

MONGE PROJECTION OF A FOLDED PLATE - DIDACTIC PRINCIPLES FOR TEACHING DESCRIPTIVE GEOMETRY

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Abstract: The main task of teaching Descriptive Geometry (DG) for architects at university is to train three dimensional thinking. Nowadays the German school system completely neglects to encourage this. Great efforts are required to prepare first year students for their task to design in three dimensional space. Abstract thinking in DG is a perfect medium for this purpose. Since the students will realise this only in retrospect, topics and tasks are to be used which are naturally related to architecture. This will maintain a high level of motivation that is essential for successful building up three-dimensional imagination and thinking. The main concern of this paper is the demonstration of various didactic and methodical principles which optimise a thorough learning of Monge projection: the segmentation of a complex problem into abstract basic tasks, the visualisation of all phenomena in models and realistic illustrations, the computer animated movement (interactive variation of the basic elements of a drawing to demonstrate their significance), the following of the lecturer's presentation and at the same time the copying of the constructive development by the students, the transfer into their homework and the subsequent conversion into models.

Key Words: descriptive geometry, Monge projection, architecture, didactic principles.

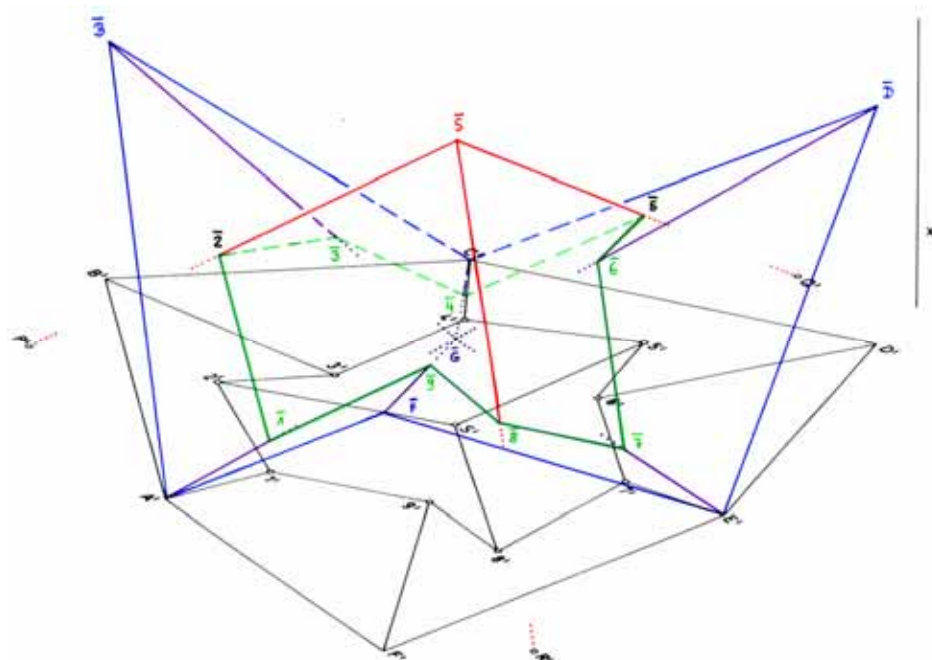


Figure 1: Orthogonal Axonometry of the folded plate

1. Introduction

Being a compulsory subject for architects at RWTH Aachen with only two weekly hours for one year Descriptive Geometry is having an extremely small teaching load at disposal. In addition this class is annually attended by about 250 students. To be able to supply a qualified contribution to the course of studies on architecture which is also approved by the stu-

dents, the faculty of mathematics has to develop a very sophisticated and broad teaching concept under disadvantageous conditions. In order to prevent DG from being removed from the syllabus great acceptance by both teaching and learning architects has to be called for. A smooth organisation of the lessons is a must if we want DG to appear useful to the students and keep them motivated during class. It is also essential, that the students' energies go completely into their dealing with the subject, so that counterproductive frustrations do not arise. The success of this concept is indicated by course evaluations: e.g. in July 2003 the DG course achieved by far the best score with a mark of 1.3 (on a scale from 1 (best) to 6).

2. Aims of DG within the architectural education

The main task of DG as subject in the architectural education is in my opinion the training of three-dimensional imagination. To achieve this aim a great deal of motivation is necessary, which can be maintained and even increased, if e.g. contents [1] and exercises with an obvious reference on architecture are employed. An additional aim is dealing with drawings, which is best learned by drawing by hand. Attending the course of classes developed by us the necessary competence is built up during a few weeks [2]. An additional emphasis is on the conscious dealing with different ways of projection, for architects should always be able to choose the most adequate and reasonable way of projection meeting the respective purpose; within this the different options on parameters are very important [3]. The application of CAD at the beginning of the study is a useful addition, but from the didactic point of view it cannot replace the classic DG.

3. The concept of the lectures for architects

Unfortunately lectures are among the first events avoided by the students, if the temporal burden becomes uncomfortable. Therefore the lecture has to be designed in a form, in which the prospective architects clearly can recognize their profit. Also the concentration during 90 minutes should not be overestimated. To maintain the students' motivation architectural examples illustrating the key point of the respective formulation are always demonstrated by means of a second overhead-projector.

The basic tasks introduced in the lecture are deepened during the presentation and explanation of the exercises. Within the exercise sessions the students have to apply the basic tasks to more complex problems. The basis for this is an exercise booklet which contains detailed descriptions of the tasks and several special worksheets for each exercise. The booklet is distributed as a file, so that single pages needed for specific lectures can easily be extracted.

Due to the concept of drawing on the prepared worksheets, the students are required to attend the lectures, because the worksheets cannot be dealt with without the explanations given during the lecture. In this way students have a reference book about the treatment of geometrical tasks to their disposal they have worked out by themselves. By drawing during the lecture the students' attention is kept at a high level; even if some students only repeat the constructions in a mechanical way, they are still exposed intensely to the contents.

By using colours wherever possible repeated elements in the construction are emphasised. Students are enabled to identify them easily in complex drawings and to find the explanations on the corresponding geometrical background within the booklet.

Apart from training three-dimensional imagination I consider it essential to work out clearly the specific transfer into a step-by-step construction and - if reasonable – even to offer “recipes”. The experiences of professional architects show that the combination of the recipes and the geometrical knowledge acquired during their studies provide them a lasting ability to tackle various geometrical tasks efficiently.

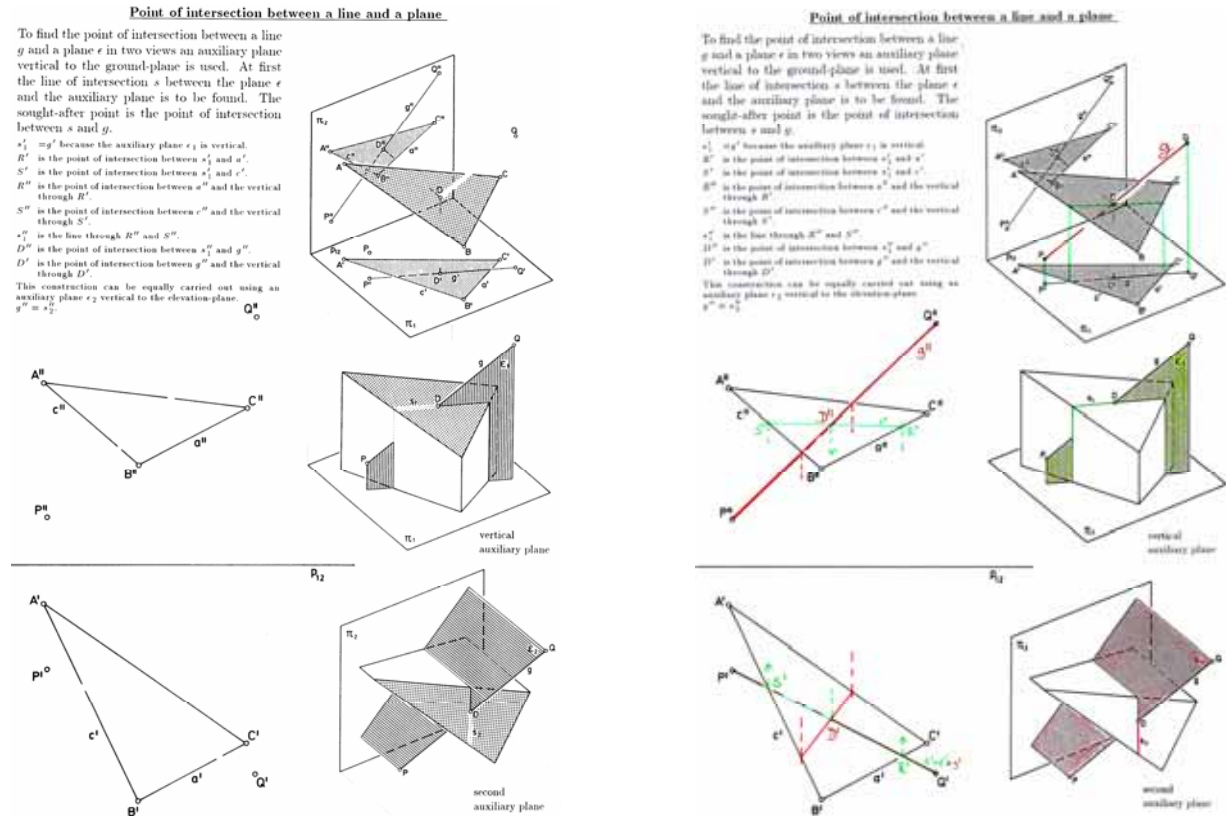


Figure 2: Worksheet before and after completion by the student

4. The concept of the exercise sessions for architects

The theoretical basis of the exercises is provided during the lectures. The lectures' structure is as far as possible fitted with the systematic sequence of the exercises. For easier integration of DG into the architectural course of studies examples of relevant architecture reduced to their essentials are employed as basis of the exercises wherever possible.

A 90 minute introduction to the exercises is given in the lecture room during which the students participate by drawing on the prepared worksheets using different colours. The basis for this is an exercise booklet with about 100 pages which includes detailed descriptions of the tasks and several special worksheets for each exercise. In case there is a loss of clarity due to too many constructions on a single worksheet, the next worksheet shows the steps already completed and the construction can easily be continued. Furthermore the students who got lost in the construction can join again at a later stage without any problems.

The basic tasks introduced in the lecture are deepened during the presentation and explanation of the exercises. Within these exercises the students have to apply the basic tasks to more complex problems. This happens with obvious reference to the lecture without repeating its contents. As a side effect the students' motivation to attend the lectures is increased.

In total, there are nine exercises to be successfully completed by the students. Among these are 5 exercises to be done as a homework and 4 exercises to be done in the classroom.

The homework exercises have to be completed by each student on his/her own by developing and working out an independent sketch within the set guidelines. During the homework each student will experience individual problems, so that the solution of the exercises is beyond the mechanical application of constructional recipes. To prepare the students as versatilely as possible the presented examples are in general more challenging than the ones given to the students later on. The homework exercises have to be completed within 10 days after their presentation using pencils on several A2 sized sheets of tracing paper.



Figure 3: A folded plate at the Expo 2000 in Hannover

The exercises to be done in class are prepared on A4 sized sheets and have to be completed within 90 minutes; handing out slightly different versions to each student ensures that each one handles his exercise on his own. Only a sound command of the tasks allows the student to deal with the relatively challenging exercises within the limited period of time.

4.1. The structure of the exercises' sequence

The sequence of exercises is designed in reference to increasing complexity of the geometrical phenomenon.

The lectures begin with the easily understandable application of cuboids in axonometries (oblique parallel projection); these exercises are followed by abstract geometrical basic task of Monge projection (orthogonal parallel projection) and the more complex connections of the central projections especially the perspective application of cylinders; the course ends up with the construction of shadows (parallel projection) in perspective images (central projection).

The course starts with the birds-eye-view, since this requires a rather simple construction and the underlying geometrical principle is easy to understand. Experience shows that the main difficulty of the first exercise, apart from the ability to think in three dimensions, is the skilful handling of the drawing tools. The second exercise is the reproduction of a complex building, where the required dotting of hidden lines presents a challenge in three-dimensional imagination.

The results of both exercises represent a sound basis for the development of the topic "Monge projection": On the one hand, this topic is especially difficult for students to understand because of its high level of abstraction, on the other hand, it is the main basis of the architect's daily work. Therefore, the treatment of "Monge projection" should take the key position within the DG lectures. The students benefit immensely from this solid knowledge when dealing with cones, cylinders, perspective and construction of shadows later on.

4.2. The homework exercise on the subject of folded plate within the Monge projection

Having completed the first two exercises the students are able to draw exactly and therefore are prepared to deal with the more demanding constructions of Monge projection.

The third exercise contents the development of a pavilion which consists of a folded plate which is intersected with a three-sided pyramid. The difficulty of the exercise lies within the three-dimensional imagination, thinking and constructing.

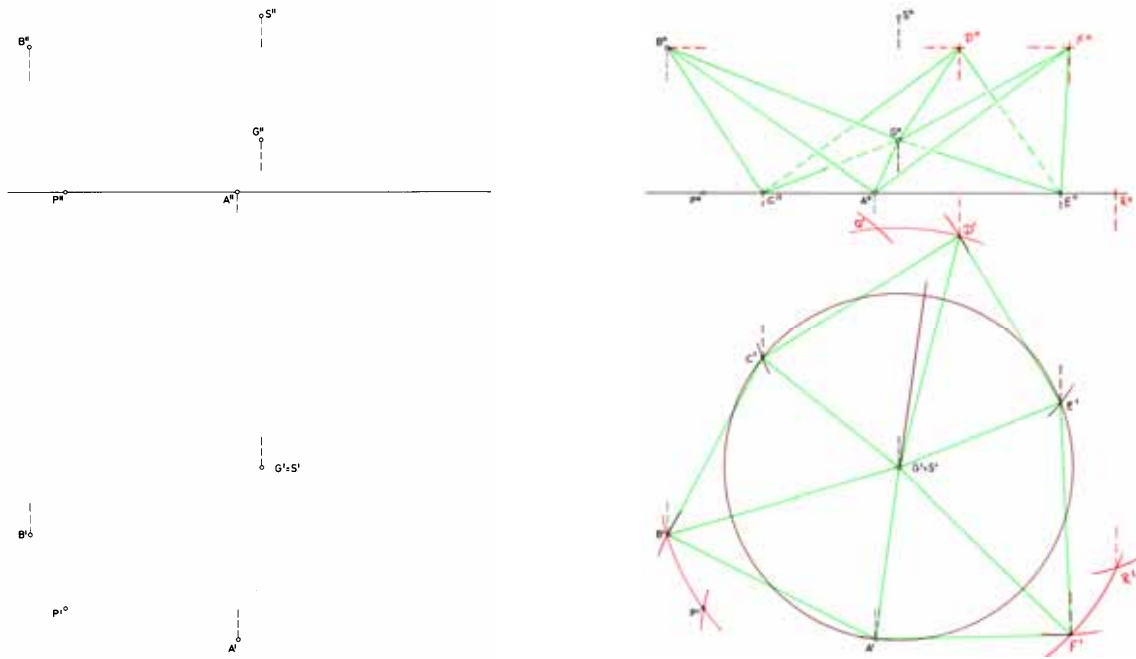


Figure 4: Choosing a symmetrical folded plate (before and after completion)

At first one has to determine a folded plate which is situated on the ground plane. The building should be symmetrical and the outline in the top view should form a hexagon. The building is standing on three points which form an equilateral triangle. A further equilateral triangle with different length of sides from the earlier described triangle is lifted parallel from the ground. The center of the plate lies on the vertical line which connects the focuses of both triangles.

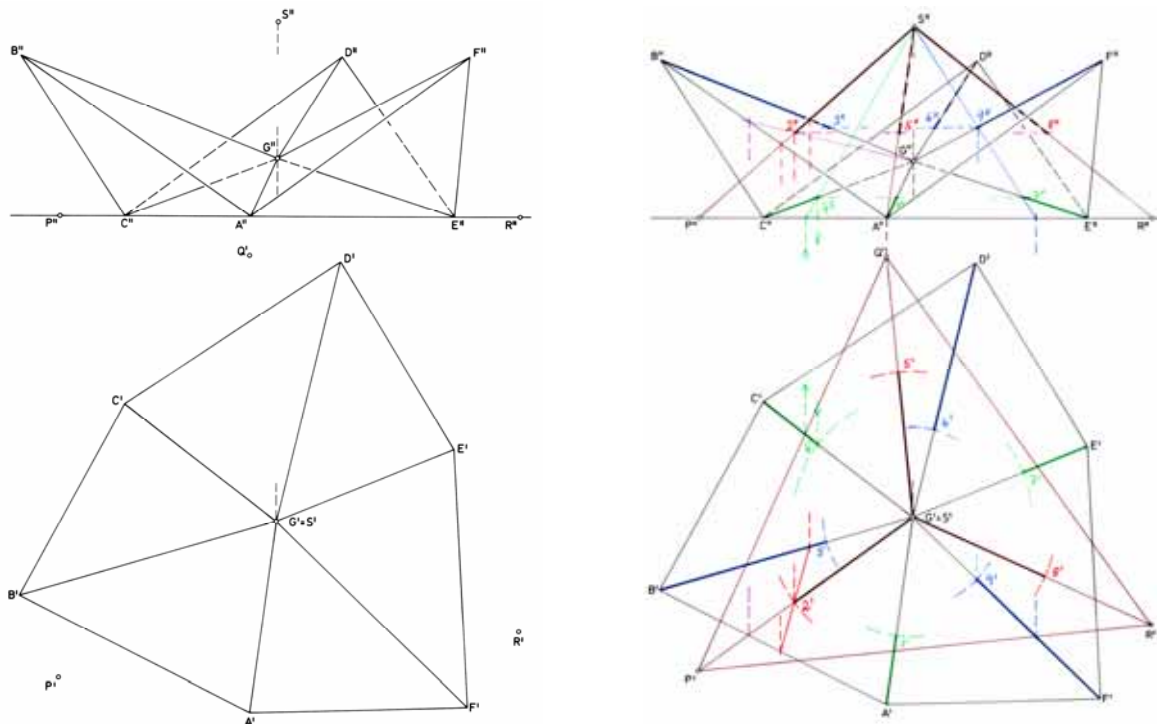


Figure 5: Intersection of lines and planes (before and after completion)

Furthermore a pyramid based on an equilateral triangle has to be chosen: The focus of the ground-triangle and the apex of the pyramid lie on the above mentioned vertical line.

The intersection of the folded plate with the chosen pyramid is done by repeating the basic task of “determination of the intersection of a straight line and a plane“.

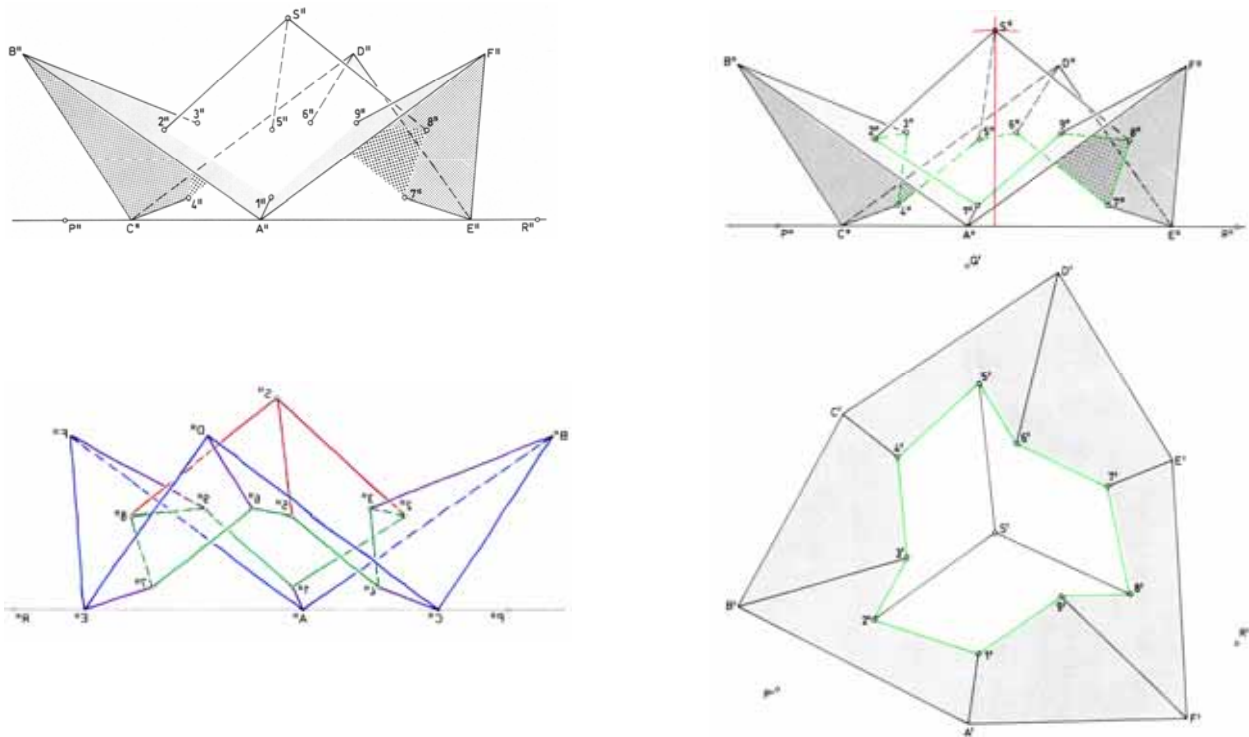


Figure 6: The blended figure (ground-plan and two elevations)

The visibility of the figure of intersection has to be indicated by both drawn through and interrupted lines. The drawing presents a great challenge to the students’ power of imagination, as our experience shows.

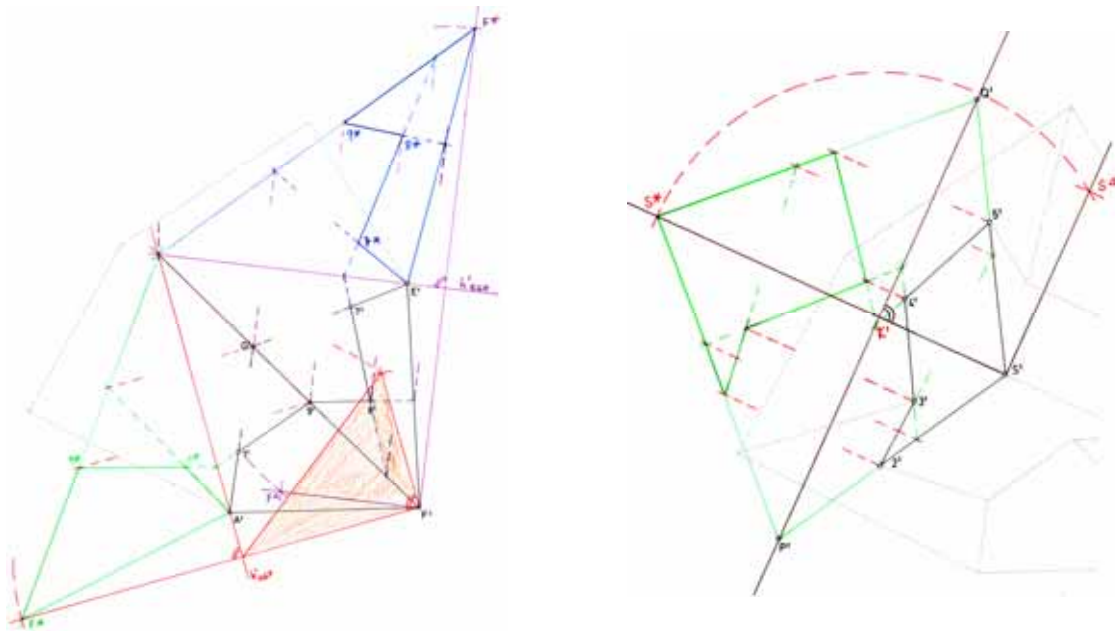


Figure 7: Unwinding of the pyramid and the folded plate (after completion)

In addition the true lengths of all facets of the pyramid including the blended figure have to be determined. The same task has to be carried out for the folded plate.

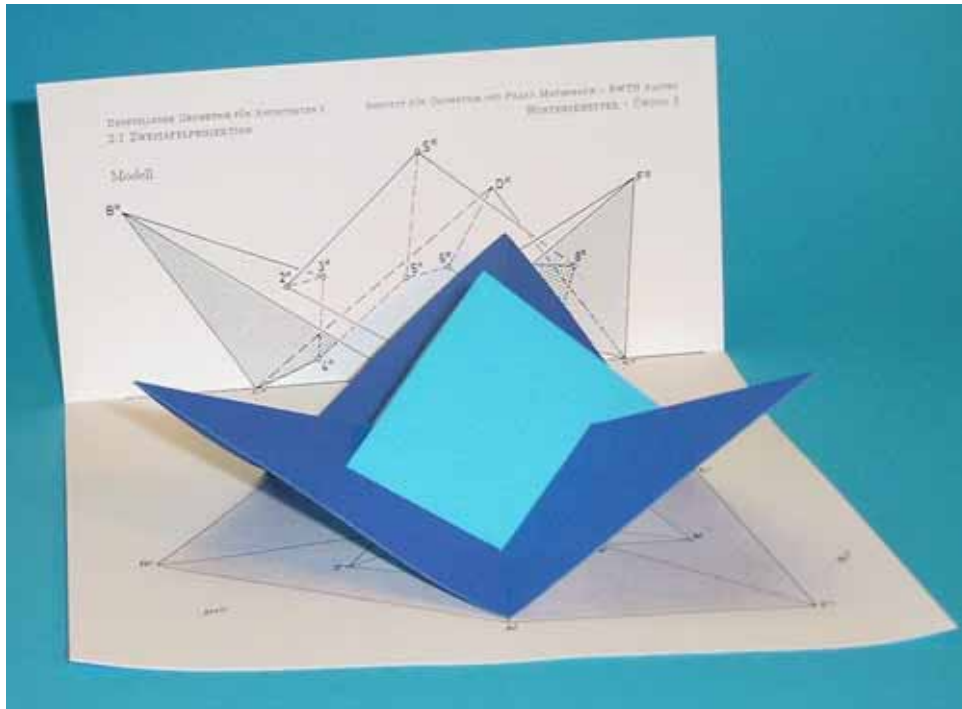


Figure 8: Model of the exercise “folded plate”

The learning effect is clearly increased, if a model based upon the abstract construction drawings is to be built in teamwork. The use of a model ideally supports three-dimensional imagination and provides means to check the students reasoning in three dimensional space.

4.3. Supporting the dealing with exercises

A seminar with about 250 students is surely unfavourable to teach. To balance the drawbacks of such a large audience, we offer a distinguished system of supervision:

- In a 90 minute lecture the geometrical foundations and specific construction methods referring to the exercises are taught.
- In a 90 minute exercise session the exercises are presented by carrying out the constructions with a complex example. Furthermore the coloured drawings presented are displayed in a showcase; in addition detailed and specific guidelines as well as descriptions of the constructions are available in the booklet [4].
- Also a 90 minute weekly tutorial is offered in order to answer any questions still left.
- There are another 30 minutes of personal consulting available for all those, who encounter special problems when dealing with their exercise.
- 15 minutes are reserved to examine and discuss homework in view of a pre-certificate which will be issued accordingly.
- Special exercises are handed out in view of training for the exercise done in the lecture room in limited time.

The students get their drawings returned thoroughly corrected and marked as soon as possible so that the results can be taken into account in the next exercise. For the personal consulting, the issuing of the pre-certificate and the marking I am supported by six teaching assistants who work under my guidance. My own participation in the personal consulting on the one hand gives the students the opportunity to get into personal contact with me and on the other hand it provides me the chance to control the success of the seminar. My guideline for this is due to Thomas Gordon who suggests viewing the critical student as best friend, because he is probably speaking also in the name of others hav

ing the same opinion but not expressing it. The course evaluations mentioned above show that the students highly appreciate the close supervision which this system provides.

5. Using media within the presentations

The drawings are presented by two overhead projectors and a beamer by projecting the images next to each other onto a screen. The lecture room is only slightly darkened, which at the same time allows the students to continue drawing and for the lecturer to stay in contact with the audience. The students look at three different pictures side by side, e.g. for the Monge projection the mid picture shows ground plane and elevation, on the left hand side they see the corresponding axonometry and on the right an illustrating architectural example; during the seminar they can look at the complex exercise on the middle screen, on the left the basic task under construction and on the right the solution that is aimed for. In view of the rapid progress during the presentation it has turned out very useful to leave the drawing just completed a little longer projected to one side of the screen in order to enable the students to complete their own worksheets.

In addition I use the geometric computer program WinCAG [5], developed by my colleague Karl-Heinz Brakhage, also projected to the screen by a beamer. This program allows to demonstrate the temporal sequence of the constructions and to vary the configurations in a dynamic and fluent way. The effects of these modifications can be followed simultaneously within different sections. This animation can be downloaded from www.dg-ac.de/wincag.

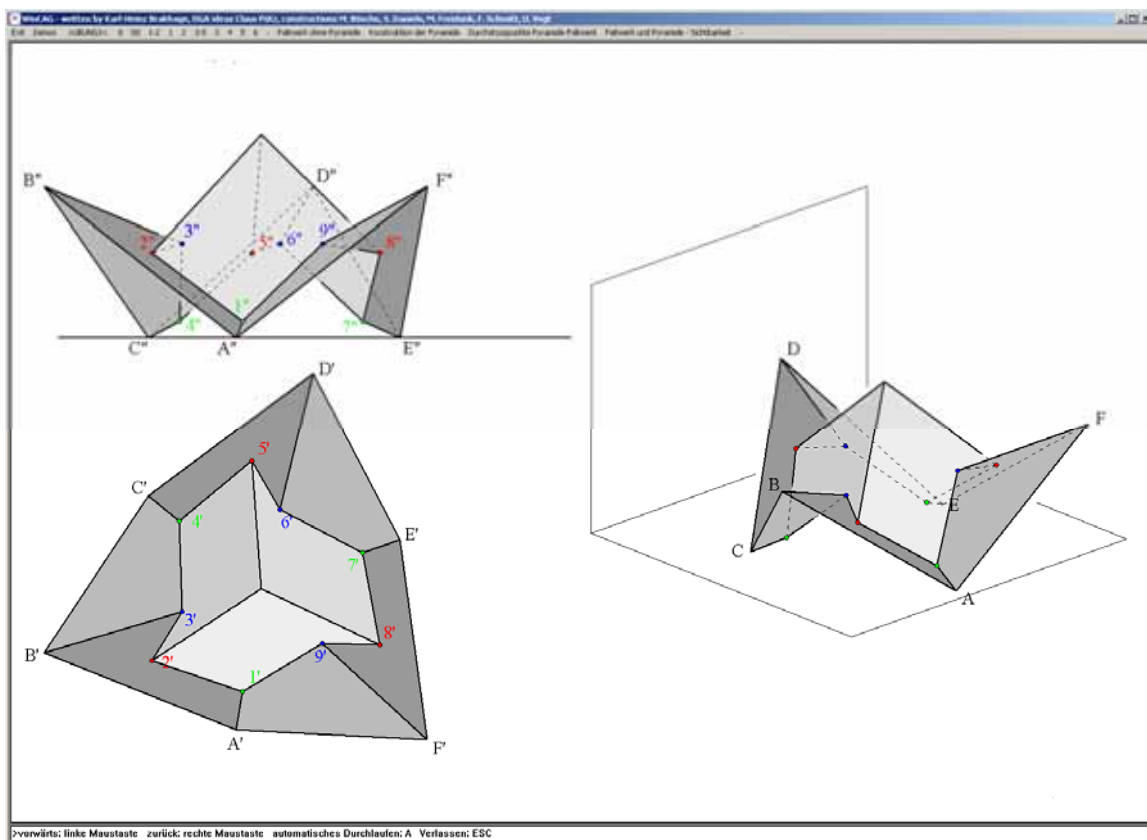


Figure 9: Diagram from the program WinCAG

The use of models is very important, although it is not easily handled in a lecture room with about 250 students. However the problems could be avoided by using very large models.

Conclusions

My emphasis is to design the studies on DG for the prospective architects in a way that it is both satisfactory and a lot of positive experience to them. The workload is only manageable with an optimal schedule; the concept presented here provides the formal conditions for such a schedule. If doing DG is fun for the students, they can be expected to be easily willing to invest a greater work expense. For this a smooth schedule is needed in order to ensure modest waiting periods, clear requirements directed to the students and prompt and comprehensible feedbacks on the students' work. The pedagogical attitude behind this approach is based on the models of "Living Learning" and "theme-centered interaction (TCI)" by Ruth Cohn and the "person-centered approach" by Carl Rogers.

To come up to the significance of DG and to be able to go even deeper into this subject, it would be necessary to increase the number of weekly DG hours at the RWTH Aachen. This would make some further promising attempts possible which would increase the later range of competence of architectural designers.

Highly successful course evaluations by the students demonstrate their great acceptance of our teaching method as well as that the DG lectures and the exercises are viewed as an integral part of architectural studies. They also have valued greatly the importance of DG with respect to their future professional life as architects.

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RZUTY MONGE'A PRZESTRZENNEJ TARCZOWNICY – DYDAKTYKA NAUCZANIA GEOMETRII WYKREŚLNEJ

Geometria wykreślna jest przedmiotem obowiązkowym (2 godz. zajęć w ciągu 2 semestrów) na Wydziale Architektury RWTH (Rheinisch-Westfälische Technische Hochschule) w Aachen. Autorska koncepcja realizacji dydaktycznej przedmiotu uwzględnia zarówno cel dydaktyczny (rozwijanie wyobraźni przestrzennej) jak również metodykę dydaktyki przedmiotu na tamtejszym wydziale. Tematyka wykładanego przedmiotu zawiera następujące problemy: aksonometria ukośna, podstawowe konstrukcje w rzutach Monge'a oraz ich zastosowanie w praktyce projektowania architektonicznego, rzut środkowy, ze szczególnym uwzględnieniem perspektywy, konstrukcja cieni, powierzchnie obrotowe. Metodyka realizacji dydaktycznej przedmiotu składa się z kolejnych etapów i elementów:

- wykład na zadany temat (90 minut tygodniowo), w czasie którego prezentowane są podstawy teoretyczne zagadnień na dwóch rzutownikach pisma i za pomocą rzutnika

komputerowego, na którym demonstrowane jest rozwiązanie z zastosowaniem programu WinCAG,

- ćwiczenia na zadany temat (90 minut tygodniowo), w czasie których studenci wykonują rysunki na specjalnie przygotowanych formatkach z podkładami; tu wykonuje się rysunki „odręcznie” z zastosowaniem kolorów; szczegółowe wskazówki podawane są studentom,
- studenci mogą dodatkowo skorzystać z nieobowiązkowego, 90-minutowego seminarium, w czasie którego wyjaśniane są wszelkie niejasności;
- indywidualne konsultacje (30 min.),
- dyskusja z każdym studentem (15 min.) w momencie oddawania zadania.

Każdy student musi w ciągu semestru wykonać 9 ćwiczeń: pięć – jako zadania domowe na formacie A2, cztery ćwiczenia wykonuje na zajęciach na formacie A4. Tematy wydawane studentom są różnicowane. Rysunki wykonywane są tradycyjnymi metodami wykreślnymi.

Jako przykład zadania domowego autor demonstruje na rysunkach 1, 3 ÷ 9 rozwiązanie problemu konstrukcji linii przenikania między przestrzenną tarczownicą a ostrosłupem prawidłowym trójściennym. Konstrukcja taka była elementem wystawowym w czasie Expo2000 w Hanowerze (rys.3). Uogólniając, każda konstrukcja omawiana w czasie kursu geometrii wykreślnej znajduje odwołanie do istniejących obiektów architektonicznych.

Sukces opracowanego kursu polega na jego wysokiej ewaluacji przez samych studentów (1.3 w skali 1-6; gdzie 1 jest oceną najwyższą, a 6 - oceną negatywną). Prowadzący zajęcia uzyskali wysoką ocenę merytoryczną zawartości kursu w uczelni, w której istnieje mocna tendencja do eliminacji geometrii wykreślnej z programu. Fakt ten jest niewątpliwym sukcesem naszych kolegów z Aachen.

Reviewer: Renata A. GÓRSKA, PhD, MSc

Received March 17, 2004