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EDUCATING ARCHITECTURE STUDENTS TO DESIGN BUILDINGS FROM THE INSIDE OUT:

Experiences from a research-based design studio

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Abstract

In this paper we describe a multi-faceted approach of introducing a user-centred perspective into the architectural design studio, drawing expertise from cognitive and environmental psychology, computational approaches in (generative) architectural design as well as space syntax. The one-semester design studio was combined with a theory seminar, excursions and workshops in order to familiarize architecture students with research-based design and to a) better understand the relationship between architecture (form) and its use (function) and b) open up new possibilities for design based on research results. A structured course evaluation with questionnaires was conducted to identify to what extent the course influenced how students judge, understand, and design architecture. Based on the outcomes of the questionnaire, we draw conclusions for further "research-based" design education.

Keywords: *Architectural Education, Evidence Based Design, Wayfinding Cognition, Virtual Reality*

Theme: *Architectural Design and Practice*

Introduction

Designing buildings requires architects to put themselves in the perspective of a building's future users and to predict the likely patterns of use in this building. At the same time, they must generate shapes and forms corresponding to the expected user needs. This process of designing buildings, whilst considering all these issues, is difficult for several reasons: First, to our wide experience, no adequate model of human behaviour is taught in architecture schools and second no systematic approach is known on how to use this information to generate shape/form. While numerous criteria are explicitly addressed evaluate buildings during architectural education (e.g. structural, fire protection, costs) functional criteria (e.g. user behaviour) remain almost completely unstated. This is critical because without the knowledge of how a spatial configuration functions, one can indeed produce form, but, as Hillier (1996, 326) formulated, just hope that it works ("Architects design shape but hope for function").

In this paper, we describe a multi-faceted approach of introducing a user-centred perspective into the design studio, drawing from cognitive and environmental psychology, computational approaches in architectural design as well as space syntax. The one-semester design studio, termed "Design by Research", took place during the winter-semester 2012/13 at the Bauhaus-University in Weimar and was intended to examine how far designs can be derived from evidence. It was combined with a theory seminar, excursions and workshops in order to familiarize architecture students with research-based design and to a) better understand the relationship between architecture (form) and its use (function), and b) open up new possibilities for design based on research results and generative principles.

20 students participated in the project (9 female, 11 male, M = 25 years, SD = 2.74). All students were masters students and had at least 6 semesters of architectural training (M = 8.79, SD = 1.89), and had no special knowledge of peoples' orientation in buildings, wayfinding or space syntax.

The following paragraph/section briefly describes the different modules of the design studio. Based on the analysis-synthesis cycle, which is often used to describe design processes (see e.g. Simon 1996; Zeisel 1984), a differentiation of the modules was made. On the one hand, methods were taught for the analysis and evaluation of designs, on the other hand, we focused on the integration of these evaluation methods into the process of creating form. The courses were designed in a way that the theoretical content was always deepened by practical applications. Furthermore, the students were given the freedom to develop their own strategies to apply the theoretical aspects in the design process. Some parts of the course, such as a field trip to various university buildings, and a literature research on project-related issues are not explicitly explained in the following, since they belong to the standard repertoire of a design project.

After completion of the entire project, an evaluation was carried out. The results of this evaluation are compared with the module objectives and it is examined to what extent the objectives have been met. In summary, conclusions are drawn how to improve evidence-based design projects.

Warm-Up Exercise - Experiencing Orientation & Representation Problems

The topic of "orientation in buildings" was largely unknown to the students prior to participating in the project (despite their individual experiences as users of architecture). To sensitize the students for this aspect of the evaluation of buildings, a "warm-up" exercise was conducted. The students had to walk through a building of the Bauhaus University in Weimar, which was unfamiliar to them. The building consists of several parts, built in several stages, resulting in a fairly complex layout (Figure 1, top left). Many users of this building complain about orientation problems in this building.

The students had one hour to explore the building. They were instructed to try to understand its structure. After which they were asked to draw sketches of the building floor plan. The aim of this exercise was for the students to experience their own orientation difficulties in a building. Additionally, they were familiarized with the concept of "cognitive maps". We consider this a relevant prerequisite for architectural design, since people learn about the structure of their environment primarily through exploration and the resulting mental images form the basis for much of our behavior(Richter 2008). Students were given the opportunity to experience the differences between real space and two-dimensional representations of a building by drawing its layout from memory. Since two-dimensional drawing plans are still one of the central tools in the design of buildings, we found that experiencing this difference is important to better understand the real physical layout during the design process. In Figure 1, examples of these drawings are shown.

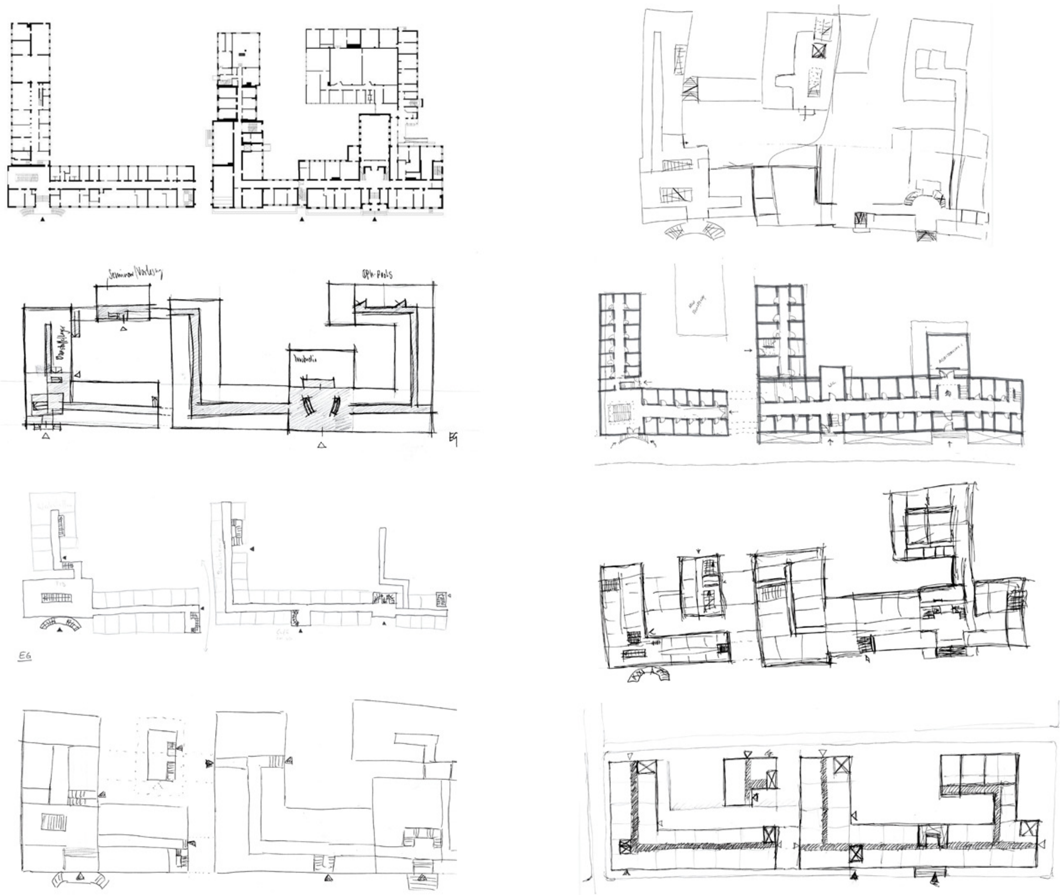

Figure 1: Examples of students drawings after visiting a complex building for 60min (top left: real plan of the building)

Based on the drawings, we discussed difficulties in orientation, with respect to the geometry of the building, with the students and agreed that the main problems relate to the fragmentary connections of multiple buildings, mis-aligned corridors and a lack of views to the outside.

Furthermore, we used the drawings to clarify the difference between topological and metric properties of the plan geometry. The metric properties of the different drawings varied considerably (length, width, shape of buildings, rooms and corridors), while the topological properties essentially coincided with the actual building (three entrances; the main building block; three side wings; main staircases). On closer inspection, however, we also found topological differences in the details: Most striking was that some staircases have been omitted from the drawings. These missing elements were counted and the layout of the building was analyzed using Visibility Graph Analysis. A high correlation between Visual Integration and the number of forgotten stairways (r^2 = 0.76) was determined. This means that more integrated staircases in the building were less likely to have been omitted from the sketch-plans. This supports the findings of Haq&Zimring(2003)that *"movement itself rapidly helps create a cognitive representation of the most paths for natural movement. Therefore, a cycle can be proposed. Configuration creates movement, which in turn promotes an understanding of the configurational properties."*

Workshop I - Understanding the function of form

The project brief focussed the students on two issues: the social interaction in and the navigability of the building. Both are important criteria for good buildings (Carlson et al. 2010; Sailer et al. 2007) and both criteria are dependent on the geometry of a building.

The formation of building geometry is one of the main tasks of an architectural designer. Therefore, an understanding of the consequences that building geometry has on its occupants' behaviour is crucial to good building design. As Hillier and Hanson(1984) state: "it has become clear that a lack of understanding of the precise nature of the relation between spatial organization (morphology) and social life is the chief obstacle to better design". Although the idea to develop a form from function ("form follows function") is well-known in architecture, the question of how form can be evaluated in terms of functional criteria (in our case, social interaction /orientability) cannot be answered clearly. In practice, the evaluation of a floor plan in terms of functional aspects is often left to the own subjective experience of the designer, as many architects are unable to objectively assess these criteria. Hillier (1996) describes them as "non-discursive" properties of buildings.

Space syntax researchers have a goal of making these "non-discursive" aspects of building form descriptive and thus discursive. To this end, an extensive set of methods have been developed to describe the physical environment (morphology of buildings and cities), which has been shown by Reveron(2009) and Vaughan et al.(2007), to be very powerful tools for teaching spatial-functional relationships to students of architecture. These methods are pertinent to this project, since they are based on visual relationships and correspond to the user perspective ("from the inside"). Introductory lectures in the course covered these aspects. The lectures emphasized – and this is an important point for novices – that these measures cannot predict how individual people behave in a specific situation, but that they help identify potential for certain behaviours. This corresponds with Gibson's concept of affordances(Gibson 1982), i.e., certain shapes having 'action potentials' that promote or hinder certain activities. Using Space Syntax methods, such potentials can be identified and examined to determine whether a configuration is suitable for specific purposes. Subsequently, methods for representing spatial configurations (convex spaces, axial lines, isovists) were presented to the students and illustrated by examples. The calculation of graph-based values (integration, choice) was explained via simple cases, which students calculated by hand to ensure that they understood the underlying mathematical model(Vaughan et al. 2007).

Application of these analytical methods was extended through two exercises: One based on existing buildings in Weimar, selected to be problematic in terms of orientation or social interaction, the second encouraged students to apply these methods in the design process. In design, one simultaneously creates and needs to evaluate form. Therefore, the students should develop the ability to identify spatial properties in new configurations to reach an intuitive understanding of their designed forms. In previous Space Syntax seminars it was observed that students have problems assessing honestly their own designs partly due to a general difficulty of distinguishing between analysis (evaluation form) and synthesis (generation form) in the design process. As Lawson & Dorst(2009, 30) state: "when steeped deeply in your design activity you just keep switching between analysis and creativity, between 'problem' and 'solution' without any effort". Thus, the students are often overwhelmed by the critical evaluation of their own designs. To free the students from evaluating their own designs, an algorithm for generating a random floor-plan was introduced: rectangles placed sequentially, whereby each newly-placed rectangle must overlap with a previously-placed one (see Figure 2, top row, left). Based on this algorithm, the students drew random floor plans that they could analyse with Depthmap(Turner 2001)thus applying methods learned in the lecture.

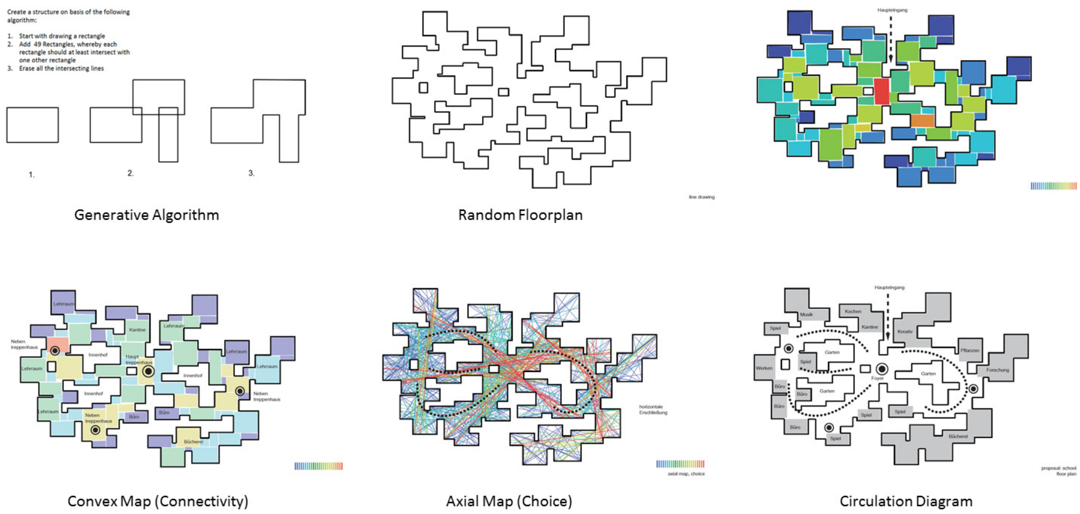

Figure 2: Example of students project that resulted from the workshop

Figure 2 shows an example of a students' randomly-generated building and the associated analysis and interpretation results (a school building was subsequently proposed by the students as a suitable 'use'). A convex and an axial map were created. From the Convex Map both connectivity and integration values were calculated and interpreted. Convex spaces with high connectivity were interpreted as local meeting places (Figure 2, bottom row, left), the area with the highest level of integration as the main hall (Figure 2, top row, right). Functions were allocated according to the desired degree of privacy based on the integration-values (diningroom and playroom in areas with high integration; office and library in areas with low integration). From the Axial Map choice was calculated, which suggests the probable preferred movement-paths (Figure 2, bottom row, center). Finally, the students presented their interpretation of the analyses in an abstract diagram (Figure 2, below row, right) and discussed ways how to improve the design based on their findings.

Synthesis I – Rule Based Design "From the inside out"

After the students were familiarized with the basics of evaluating spatial configurations, a design task was introduced. The task was to design a university building (the Academic Interchange Bremen) from “the inside out". Designing "from the inside out" means developing the geometry of a building from the user's perspective, or as Benedikt (1979) describes it, "to design environments not by the initial specification of real surfaces but by specification of the desired (potential) experience in space". The Academic Interchange is a complex building, whose program includes seminar rooms, lecture halls, exhibition areas, jobs, accommodation, etc. Special emphasis has been put on the orientability and navigability through the building. On the other hand, the building is intended to promote social interactions between users (formal and informal). The design task stems from a competition which was organized by the SFB/TR8 "Spatial Cognition" (Hölscher, Brösamle and Conroy-Dalton 2011).

The exercise was conceived to assist the students to focus on formulating the rules for spatial relationships without the distraction of geometric-formal approaches. To achieve this, a formal system was specified. The students were only allowed to use rectangular rooms. Each room has a variable number of entrances, by which the room can connect to others. The task was to arrange the rooms in a way that social interactions are promoted (potential for social encounter) and that it is easy to orient when walking through the building. Therefore, precise rules (e.g. regulating the visual relationships between the entrances of rooms) had to be formulated to derive the final the floorplan layout. Information about the room types, number and sizes were taken from the competition. Finally, the students were asked to annotate spatial qualities in the plan. This type of representation can be found in Zeisel (1984, 60-61) and should force students to make their design intentions explicit and readable to others.

The students had two weeks to finish this task. After one week, the design rules were discussed in individual tutorials when, it was found that the students had difficulties formulating them. This may be due to the fact, that previously they rarely used explicit rules for the generation of shapes. Under guidance, rules for wayfinding and social interaction were derived focussing primarily on the inter-visibility of room-entrances. Rules were formulated so that entrances to private rooms (e.g. living rooms or offices) were not visible from the main corridor or the main entrance, or that the interior of a living room was not visible from another room. Other rules prescribed that the reception should be directly visible from the entrance and the main corridor, and from important public functions (cafeteria, auditorium) and needs to control the access to the apartments. Moreover, the students were encouraged to think about the spatial sequence experienced by the user whilst moving through the building. A resulting rule was, for example, to promote a sense of surprise for the building-user by entering a large open space via a narrow space after a change of direction. Some students also developed rules that were not related to internal movement; such as that every room must at least have one exterior wall (for placing windows), that each room must be adjacent to another room or that the walls of the rooms of different storeys should lay on top of each other structural reasons. This made clear that it was difficult for the students to focus exclusively on a few criteria, since in previous design projects they were used have as many criteria in mind as possible. Figure 3 shows some of the results that emerged from this exercise.

One observable approach to several projects was to categorize the rooms according to their degree of privacy and the subsequent clustering of spaces with similar publicity (see Figure 3, first row). Often courtyards were formed, around which similar rooms were arranged. These courtyards were connected by corridors. The geometry was laid out in such a way that courtyards with higher perceived privacy (living rooms) were less visually connected to other parts of the building (see Figure 3, second row). One group created a diagrammatic plan based on anticipated spatial relationships and varied the dimensions and angles of the geometry to strengthen or weaken certain lines of sight (see Figure 3, bottom row). Another group first calculated the total areas required (incl. 20% for the circulation) for defining the size of a square building footprint. This was divided by a major axis, on which all the public rooms were placed. More private functions, such as housing or offices were located on a minor axis. This procedure may also be referred to as a top-down approach, in so far as the arrangement of the rooms is not primarily derived from their individual requirements, but primarily following a formal idea (arrangement on square footprint with one main axis). The students reported that it was difficult for them to design without a clear formal order.

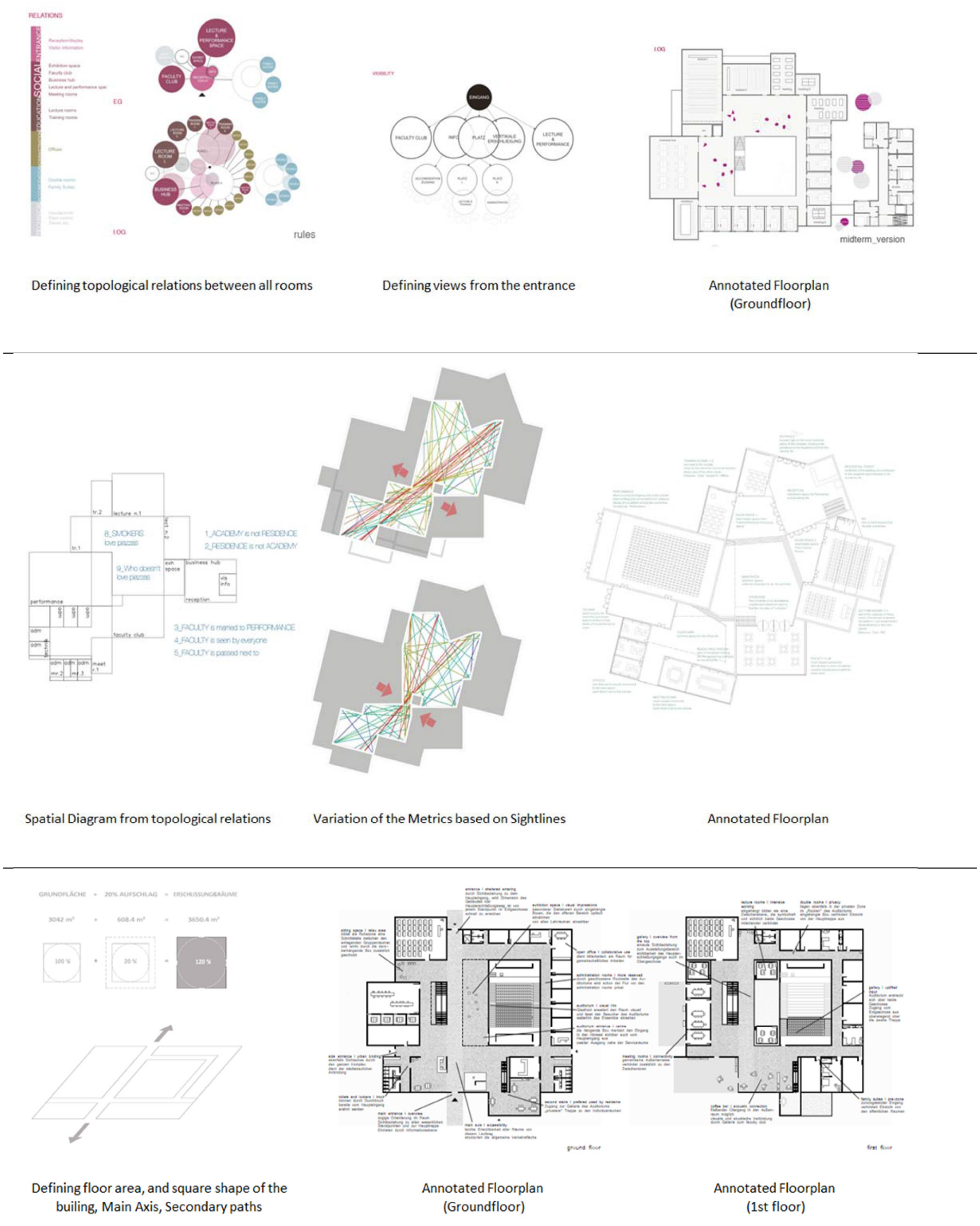

Figure3: Example of a student works(Top: TasjaLindnder & Andrea Leitmannova; Middle: ArranchaLorenzanaUrrutia & Edgar André Solórzano Villegas; Bottom: Jenny Wensien & Granit Buja)

Before the students were allowed to give a traditional presentation of their design outcomes, the designs were tested in a VR-environment. The intention was that the assessment of the building should not be affected by conceptual descriptions or floor plans, but rather judged by the experience of entering and walking through the building.

Virtual Reality Design Evaluation

The designs were presented in two steps: The first step was to experience the design in an immersive VR-Setting without any comments on the design intentions and through the lens of a building visitor. Since the VR-Setup allowed up to six concurrent viewers with perspectively correct projections for each (Kulik et al. 2011), we were able to walk through the design with jury members, student designers and at least one layperson who had never seen the building before. Critically, the layperson had the task of navigating through the building and finding specific rooms in a prescribed order. In a second step the students had to explain their design with conceptual sketches and plans. The comparison of the experience in the VR Environment and the stated design intentions of the students was a key aspect of the design evaluation.

Figure 4: Evaluation of the designs in a VR-Environment

The layperson (for all presentations) was a member of the VR-Lab of the faculty of media, familiar with the technical interface for the handling the virtual environment. The task was to explore the building models of each project group corresponding to a typical usage sequence. In this scenario, a visitor for the first time arrives at the Academic Interchange to attend a conference: Upon entering the building he (or she) searches for the living quarters to off-load his luggage, then seeks the auditorium, the toilets, a seminar room, and finally the cafeteria to meet with colleagues.

While walking through the building the lay person made observations such as, “this floor looks more private, I [will] try to find my room there” or “this seems like a dead end, think I’ve got lost, let’s go back to the foyer”. Such comments were very helpful for the students, since they illustrated the perspective of a first-time-user and helped them realize what others might think about their building. VR walkthroughs also allowed for checking the size of and distances between rooms. This was supported by a large screen (2.7 × 4.3 m), and a movement speed while navigating corresponded to normal walking speed.

The criticism of the jury on the designs after the tour was quite differentiated. In some buildings it was hard to navigate either due to the complexity of the plan or lack of visual differentiation (Weisman 1981). Some of the rooms were perceived as disproportional. Some movement areas were too narrow, others considered too large. Occasionally it was reported that the buildings were unnecessarily complicated or created long distances between the rooms. The intention to assure a high degree of privacy for the living rooms often resulted in them being only accessible after making several changes of direction. Interestingly, the design based on a simple top-down scheme (Figure 3, bottom row) was the rated best: It provided a clear spatial hierarchy and good proportions of the rooms and it was easy to orientate in this building.

Workshop II - Psychological aspects of orientation / way-finding / usability in architecture

After this first attempt to create a building on the basis of rules, and to evaluate these in a VR walkthrough, the class made a two-day excursion to Bremen. There, the SFB/TR8 spatial cognition hosted a thematically focused workshop “Spatial Cognition for Architectural Design” about the psychological aspects and usability of buildings, which was organized by a team from cognitive science, architecture and computer science.

A half-day set of lectures focused on interior wayfinding cognition and usability for architects and designers, and aimed at integrating knowledge from spatial cognition research into architectural design, in order to support the design process of navigable buildings. The course introduced basic concepts from cognitive science, such as cognitive maps and mental representations, and the development of human spatial knowledge. Wayfinding was discussed as human decision-making processes that are influenced by the user's cognitive abilities, heuristics and strategies as well as architectural features. The lectures linked space syntax measures (e.g. visibility graph analysis & step depth) to Weisman's (1981) framework for wayfinding (e.g. focusing on visual access, architectural differentiation, signage, and layout complexity) and “usability hotspots” in case study buildings. Furthermore the lecture demonstrated how wayfinding can be addressed in an evidence-based design approach that includes testing design options with test users in Virtual Reality. The integrative wayfinding framework of Carlson et al. (2010) was illustrated by a detailed account of wayfinding experiments and analysis in the Seattle Public Library (building analysis via space syntax, interviews with architects, and behavioural, cognitive and emotive user data). During these lectures, the students worked on two practical case studies: Students had to mentally simulate the perspective of participants from an earlier wayfinding experiment in a conference facility (Hölscher et al. 2006), and based on schematized floor plans, they had to identify possible wayfinding problems of the setting. The results were discussed in relation to space syntax values to explain why users might experience navigational difficulties at certain points (e.g. step depth between destinations; see Hölscher et al. 2012). The second case study involved similar tasks based on plans of Berlin central station.

Figure 5: (Left) Floorplan of the Günne Conference Center for Mental Walkthrough; (Right) Photographs taken inside the GW2 during the wayfinding exercise

Wayfinding Experiment

The students conducted a real-world wayfinding experiment in a multilevel campus building of the University of Bremen. Build in 1971, the "GW2" is known for its complex layout, and has been subject to previous research (e.g. Tenbrink, Bergmann, Konieczny 2011; Mast, Jian & Zhekova 2012). Architecturally, the building could be understood as two similar building parts that are wrapped around two central courtyards. However, from a user's point of view, the building's narrow, parallel hallways look dazzlingly similar, with staircases and elevators located at unexpected places, while at least three different signage systems add navigational challenge.

The aim of the experiment was that the architecture students could experience wayfinding from the user's point of view. Six groups of four participants each had to find destinations in the building: two rooms and the way to the cafeteria. Each team consisted of two 'wayfinders' who had to find the correct location, and two 'observers' who documented the wayfinders’ behavior and verbal utterances. After completion of the tasks, the students analysed their observations for two hours and shared their impressions in short plenary presentations.

The wayfinders were not allowed to use elevators, talk to other people besides their own team, or to look at survey plans (the perspective most common for architects), but were encouraged to experience the user-perspective from an eye-level movement through the building. Using the "thinking-aloud" method (e.g. Ericsson & Simon 1984), wayfinders were further encouraged to verbalize what they were thinking about during the tasks.

One of the two observers examined the wayfinders verbal utterances and annotated at which points in the floor plan wayfinders commented upon their navigation. The other observer focused on behavior by documenting movement trajectories and by annotating behaviors (such as pausing or looking at signs) directly into a floor plan. During navigation, only two wayfinders felt confident about their exact location in the building, while five did not know where they were or experienced navigational difficulties. The groups identified missing signage, unconventional circulation, counter-intuitive staircase placement, incomprehensible building layout, and missing views to the outside as main problems for orientation.

Synthesis & Evaluation II

Based on this input, students worked on the design brief for a further two months. The supervision of students took place through weekly studio-tutorials. The focus during tutorials was on how people move/navigate inside the building, how people experience the rooms, privacy, opportunities for interaction in public circulation areas. In contrast to the first design exercise, no restrictions were made on the generation of form and students used more complex generative principles and formal elements like ramps, spirals, curves and polygonal shapes. In most projects complex 3-dimensional spatial configurations emerged. Analysing these in Depthmap was ineffective since the effort for plan preparation was too high. Instead, axial lines and isovists were mostly drawn by hand. As the students were familiar with the principles of the analysis, problems in the floor plan layout could be formulated more easily (such as privacy needs visual barriers, interaction occurs at central locations, movement flows can be reduced by “broken” movement-axes). The most successful tool for identifying design failures during tutorials was, as expected, the isovist, which helped to clarify what a visitor can see from a certain point of view. Thus, it could be easily shown that. e.g., a door to the storeroom falls in a well integrated sight line after entering the building.

In the following section, some of the results of student work are briefly described. In Figure 6 and 7, five projects are shown. On the one hand, the results illustrate various different geometrical-formal approaches, and on the other, very different circulation systems. All basic circulation types, such as the central, linear, circular and network-like circulation system, mentioned by Arthur and Passini(1992), as well as various hybrid forms could be found in the projects. One group designed a building with an open and continuous circulation space. They used the concept of an amphitheatre to define a central place (entrance foyer) and provide access to all the rooms. Using differences in height and staggered volumes, differentiated spatial qualities and a very successful transition between public and private areas were created (Figure 6, top row).Another group created a circular circulation system and tried to integrate visual effects when moving through the building (narrow to wide and open and closed), using isovist-analyses (Figure 6, 2nd row).A third group created a linear circulation system that spirally led to the upper floors of the building. The aim of the linear sequence of rooms was to increase the degree of privacy by increasing the distance to the rooms. Concurrently, the students generated a "continuous" split level that creates various visual relationships between the floors (Figure 6, 3rd row).

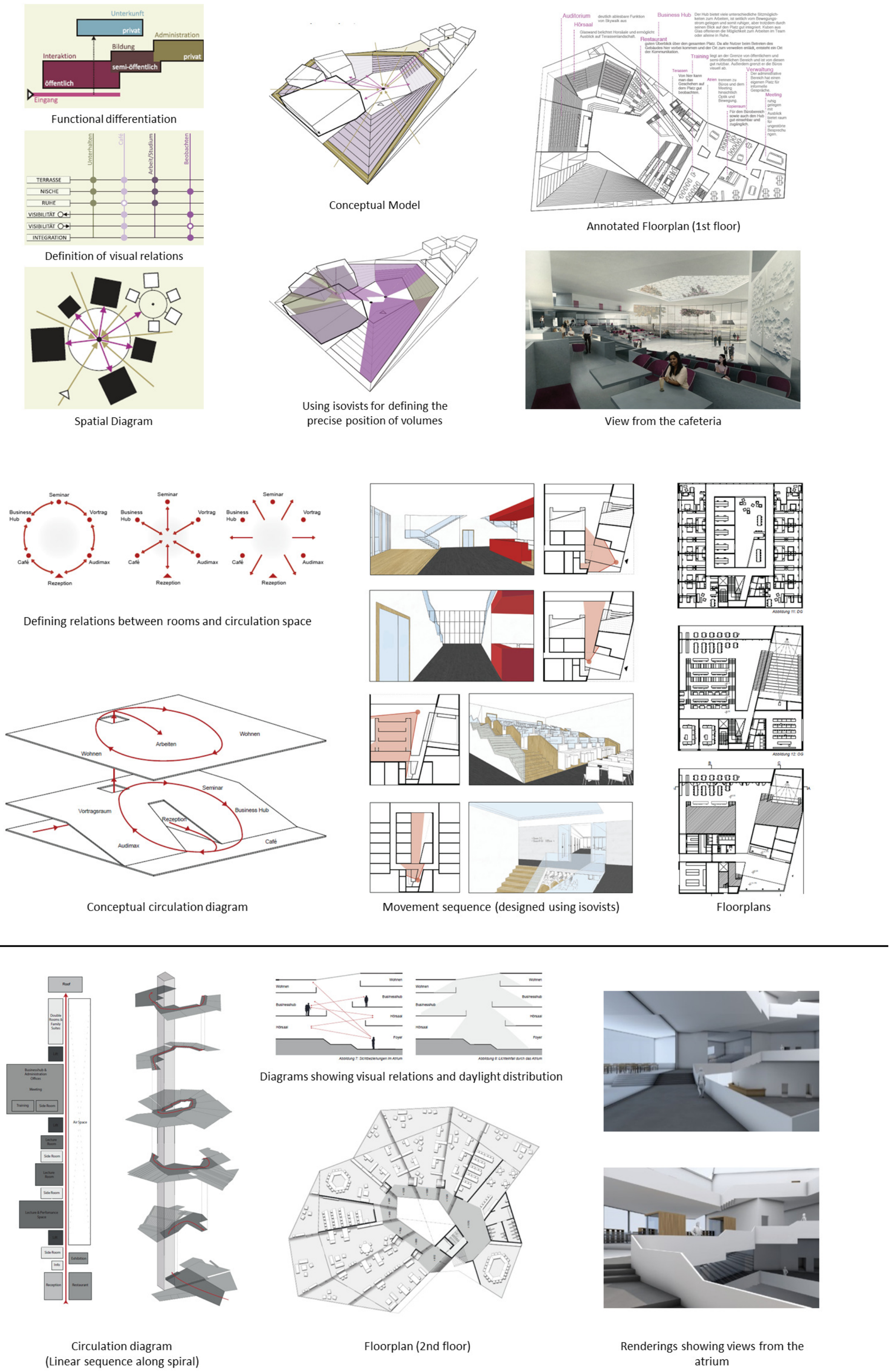

Figure 6: Examples from student design projects (Top: TasjaLindnder & Andrea Leitmannova; Middle: Ferdinand Sammler & Bianka Börner; Bottom: Torben Oltmanns & Lisa Blumenthal)

Two groups followed an urban approach (shown in Figure 7). The idea was to break up an existing barrier observed at the Bremen campus. This was done by siting the building at this problematic location, and developing existing axes and in-changes when defining the building geometry. The result was analysed with an axial map, showing that the average integration was improved greatly by the new design. In addition to improving the urban situation, the aim of the students was to create a busy centre for academic exchange by placing it on a central node of university life.

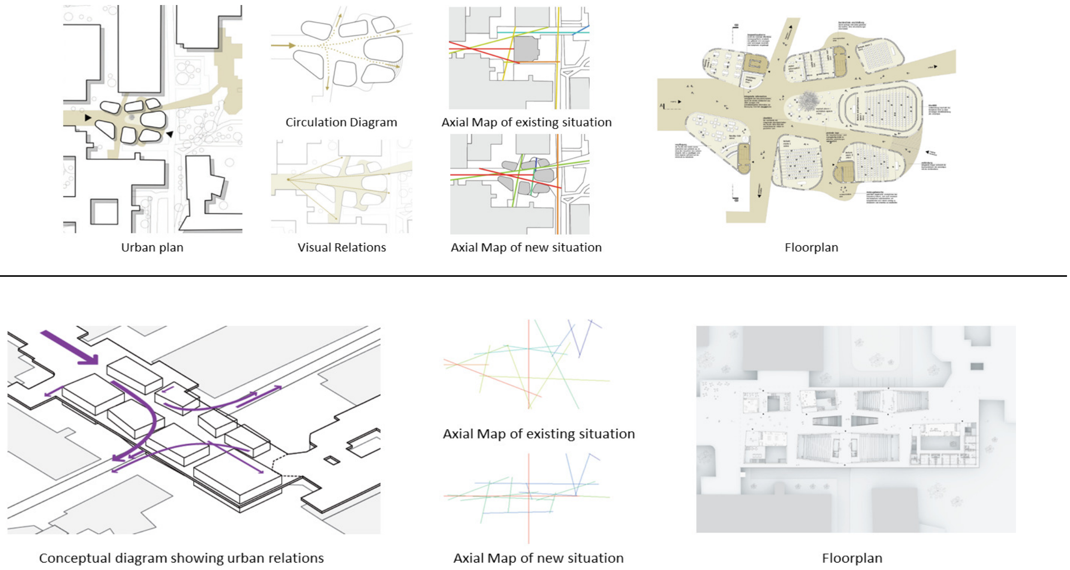

Figure 7: Two student design projects concentrating on urban relations (Top: Ray Hotka & Alexander Haun; Bottom: Tuan Anh Dang & Florian Politz)

One group took a radical approach to develop the spatial configuration of the building by only looking at the use-frequency of different rooms by different user groups (see Figure 8). For this they first defined three different user groups (casual visitors, academics and administrative staff) and documented various sequences these users take through the building (e.g. entrance -> auditorium -> Cafeteria -> Living Room -> Seminar Room). By means of an interesting clustering algorithm (whose description must be omitted here for the scope of limited space) they conducted for each group of users abstract spatial diagrams in which all movement-sequences are considered. These abstract diagrams were examined for similarities and then transferred to one three-dimensional spatial configuration.

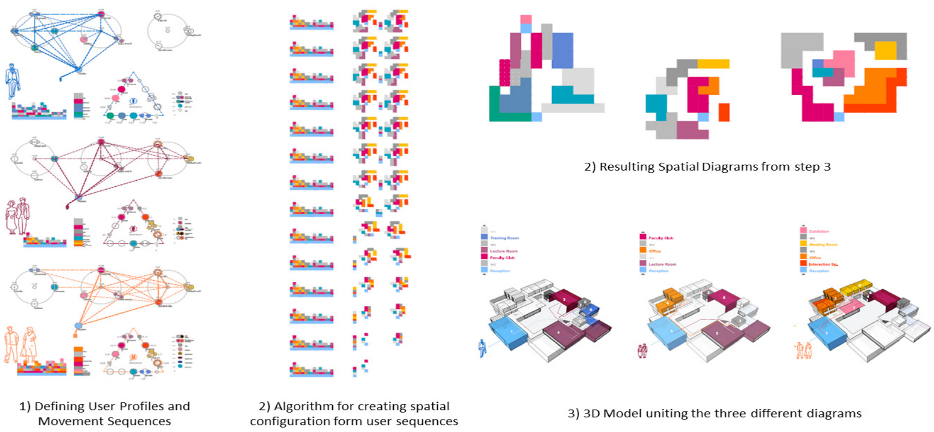

Figure 8: Students design project following a generative approach (ArnachaLorenzanaUrrutia & Edgar André Solórzano Villegas)

The presentation of the results once took place in the VR lab. First, the walkthrough was conducted, whereby, once again, a wayfinder had to take a specified path through the building. After the walkthrough the students had the opportunity to explain their project using diagrams and floor plans. The presentation ended in a discussion with both the wayfinder of the VR-presentation and a jury consisting of experts from architecture and cognitive science. Judging from their presentations, students appeared to have integrated the knowledge from the course directly into their design cases. For example, the presentations included various methods for analyzing groups of users and user needs, as well as analytical computer tools to analyse their designs for ease of wayfinding in an early stage. Their designs included unimpeded lines of sight, direct routes between entrance space and key locations, such as vertical circulation, atria, analogous floor plan configurations, and disambiguation of similar looking places. The students reflected critically on the knowledge they had gathered throughout the course and their designs were judged aesthetically pleasing. Interestingly, the project using a generative algorithm (Figure 7) – which can be rated as probably the most direct transfer of spatial relationships into form – was rated as most problematic in the walkthrough. This may be due to the fact that only one criterion was applied for generating the building. While this, from a scientific perspective is a ‘clean’ method, the result remains unsatisfactory from an architectural point of view.

Evaluation of the project

Both the architectural and the spatial cognition team evaluated the project with structured course evaluation questionnaires to identify the impact of the various course modules on how the students understand and design architecture. The first questionnaire was handed out directly after the workshop in Bremen, and focused on how the students assessed the lectures, case studies and navigation exercise provided by the spatial cognition researchers. This questionnaire was repeated directly after the student’s final presentation in Weimar to check for the stability of ratings and to compare students’ initial impressions of how much the psychological input would impact their final designs. The other questionnaire (in the following termed *final*) investigated the project as a whole and tested in how far the intentions of the course-modules were fulfilled. The following section provides a summary of the outcomes, results are based on Likert-Scale (1=not applicable; 5=very much applicable).

In general, students were highly satisfied with the project (M_{final} = 3.93, SD = .99). They agreed that the project helped them understand how to evaluate floor plans for aspects of orientation and navigation (M_{final} =4.00, SD = 0.89) and for a useful allocation of functions in a building (M_{final} = 3.87, SD = 0.88). Students also had to rate in how far each module helped to understand the topic of orientation and navigation in buildings, and all modules received positive ratings: warm-up excercise (M_{final} = 3.87, SD = 1.02), space syntax lecture (M_{final} = 3.80, SD = .83), workshop “Understanding the function of form” (M_{final} = 3.5, SD = 1.18), workshop “Spatial Cognition” (M_{final} = 3.57, SD = .98) - both workshops are discussed in detail below. Interestingly, the project-related consultations were rated highest (M_{final} = 4.33, SD = .79), suggesting that the topic is quite manifold, and needs special care on individual problems. The second highest rating from the course module comparison was given to visiting buildings during the excursion (M_{final} = 4.29, SD = .97), compared to the VR-Walkthrough (M_{final} = 3.79, SD = .94). This suggests that learning about spatial configurations still requires experiencing the space of real buildings.

The workshop “Understanding the function of form” was rated lowest for helping to understand orientation in buildings, but helped understanding space syntax methods (M_{final} = 3.71, SD = 1.03) and the relation between floorplan-geometry and building use (M_{final} = 3.93, SD = .80). The question in how far the workshop had a positive influence on the design of floor plans during the design project was just slightly rated positive (M_{final} = 3.14, SD = 1.06). This may be due to the fact that the exercise was very abstract in nature.

The design exercise "From the inside out" was intended to get the students to focus on spatial relations when designing a building. The difficulty of this task was rated moderate (M_{final} = 2.93, SD = .85). The specification of a formal system was seen as restrictive (M_{final} = 3.60, SD = .95). Nevertheless, students felt that it is useful to develop a building based on explicitly formulated rules (M_{final} = 3.73, SD = .93). The exercise helped to design the building in the later course of the project based on rules (M_{final} = 3.67, SD = .70).

Regarding the use of VR-Technology, students felt that experiencing the 3D-model in real size helped to evaluate the design (M_{final} = 3.73, SD = 1.17). The high SD might be caused due to the fact that the quality of the models differed between groups. They felt that they were able to assess the spatial dimensions very well (M_{final} = 3.87, SD = .50) and able to assess the distances very well (M_{final} = 3.47, SD = .81). The students highly agreed that it was important to experience the building from different positions and perspectives (M_{final} = 4.53, SD = 0.72) and helpful to share the experience with others (M_{final} = 4.20, SD = 1.17). The latter was just possible because we were using a multi-user VR-systems. Finally, the students reported that they would like to use such system more often (M_{final} = 3.80, SD = 1.05).

The questionnaires for the spatial cognition workshop (*pre* and *post*) revealed that most students felt the workshop helped them take the perspective of a building user/visitor/inhabitant more easily (Initial test: M_{pre}= 4.05, SD=.78; M_{post}= 3.46, SD=1.10). Students felt that the lecture helped for the perspective-switch (M_{pre}= 3.57, SD=1.10; M_{post}= 3.27, SD=.90), and ratings were similar for the case studies (M_{pre}= 3.57, SD=1.43; M_{post}= 3.41 SD=1.12), while the navigational exercise received the highest, although in the retest someone lower, rating (M_{pre}= 4.30 SD=.96; M_{post}= 3.90 SD=1.33). Some students judged the case studies as being too easy.

Directly after the Bremen workshop, students rated the collaboration with behavioural scientists as very useful (M_{pre}=4.37, SD=.52), although this rating was somewhat lower in the second assessment (M_{post}=3.85, SD=.71).Yet, this lower rating is likely to be an artefact, as the students' written comments on this matter were very positive.

Finally we included questions about architectural education. Students felt that they usually encounter little scientific input during their studies (M_{final} = 2.17, SD = 1.19), whereby the amount in the project was clearly rated very high (M_{final} = 4.55, SD = .57). Furthermore the students wished to know more about scientific methods for evaluating architecture (M_{final} = 4.04, SD = .71) and felt that these methods could help to improve the quality of designs (M_{final} = 3.84, SD = .85). The students indicated consistently that they intend to use the methods learned during the project in their future design-projects (M_{final} = 4.20, SD = .54).

The students written comments emphasized, e.g., "the intention of designing a building with a totally scientific perspective. I think it is very nice to try different methods of designing since you are able to combine them, and make for a more fruitful learning." They appreciated "new facets of designing", the integration of theory and practice, working with literature on new subjects, the excursion and the VR walkthroughs, among others. They liked "the opportunity of having time and support for our own and personal investigation process. And therefore having the feeling of 'owning' the outcome of that process". More specifically they commented that the project helped them to switch to the user-perspective and to simplify designs, e.g. to design shorter, straighter hallways, with simplified main routes, and more layout consistency and differentiation ("don't make it too different and don't make everything too similar"); how to use programs for evaluation; what navigational 'error's could occur and how to avoid them ('rules'); how to analyze groups of different users and their needs during design; to understand user movement patterns and flows; to understand users in terms of (contrary to the architect) not knowing anything about the building.

Critically, they mentioned that they were partly overwhelmed with the breadth and volume of the course content, and one student mentioned that there were too many different ideas in the course that students could not process or apply in such a short time. Students felt that shorter lectures and more practical examples should be given in a future workshop and that the many preparatory activities reduced the time available for the final design. Furthermore students would have liked to use the VR-Lab more frequently: "I think the more frequent use of the VR lab would benefit the project, since we would be able to design from an inside perspective, instead of only trying out a design afterwards."

Conclusion & Outlook

This project presents an integrated effort to teach architecture students to design a building using scientific methods. The focus was on considering the user perspective. In addition to teaching theory and its practical application, the students were encouraged to develop their own "research-based" design strategy. We summarized the course modules and the experience we had with this project. In the questionnaires, students rated the project very positive, and appear to have gathered valuable knowledge and insight for their architectural design process and way of looking at their own designs. The collaboration between architects, spatial cognition and environmental psychology researchers and computer scientists, and the integration of similar modules into the education of architecture students, in general, appear highly valuable to provide understanding of the user's perspective and possibly to design more user-friendly buildings.

From the point of view of the architectural team, we can state that, contrary to our expectations (at the Bauhaus-University architectural education is stamped strongly artistically), the students were enthusiastic about the idea of using scientific methods in their design process. Nevertheless we must admit that integrating research into the early stages of design is a challenging task for teachers as well as students. The scientific way of working is difficult for architectural students because they are trained to work results-oriented and used to consider many things at once, which can be at odds with the analytic perspective of behavioural science. In assessing the projects it was evident that the most 'scientific design approaches focusing on one single criterion are not sufficient to create good buildings. On the other hand, designs that were based on simple geometric formal approaches satisfied many functional criteria very well, although the shape of the building was not explicitly developed from them. Finally, we were surprised by the variety of results. The students defined quite similar demands for the building, the individual rooms and the circulation space completely different solutions emerged, which suggests that the use of a scientific design approach (and the strong focus on functional requirements) has little influence on the geometrical-formal appearance. Rather contrarily, compared to other design classes at our University, mainly focusing on style, the confident knowledge about function seems to enable students to freely design form.

The use of VR technology for evaluating design intentions and the spatial effects of the building (in realistic scale) has proven to be very effective. A seamless integration of this technology into the design process would be highly desirable. This was not possible in this project, since the effort to prepare the models adequately was very high. In the future, we expect that more affordable display systems, like commodity HMD's, can become a useful tool available for all students. One limitation is that the current setup is geared towards evaluating orientation and wayfinding, but not the potential of the building for social interaction, as this would require having a larger group of users interact in the VR or the introduction of computer-controlled avatars.

For future versions of this course, we intend to develop structured summaries of findings from the spatial cognition and environmental psychology literature as well as a number of further case studies and movement analysis tools. While many architectural books present buildings examples and guidelines (like the Neufert(2005) for dimensioning of building-elements) there currently is a clear lack of a comparable textbook that would serve as an introduction to and reference about cognitive and behavioural aspects in a format suitable for architecture students and practitioners.

The initial evaluation of this course is very encouraging, yet many open issues remain on how to best combine the available educational tools towards a comprehensive and rewarding student experience that convincingly conveys the value of behavioural science and methods in architectural design.

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