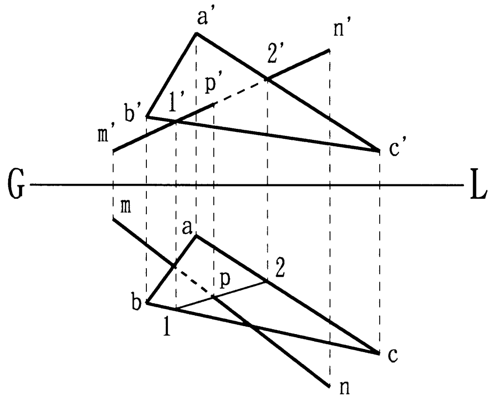
(5) Cut the triangular pyramid with plane T and draw the plan elevation and true shape of the section.

(6) Draw the elevations from the plan of a cube and a regular octahedron.

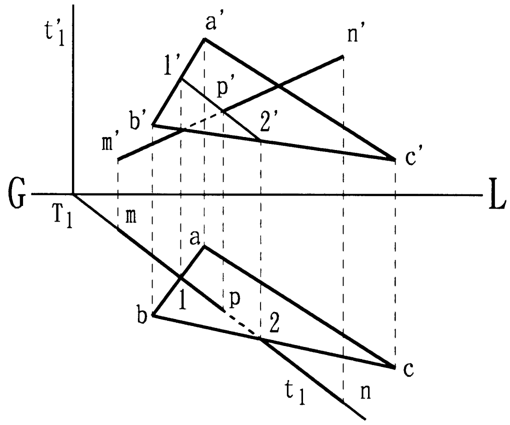
(7) Draw the true angle that is enclosed by two straight lines of intersection.

(8) Obtain the point C that is on the line segment AB in the distance 2 cm from the point A in direction to B.

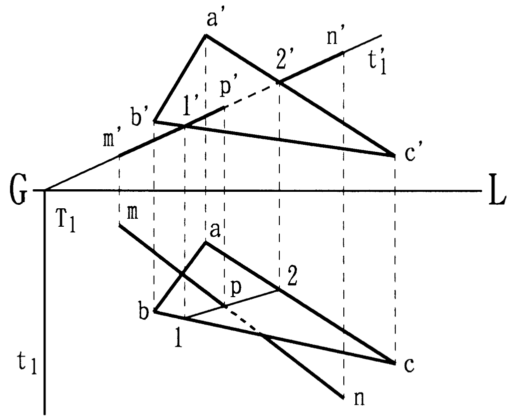
Problem 2. Determine the point of intersection between a triangle ABC and a straight line MN. Let the surfaces of the triangle be opaque. The hidden parts are shown with broken lines. Five possible constructions, solutions 1 to 5, are shown on this page. Mark the box under each construction with a circle if it is correct and an 'X' if it is incorrect.



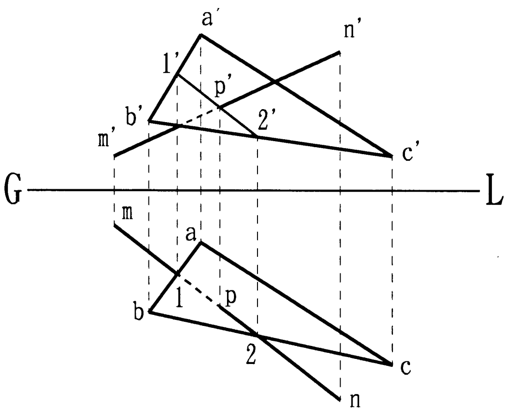
Solution No. 1 □



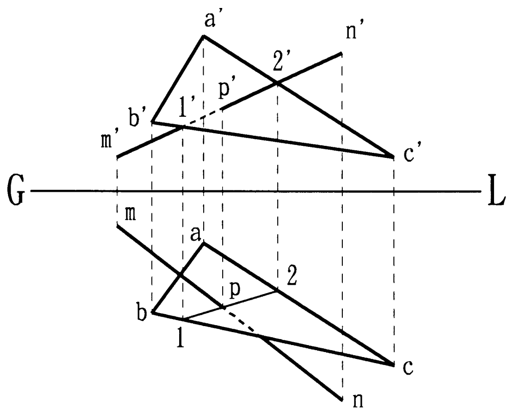
Solution No. 2 □



Solution No. 3 □



Solution No. 4 □



Solution No. 5 □

Figure 3: Problem no. 2 of OTO

(9) Draw the line of intersection of two given planes.

(10) Draw the vertical distance between the given point P and the given plane T.

In 1995 the test consisted of the five problems (1), (2), (3), (4), and (5), in 1996 of the five problems (2), (3), (5), (6), and (7). 1997 the six problems (1), (2), (5), (8), (9), and (10) had to be solved.

Appendix B: Test problem of OTO

OTO consists of the following five problems:

1. Determine the line of intersection between planes T_1 and T_2.
2. Determine the point of intersection between a triangle ABC and a straight line MN.
3. Determine the true shape of a triangle ABC by means of rabat.
4. Determine the lines of intersection between a pyramid $VABC$ and a plane T_1.
5. Determine the shade of a triangle ABC and a line MN for parallel rays R of light.

At each problem five possible solutions are proposed. One of these problems together with the solutions is shown in Fig. 3.

Received August 14, 1998