Virtual and Real
Geometry Learning Environments

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Abstract. In the Descriptive Geometry course in winter semester 2007/08 we introduced the "Blackboard Learning System CE" through the Virtual Campus Rhineland-Palatinate as an e-tutoring tool. In this system we take advantage of multimedia technologies for communicating, sparking the interest of the students in geometry and supporting the spatial visualization processes in learning descriptive geometry. In such a way of blended learning, e-based materials and e-tutoring are combined with face-to-face sessions, lectures and labs. The e-learning system supports the students in their self-paced learning and in solving the homework assignments. Components in the system are for example: discussion forums and chat, summaries of each lecture in flash movies, hyperlinks as well as virtual models. In this paper the content of the e-learning system will be presented in the interactions with the face-to-face sessions. The use of the system and the effectiveness of the tools for the students' learning processes were evaluated at the end of the semester. The results of the evaluation will be presented and discussed.

Key Words: Blended learning, e-learning, virtual environments, geometry education, spatial visualization, 3D-modeling

MSC 2000: 51N05

1. Introduction

When students start with their studies they enter our university today with more and more diverse knowledge in geometry and diverse spatial visualization abilities. Therefore it becomes more difficult to teach a large group of students at the same time with such diverse qualifications. While a face-to-face teaching and learning remains essential in the education processes, we can take advantage of e-learning tools to interlock the lectures with the necessary self-paced learning processes. We may call it *blended learning*. Figure 1 shows the elements of blended learning with their interferences.

Figure 1: Elements of blended learning

Blended learning [7] is usually used to define a situation where different delivery methods are combined together to deliver a particular course. In our case these methods include a mixture of face-to-face sessions, online materials and communication as well as self-paced learning. E-learning tools meet the students in their everyday habits. The combination of real and virtual learning environments may be a chance to come up against these difficult conditions and to reach a higher motivation to be engaged in geometry at home in the self-paced learning part.

2. Descriptive Geometry course in the Virtual Campus

2.1. Virtual Campus Rhineland-Palatinate

The universities of Rhineland-Palatinate introduced together in 2003 an institution to initiate and coordinate all e-learning activities in our federal state. The *Virtual Campus Rhineland-Palatinate* (VCRP) [8] set the target to reach a wide integration of multimedia- and internet-based components in the face-to-face education of universities. Therefore the WebCT learning management system, since 2006 "Blackboard Learning System CE" [1], was introduced as the technical infrastructure of the VCRP. The Blackboard Learning System (BLS) is a course management system with tools for course contents, interactions with and between students as well as organization. At our university the *eTeaching Service Center* was established to support the professors introducing and implementing courses with BLS. Therefore we took this already introduced system to use it as an additional tool for information, tutoring and communicating enhancing the face-to-face course in Descriptive Geometry for students of architecture, civil engineering, and education in building techniques at our university. The e-learning course should not replace the lectures and labs. It is thought to be an additional component in the blended learning environment.

2.2. Components of the course

BLS gives the possibility to select out of several tools for the specific course. The students are able to use the course through internet with an individual account. The offered tools of the Descriptive Geometry course in the Virtual Campus are, besides the course content, anouncements, calender, e-mail, forums, chat, who is online?, list of members, assignments, and weblinks. The course content is organized according to the face-to-face learning system: lectures, labs, assignments and project, where the students find materials to work it over at

home. Important elements of the e-course are, besides flash movies of the lecture slides, 3-D models of illustrations in the lecture book and of the examples solved during the lectures and labs. Figure 2 shows the comparison of the properties of parallel and central projection. With the 3-D model the students can discover the invariants of the projections by themselves.
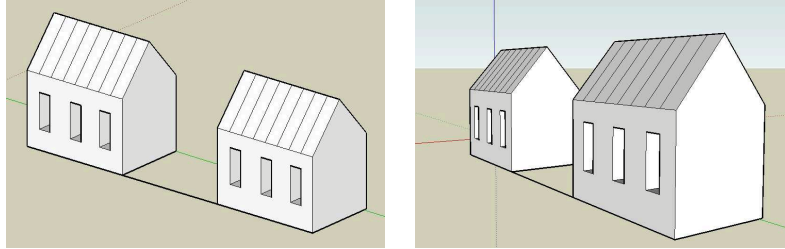

Figure 2: Invariants of parallel and central projection

To generate the 3-D models we took the software Google SketchUp [6] because it is easy and intuitive to understand and is available free of charge for the students to use it on their own computers. We made a short introduction for the students how to use the software. The presented SketchUp models should also motivate the students to clear up spatial problems by creating corresponding virtual models by themselves. The virtual models should help understanding that all drawings are representations of spatial problems which have to be solved by spatial thinking. In Fig. 3 we see the virtual model of a pyramid and a prism with their intersections. The model helps understanding the intersections and visualizes the method to find the true shapes.
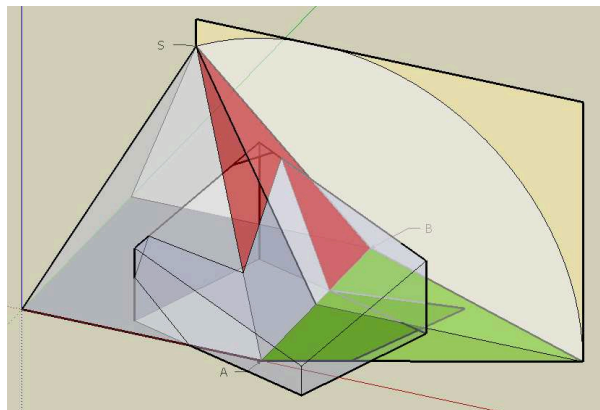

Figure 3: Intersections of pyramid and prism and method to find true shapes

VRML can also be an appropriate tool to create 3-D models for visualizing the spatial geometric problems [2], [5]. In this course we focused on the use of SketchUp to receive a consistent platform and to motivate the students of creating 3-D models by themselves. Another important goal of the online course is to support the students in their homework assignments. Each assignment consists of an architectural geometric problem which has to be solved by a paper model (in most cases), a SketchUp model, and drawings by pencil. The assignment tool of Blackboard enables the students to deliver the SketchUp model, the professor to revise it and to give the students feedbacks. The forum was used by the students to discuss the problems while working on the assignments. Figure 4 (left) presents the SketchUp model of the assignment to find the intersections between three houses. This task was a detail
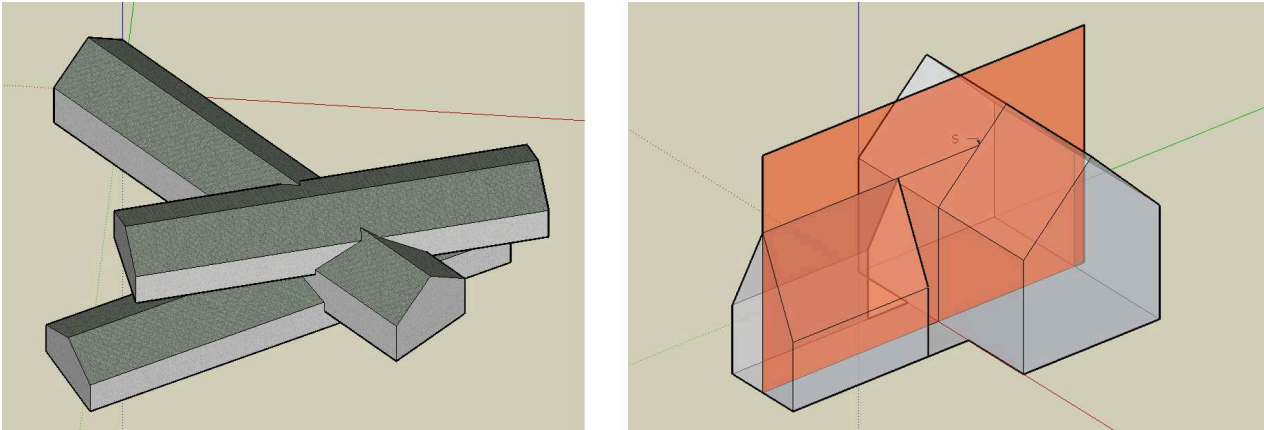
Figure 4: SketchUp model of *Vitra House* detail, created by student Monique Brosig and snapshot of the movie to find the intersection between a line and a plane

of the new designed *Vitra House* in Weil am Rhein, Germany by the architects Herzog & de Meuron planned to be completed in 2009 [9].

The information in the BLS course for this assignment includes not only the problem formulation but also some weblinks and a movie of the necessary steps to solve the cutting problem between a line and a plane. The movie was developed out of the 3-D model which is also available for the students. In Fig. 4 (right) we see a snapshot of the movie.

The 3-D virtual models were also integrated in the real learning environments of the lectures and labs. An important condition for the success of this course concept was to interlock the face-to-face learning with the e-learning part.

3. Virtual and real learning environments

The content of the course in the Virtual Campus has the same structure as the face-to-face sessions: lectures, labs and assignments. So it is already obvious for the students that the e-learning part is not a stand-alone course. By using the e-learning materials also in the lectures and labs the students get aware of the available materials and their possible applications. The 3-D virtual models correspond with the examples in the lecture book [4]. In the labs the students transfer the topic to more complex assignments provided in the workbook [3]. The corresponding real and/or virtual models from the e-learning platform are shown to support the spatial solving processes when drawing with pencil and paper. The way of blended learning will be shown in some examples. When we deal with the topic "Light and Shadow" in the Descriptive Geometry course we first have to define the sun light direction with the help of two angles: azimuth angle and altitude angle, then to implement the angles in the drawings.

In the lecture we take an easy example to draw in the angles and construct the shadow. The students find the associated drawing template in the workbook where they draw the solution with pencil according the drawing on overhead transparencies. The solved example with explanations can be found in the lecture book. In the corresponding virtual model we can capture the various views on the object with the shadow and are able to visualize the changing shadow in real time according the time of the year and the day (Fig. 5).

The students have to transfer the knowledge about light and shadow to a more complex example in the labs. A virtual model again supports the spatial imagination (Fig. 6).
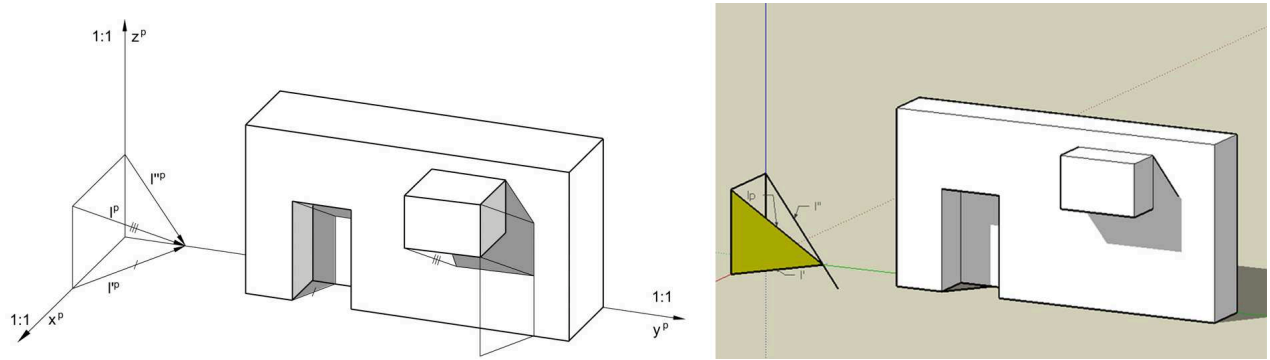
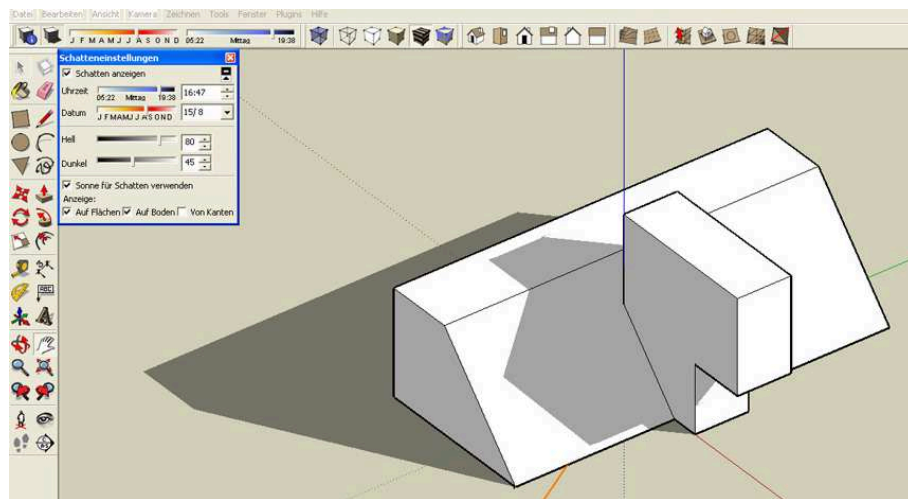Figure 5: Shadow example and virtual model in the lecture

Figure 6: Virtual model of the shadow example in the labs

Finally the students transfer the topic to an own architectural project, designed in the subject building construction. The task is to choose a proper axonometry and adequate values of the azimuth and altitude angles corresponding with the geographic location of the house and draw it with pencil (Fig. 7).
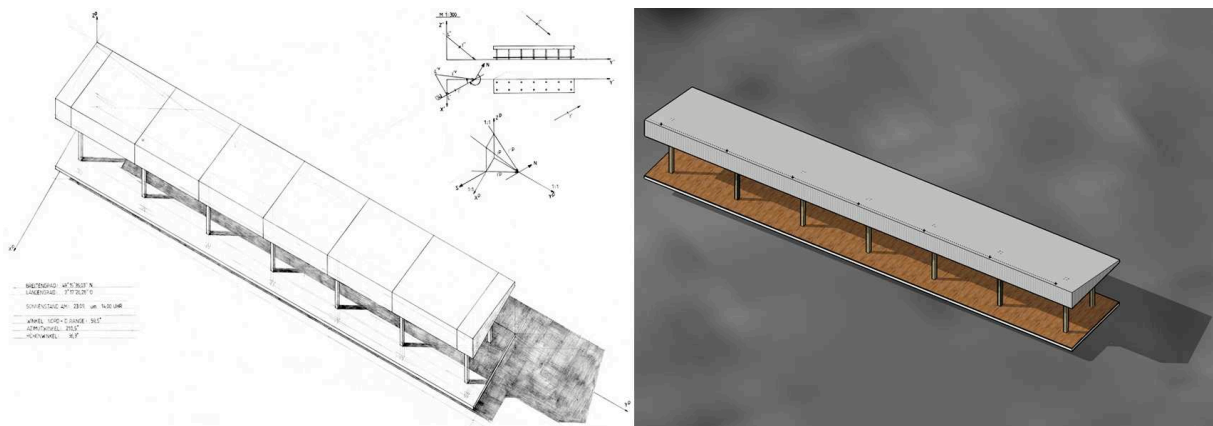

Figure 7: Pencil axonometric drawing and SketchUp model by student Thomas BURGARD
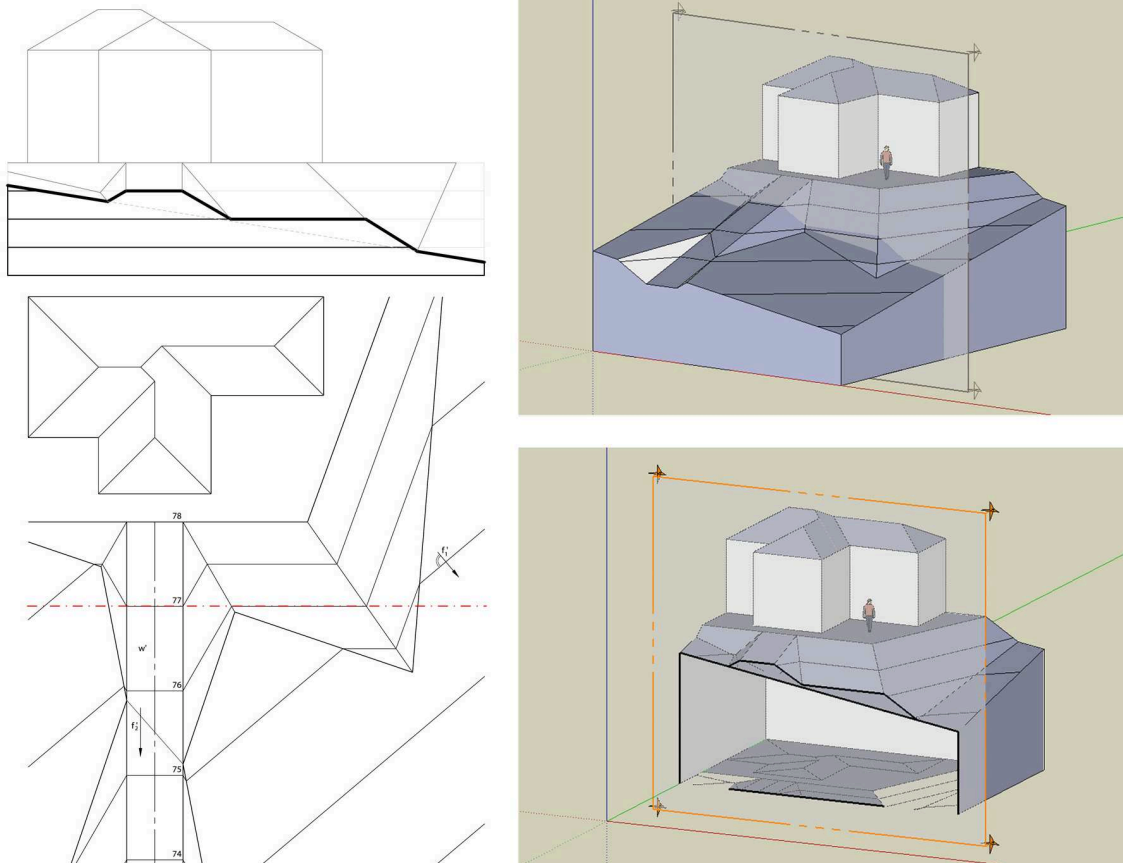
Figure 8: Terrain in topographic projection and cross-section —
drawing and SketchUp model

The SketchUp model supported the decision by varying the view and date. In the self-paced learning part, especially when they work out their project, the students can take advantage of the interlocked materials of the real and virtual learning environments.

A second example refers to the topic of topographic projection. By drawing a terrain with its adaptations to planned elements like a roadway or terrace we work with the contour lines of the various surfaces and planes. Sectional drawings help to understand the spatial situation. In the corresponding SketchUp model, available in the Virtual Campus, the cutting for the sectional drawing can be visualized very clearly (Fig. 8).

We expected from the e-learning course as a main aspect to support the students in their homework assignments to achieve a better transfer of knowledge in applied projects. Therefore
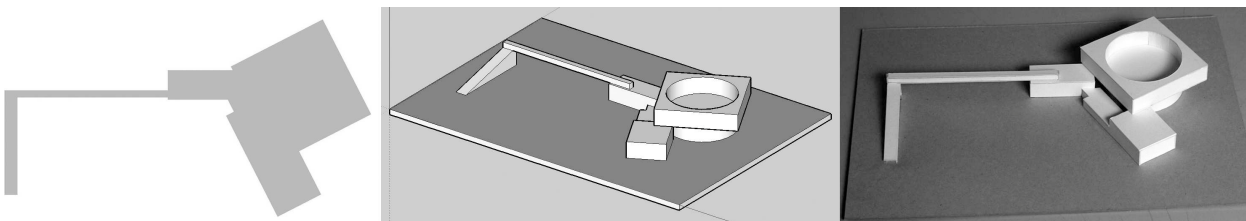

Figure 9: Outline, SketchUp and paper model of a 3-D configuration
by the students Isabell KUPPER and Jan LEIS

the last example in this paper deals with the homework assignments and the realization of blended learning in this reference.

The very first homework in the Descriptive Geometry course was to develop 2-D figures and then 3-D configurations out of a given outline, shown in Fig. 9 (left). The students were not told that the outline was the ground figure of the *"Vitra Conference Pavilion"* by Tadao ANDO in Weil am Rhein, Germany. The students used SketchUp to develop their ideas. They could deliver their designs through the assignment tool in the BLS and received feedbacks before the final delivery. The designed 3-D configuration was transferred in a virtual and a real model (Fig. 9) as well as drawings. Finally an excursion to Vitra in Weil am Rhein let the students explore the realized building and compare it with their solution.

The second assignment, shown already in Fig. 4 (left), referred also to Vitra: a detail of the *Vitra House*, designed by HERZOG & DE MEURON. Besides the virtual model the students constructed the intersections in drawings and determined the true shapes for a paper model. During the excursion we visited the building site and the original model. Figure 10 shows this model and a model of the *Vitra Campus* with the *Conference Pavilion* and the *Vitra House* and in the middle the *Vitra Design Museum* designed by Frank O. GEHRY.

Thus in the Descriptive Geometry course real and virtual learning environments were combined with each other in the receptive as well as the productive learning parts.
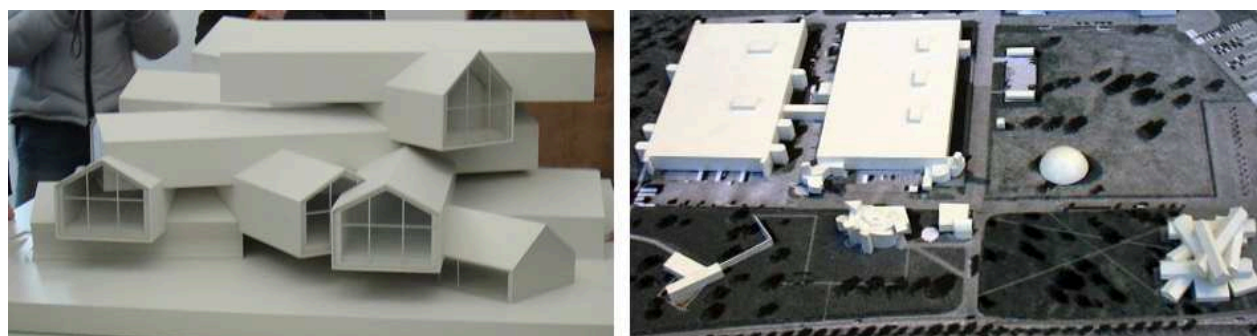

Figure 10: Model of the *Vitra House* and the *Vitra Campus* by HERZOG & DE MEURON

4. Evaluation

At the end of the semester an online questionnaire was delivered to the students to evaluate the online Blackboard course in Descriptive Geometry. There were organizational and technical questions as well as questions to the content, usability and efficiency of the online course in combination with the face-to-face sessions. From 165 students who attended the course till the end of the semester 136 took part at the online questioning (rate of return 82.42%). But not all questions were answered by all of them (system missing). In the following we present the most interesting results of the questioning:

Question: *"How often did you attend the lectures and labs in Descriptive Geometry?"* 86.96% of the students attended the lectures and labs always or almost always. We conclude that there is no reason to be afraid that the online offer competes with the face-to-face sessions. 86% accessed the online part of Descriptive Geometry course from home (80% via DSL). 24% accessed it also from university campus. Therefore the purpose that students use the online course for reinforcing the course at home and to reach an interlock of the blended

learning elements seams to be accomplished from the organizational point of view. 63.96% of the students used the online offer more than 20 times during the semester, 19.77% even more than 40 times. The average was about 32 times. But we did not reach with the questionnaire those, who did not use the online course or quit off the course during the semester.

Question: *"Please evaluate with grades from 'excellent' to 'insufficient' how the content of the online offers in Descriptive Geometry are interlocked with the face-to-face sessions!"*
The result (system missing: 59, means: 2.27, standard deviation: 0.85) is that 65% of the students evaluated the interlock of the blended learning elements as excellent or good, but 30% only as satisfactory (Fig. 11, left). The question arises how we can achieve a better interlocking. The open responses did not give a clue for it. Most of them were positive and remarked the good relations between lecture, lecture book, exercises and the online materials, especially the SketchUp models.
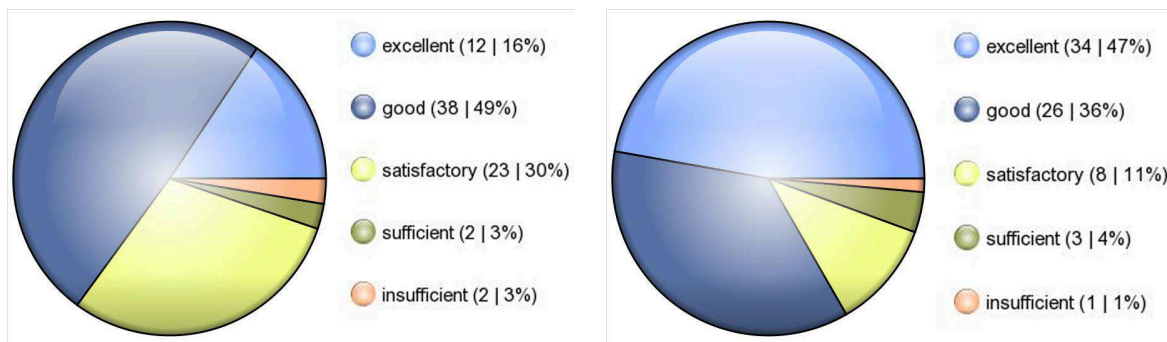

Figure 11: Interlock of blended learning elements and spatial visualization support by SketchUp models

Question: *"Please evaluate with grades from 'excellent' to 'insufficient' how the SketchUp models supported your spatial visualization in the learning process!"*
83% (system missing: 64, means: 1.76, standard deviation: 0.91) of the answers evaluated the SketchUp models as excellent or good in supporting the spatial visualization during the learning processes (Fig. 11, right). Several open answers expressed the importance of the SketchUp models parallel to the drawings to support the spatial visualization. They found also the self created SketchUp models to the homework assignments and project helpful to find the solution in the drawings. Only few had difficulties in using SketchUp and complained that it took too much time for them learning it.

Question: *"Please evaluate with grades from 'excellent' to 'insufficient' the materials in the online course to the homework assignments and the project!"*
The materials related with the homework assignments and project were evaluated as excellent or good by 70% of the answers, 26% as satisfactory (system missing: 64, means: 2.13, standard deviation: 0.85). They expressed as most helpful the drawing template, the SketchUp models, the photos and links to the real architectural objects, visited during the excursion to Vitra in Weil am Rhein. Some of the students complained that they were missing advice to the required constructions and similar examples. But the students have to do the transfer from the examples in lectures and labs by themselves to achieve an applied knowledge. If the examples are too close to the homework assignment you can not be sure that we achieve a real understanding of the problem and its solution.

Question: *"Please evaluate the online tutoring with the help of discussion forum, assignment tool and e-mail function in the Blackboard Course!"*

72% of the students evaluated the communication tools like forum, assignment tool and e-mail as very helpful, efficient and fast (system missing: 67). So the online tutoring was well accepted. Some of the students expressed in the open answers, that the forum is the best of Blackboard.

Question: *"Which of the following elements helped you most to understand the learning content or which one did you use most?"*

The students felt the information on homework assignments and project as well as SketchUp models as most helpful. Some of the students mentioned in the open answer that the face-to-face parts, like lecture, consultation, communication with other students and the lecture book were most important. Even though these comments did not meet the question, these answers show that the online course did not make the face-to-face sessions dispensable. A student expressed: *"We learn best by drawing not by looking. But Blackboard was a very good support."*

5. Conclusion

The evaluation of the BLS Descriptive Geometry course brought the result, that the virtual learning environment was introduced successfully in addition to the face-to-face sessions. The real and virtual learning environments do not compete with each other. In fact they complement one another in the blended learning. The main intentions of introducing the e-learning course were to support the students in their homework assignments and to enhance their spatial visualization abilities. These intentions were achieved. Especially the virtual models turned out to support well the students in their spatial visualizations during solving the examples by drawing. Only some students had been overstrained in working with SketchUp without a step-by-step introduction. Therefore we should offer a more detailed introduction in SketchUp at the beginning for those who need it. The materials related with the homework assignments and the communication tools like forum and assignment tool were very helpful for the students during the solving processes. We may try to improve the interlock of the various elements of blended learning. But the answers did not tell us how to reach it. There were many students who did not answer to all questions of the questionnaire (system missing). Therefore the evaluation has only a limited significance. But there were enough answers to conclude the tendencies. Perhaps the questionnaire was too long. We will develop the blended learning environments in their interactions further on to enhance the motivation and intensity of learning of Descriptive Geometry. There is the challenge to develop such approaches also through national and international cooperation

Acknowledgements

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