This paper describes the unique coupling of an architectural urban design studio with an in-depth digital media course for the purpose of exploring new avenues of architectural expression, urban form-finding, and communication through the exploration of urban parameters. By merging descriptive parameters of urban situations with digital parametric tools, the understanding of urban design processes was enhanced by the possibility to perceive and comprehend larger problems of spatial urban experiences. The paper discusses how variables, goals, and outcomes of this urban design studio, as well as its integration with digital parametric design, allowed the participants to create an innovative urban design language. It reviews the implications for design education, as well as for the understanding and communication of complex urban designs that are responsive to a variety of parameters. This work lies in the tradition of artists who push media to explore new interpretations of both the media themselves and of their artwork as much as it does of the use of parametric systems as technological tools.
1. Introduction

The exploration of the relationship between human beings and the natural world, and the subsequent implications of interactions between them, have deep roots in our social and cultural understanding of society. Cities, therefore, are direct reflections of their inhabitants, as their designs directly influence the living conditions of their people.

In recent practice, planners have designed and described cities through the means of master plans, or descriptions of picture-perfect, complete cities in which change was not part of the picture. A few, however, have tried different approaches.

In the sixteenth century, Pieter Bruegel painted a representation of the Tower of Babel as a miniature city. The painting depicts a tower piercing the clouds, showing all the problems then associated with cities and city life. It is not a picture-perfect portrayal, as it depicts a city crumbling and rebuilding at the same time, constantly going through the process of change.

In the 1960s and early 1970s, the Archigram came up with a similar idea. Reacting against the permanence of houses in what it called the “Plug-in City,” it proposed ever-changing units adaptable to different social and economic conditions [1]. However, these examples never became the norm for thinking about the concept of the city. Instead, what had been practiced for centuries had become much closer to Le Corbusier’s concept of cities as non-intelligent machines. These machines can not think, and are therefore unable to adapt to change. Once designed, they can only operate with all their components working perfectly; if one component is to fail the whole system will stop working.

Cities and urban environments cannot be designed successfully in this way. On the one hand, we can portray them as accumulations of events, changing processes, overlapping juxtapositions, and so forth [2]. On the other hand, however, urban designs commonly do not allow for any changes or reactions to the lifestyles of their cities’ inhabitants. Market economies outpace the development of cities, and therefore cities cannot be planned according to static rules from textbooks, or by using prescribed and fixed master plans. Descriptions of organic or adaptable systems would be much closer to reality for informing the generation of desirable outcomes [3].

In general, the urban design studio presented in this paper followed new trends in urban design. By its definition it reflects on a distinct method of design. This is in contrast to a development that is not planned and reaction on current situations of the city. In their design for Federation Square in Melbourne, Australia, LAB Architecture Studio developed building facades through the interactive application of sequential rules describing their visual characteristics in both quantitative and qualitative terms. Their more recent design for Beijing’s urban master plan seems to be going even further. Instead of coming up with a plan, LAB managed to translate planning codes...
A slightly different approach can be illustrated within the favela neighbourhoods in Sao Paulo, Brazil. In this project, students from Eindhoven Technical University tried to respond to traditional methods influenced by functionalism and the economic cost-effectiveness of the production process [5]. They derived their parameters from building blocks and urban contexts in order to create a model that fulfilled all requirements.

Architectural design studios are an essential learning experience for architectural students. Their traditions and proceedings are well established. These studios are, additionally, informed and supplemented by courses and seminars, which can feed into their learning outcomes. Studios go beyond pure skill training and require reflection upon, and the creation of, knowledge. There can be, however, a gap between skills training and the application of knowledge within the studio context [6].

This tension is also apparent in digital media courses. These present the underlying concepts of architectural design using digital communication tools, but also have to provide training in software skills and other technical subjects [7]. The integration of digital media courses into design studio curricula often fails, because the compound acquisition of skills prevents a deep exploration of design and the theoretical aspects involved. Participants are able to employ digital media tools within a studio context only long after they have learned the subject matter and acquired proficiency in the skills. By then, however, the studio may consider these skills to be no longer valid.

A dilemma of semester-based teaching is that students reach their highest level of skills and experience at the end of a term, after which they leave for their break and are therefore unable to apply their knowledge immediately. At the beginning of the following term, however, the knowledge and skills they had gained earlier are likely to be either inactive or not employed, because the learning foci of the next semester may have shifted to other aims.

The urban design studio presented here addressed these issues by integrating the learning experience from the beginning within compact workshops, seminars, and a variety of lectures that allowed the participants to draw from their own experiences far into the project and beyond. Participants were inspired by rich and informative sets of experiences from the first day on. They developed and communicated their understanding of urban design issues by utilising their skills training within the design-studio learning experience. Because of this, students began to think about design problems in different ways.

The studio presented design by basing it on parameters. In order to build up a philosophy around parametric dependencies and relationships, the participants used digital tools that allowed them to explore and express their designs. These tools allowed users to develop expertise and to engage
creatively in parametric design. Typically, architects employ such tools only for visualisations, or after the designs are completed, in order to feed them into the construction and manufacturing processes.

Parametric applications have inherited two crucial elements. These are that all entities start with a point in space and allow the study of urban conditions in a three-dimensional environment, rather than the commonly used two-dimensional or layering techniques, and that the underlying concept of parametric modelling is based on data, variables, and their relationship to other entities, which can then respond to variations of input data.

Participants were able to employ digital media skills early in the studio experience and expand on their understanding and communication of design issues from there. The studio built upon design studios that allowed participants to explore design methods and tools beyond their original definitions and perceived limits [8].

2. Urban design studio

A building, an urban situation, or architecture in general can be expressed and specified in a variety of ways. Commonly, drawings describe geometric properties that can explain, depict, and guide the construction of buildings or streets. Alternatively, performance specifications can describe observed behaviours. It is also possible to describe properties as relationships between entities. Spreadsheets, for instance, specify the value of each cell as the result of calculations involving other cell entries.

These calculations or descriptions do not have to be explicit. Responsive materials change their properties in reaction to the conditions around them. A thermostat senses air temperature and controls the flow of electric current, and hence the temperature of the air supplied. Using such techniques, artists have created reactive sculptures and architects have made sentient spaces, or spaces that react to their occupants or other relevant factors. Streetlights turn on if light levels fall below a threshold; traffic flow can be regulated according to need; walls can move as users change location.

Links to a variety of data can be established and serve as the bases to generate geometric forms through the use of parametric design tools. When designing urban spaces, it is usual to collect some data of the type of urban qualities desired. These are then, for example, translated into master plans, which are themselves specific spatial descriptions. Performance requirements for urban places can then be written, linking the description of the urban space to experiential, financial, environmental, or other factors [9].

Design studios mimic the typical working processes of the architectural profession and are the essential learning experience for architects. However,
little or no research exists that examines or validates the claim that the framing of design creation using parametric methods enhances the process [8]. This studio, therefore, couples knowledge about parametric methodologies within the creation of architectural design, ultimately re-framing the question and proposing new answers and methods of design thinking [10].

Participants in this study solved a typical urban design problem using applications that focused on the parametric dependencies of spatial perception, fabrication, and form finding. Their creation and exchange of ideas followed the rules of a design studio within a cyclical design-exploration paradigm (Figure 1) [11]. This design-cycle had the framing of the design question at its centre, while taking full advantage of available Building-Information Modelling (BIM) technologies to explore it [12]. This approach tested the limitations set by conventional, design-only methods. The cognitive aspects of the design creation and its relationship to parametric design methods operated as an influential factor for understanding the perception, framing, and creation of spatial knowledge within architectural design.

The studio then studied the design processes by using sets of variables and series of relations to question, create, and define the form and function of the resulting designs. Thus, it examined interaction techniques between the design intent, its framing of the design problem, and its subsequent creation, while at the same time establishing a connection to BIM. Participants engaged in a collaborative architectural design studio involving the creation and fabrication of architectural spaces. This formed the basis for a transfer of knowledge to the larger context of the profession and building industries [13].

The studio took two distinctive new-town neighbourhoods within the Hong Kong urban context as its base of exploration. These estates, both public and private, consist of 30-40 story blocks, up to 20 clustered together, easily housing populations of around 10,000. Their flats are small, and therefore their inhabitants used outdoor spaces, as well as the city in general, as extended living rooms. Hong Kong's scale and pace of urbanisation, as well as its rate of building replacement, have had an impact on its inhabitants' sense of place, sense of
community, or both. Earlier urban planning did not anticipate the changes that arose over years of population growth. A redevelopment could address these issues, creating a new urban identity for the place and the city itself [14].

The studio examined two sites with different characteristics and urban situations. The first site was a new-town urban development called Mei Foo located on the western side of Kowloon Peninsula, built on reclaimed land, and partly still under construction. It is adjacent to old, existing neighbourhoods that are rich with their own urban life. These districts therefore stand in clear contrast with each other. The second site, called Taikoo Shing, is an existing podium-tower development at the eastern side of the urban area of Hong Kong Island. It is surrounded by office towers, highways, water, and hills on either side. Being built and maintained as it was originally planned, the district lacks urban street life, organic development, and integration into the surrounding city fabric.

3. Studio set-up

Typically, architectural studio and elective courses run parallel and inform each other only slightly. Students seldom make use of the knowledge gained in courses while concentrating on their studios’ design problems. To allow the students both to acquire skills and training within their courses and to apply this knowledge to their design, the studio had been coupled with a digital media course that addressed parametric modelling in architectural design. The studio was one of the required design studios of the Master of Architecture programme at the University of Hong Kong.

Twenty-four students elected to join this urban design studio, which was supervised by two design teachers and one architectural consultant in digital media. The students were enrolled automatically into the coupled two-hour digital media course. The studio and the course shared scheduled lectures, tutorials, and meeting times, merging into one large unit. This allowed contact times two or three times per week during the semester from September to December 2005. The studio was structured into four phases that related to and built upon each other. The aim was to acquire and integrate a variety of skills during the course of the studio and to contribute to the final design outcomes of an urban design proposal.

3.1. Creation of parameters

The project’s first component included the collection and understanding of data that arrived from the site. In order not to overcomplicate the issues, the tutors asked the students during this first stage to limit themselves to investigating a maximum of three design parameters. This put the focus on the selection of the parameters that the students believed would influence the site or the site’s perception the most. Students selected for example: pedestrian flow and movement, noise-, wind-, sun-pattern, property values, activities, attractions, family situations, etc.
The students worked in pairs from the beginning. This was to facilitate a merging of individual ideas and design aspects in order to create a more complex proposal at the studio’s end. The parameters they chose informed them about the site by providing a site description based on dependencies and interconnected relationships of site-relevant information. The studio allowed the participants to explore design issues within this context, while the content of the simultaneous elective course focused on theoretical aspects of parametric designing and the possibilities that digital media offer in this context. That included: object-, rule-, generative-, evolutionary-based design, cellular automata, CNC-production technologies, hard- and software tools, etc. This component concluded after two weeks with presentations of data, parameters, and individual interpretations of the site. It was followed by the presentation of combined parameters and their influence on the site.

3.2. Learning of parameters

The programme’s second component focused on the understanding and creation of parametric design concepts and the acquisition of design-application skills that allow parametric and rule-based three-dimensional design. Participants were trained intensively during studio-time in the use of Digital Project™ [15]. This software application allows users not only to create three-dimensional models, but also to establish rules and functions and create dependencies on its entities.

As taught in the first phase, these parametric functions require a different understanding of the conceptual approaches to design. Creating rules and dependencies, which then influence the design, involved the students in a higher framing and definition of the concept of design. It allowed the visualisation and modelling of highly complex forms that may result from non-traditional design data, such as noise data or pedestrian flow.

The students used their own parametric and rule-based design analyses from the first component and subsequently studied the use and operation of the software, the creation of rules, and parametric and generative design. During this phase, they used the time allocated to the design studio to establish a basic understanding of the software in its relationship to the design intent developed during the first phase. After three weeks of interactive digital media training, the students reached an advanced level of skills that enabled them to use the parametric software as a tool for their further development of their own designs.

3.3. Designing with parameters

The programme’s third component, scheduled for seven weeks, concentrated on design creation, reflection, and the communication of urban design proposals. Using the data of the first component and the skills of the second, the students then started to establish and visualise their designs in three-dimensional forms that created spatial expressions of their
findings and explorations. During this period, the digital-media course component aided the studio with an exchange of knowledge relating to parametric design problems. Students explored a variety of rules and modelling techniques in teams and workshops, allowing them to express their creative ideas within the studio’s discourse.

The studio was in particular interested in describing building forms by creating dependencies and parameters that defined the urban spaces, voids and landscape. Normally, spaces between buildings result passively from describing the buildings around them. With the use of digital media, however, it was easy to design geometric generators that created external spaces and then defined the building forms that resulted from the subtraction of the built-up areas from the urban space [16].

3.4. Merging of parameters

The programme’s concluding component brought together the various aspects and results of the earlier three modules. Within two weeks, the students merged their individual designs and parametric dependencies of urban strategies, components, and rules into one large cluster file. This synthesis created compound models of descriptions and dependencies that were highly complex and interrelated, yet both the content as well as the tools allowed seamless communication to a larger audience by using the parameters as design descriptions. This phase created a shared authorship for all participants and allowed the students to study and understand the complexity and the interrelationships of urban design issues that they normally would have been unable to perceive immediately.

4. Results

The students had already acquired the highest level of skills in using a complex software tool within the first half of the semester. This enabled them to employ the tool as an amplifier to generate their design. Subsequently, they were not limited by their knowledge or level of skills in order to be able to express their designs.

The students produced a variety of individual design proposals as well as one large design-cluster for each of the two sites. They created rules and parameters that allowed generative designs to emerge. These highly complex representations, however, could not have been communicated using traditional urban-planning methods or tools.

Individual design solutions combined to form a multi-faceted proposal that had to be read in its entirety. However, every aspect of the proposal, from micro to macro scale, illustrated engagement with the city. For example, a student designed a noise-barrier wall that reacted to generated sound with a design composed of specific space patterns (Figure 2). This design used negative ambient influences to generate positive reactions within the city’s context. By manipulating the sound waves generated by
traffic, the student was able to generate sounds resembling music on the other side of the wall. This parametric wall allowed a great variation of possibilities with the variables of form, materials, and their performance by absorbing or reflecting the sound.

Another proposal explored the field of vision at any given point on the site as that point related to the porosity of the surrounding buildings (Figure 3). The students tried to develop a connection between the elevated recreational areas of the podium structure to the street level, where pedestrians were often unaware of what was above them. This particular project dealt as its variables not only with pedestrian movements, pedestrian experiences, and pedestrian interactions, it also allowed the exploration of alternatives to the podium structure itself. It examined the relationships between public and private areas within neighbouring districts. The students used the digital tool to create dependencies between the various voids and spaces. In a next step the parametric design strategy aided them to define the buildings that resulted from these spatial dependencies. Figure 3 illustrates the process of analysis and the incorporation of the two different sets of parameters into one proposal.

Figure 4 illustrates the influence of sunlight and the need for comfortable outdoor-space facilities that relate to human activities within a 24-hour time cycle. Here the students analysed pedestrian movement and shade conditions throughout the year as their parameters and created shading devices as protection from both sunlight and rain with a system of self-opening canopies that reacted to both pedestrian movement and weather conditions to provide a comfortable environment in all conditions. The parametric design tool allowed a design that reacts to these variables. It supported the students in defining the problem, programmatic issues and
design solutions. While another individual result involved the relationship between pedestrian flow and attraction to urban spaces with responsive structures (Figure 5). The software tool allowed modelling these abstract data and setting them into a dependency of each other. Students were subsequently able to visualize and communicate their design intentions easily.

In the studio’s four components, the students presented an in-depth cluster of multifaceted urban design proposals for two selected Hong Kong sites. They demonstrated a high level of thinking processes resulting in the generation of compound designs. Each student contributed simultaneously at both micro and macro scale in order to create this urban design proposal. The participants gained a high level of expertise with digital parametric tools as part of their development at the studio, and used their knowledge from the digital media course directly from the project’s onset to generate and communicate their designs. The shared authorship removed...
the students from their individual works and allowed them subsequently to understand the larger picture of the final cluster design.

5. Discussion

For many years, academics and professionals have been trying to point out the shortcomings of urban master plans. This criticism of the concept of the master plan has been mainly from the perspective of such plans being too precise, too prescriptive, too ideal, and for their not making allowance for changes. Some have compared master planners to gods. As a result, community participation came into fashion and flourished. Unfortunately, community participation has been mostly cosmetic and has had little to do with the real issues of urban design and its complexities of city life [17].

With the development of computers and various digital tools, designing in layers has become more popular, allowing architectural planners to deal with more complex problems. The top-down method, in which a master plan was installed at the top of the process, with other problems being organised in hierarchies, has been replaced with layers, with each different layer playing an equally important role.

This may have been a great improvement to the technique of designing master plans, but it still could only deal with simple problems and layers one at a time. More complex problems still had to be divided into separate issues and dealt with one by one. Parametric design opens up a completely different set of opportunities. It allows the analysis of problems from the bottom up rather than from the top down. This enables architectural planners to discover the causes of each problem and their relationships to, and dependencies on, other elements.

This shift of design conception allows for the creation of urban spaces that accommodate change, diversity, and varied human activities without specifying particular functions. Additionally, such designs can provide for unpredictable events in connection with an overall urban framework. City planning can then respond to unplanned changes and their resulting consequences. The outcomes of the urban design studio studied here suggest that parametric dependencies allow for this level of ambiguity.
because the design is not fixed and finalized, but open ended and variable through its inherent parametric structure.

One objective of the studio was to frame an intellectual research question that created links to a variety of data for generating urban form. Generating forms based on research data is just one of the advantages of using parametric design tools. The more interesting outcomes result from the ability to redefine and re-frame the problems themselves by stepping out of preconceptions based on experience and exploring sets of unpredictable answers.

Preconceptions based on experience influenced previous methods of urban design. The popular diagramming methods were an attempt by many urban designers and planners to allow for the reinterpretation of defined problems [18]. In a certain way, parametric design tools do similar things, yet they act at a higher level. The establishment of meta-rules has instituted a form of problem-framing that demands the reference of one problem or parameter with other ones. This is not possible as a method of problem-framing with traditional diagrams.

The examples of our design experiments illustrate how non-linear design processes and the re-representation of ideas can lead to new designs and expressions that differ from conventional approaches to design. The exploration of the gestalt within both environments can enhance the understanding of spatial issues and lead to meaningful and new architectural results [10]. Despite three-dimensional representations of an urban space being only a medium through which to aid in the understanding and communication of spatial arrangements, the designers’ comprehension of complex spatial qualities was enhanced by the re-representation by a parametric medium. The novel aspect of this studio work was the engagement of the process of translation itself as a creative act.

6. Conclusion

The studio presented in this paper addressed computational concepts of architectural urban-design creation influencing the recent development of architectural production. This partly experimental, partly realistic studio exercise explored innovative methods of architectural expression, form-finding, and communication, developing unconventional solutions coupled with a novel pedagogical approach.

It tied the studio-learning environment with an in-depth digital media assignment in order to close the gap between training in skills and the application of knowledge, as well as to explore new ways of integrating compound design issues. As Kvan [7] suggests the learning environment needs to address new opportunities digital media support to facilitate.

The use of digital parametric design tools allowed the participants to create an innovative urban design language based on rules and generative
descriptions. For this reason, the skills training that related to the studio was embedded into the studio. The students had acquired their skills in software and parametric design methods already, within the first half of the studio. This amplified their design experience and learning outcomes. The students connected their knowledge with their ambition to express their design proposals.

The synthesis of all individual projects removed the students from individual ownership of their designs, but allowed them to reflect on both their own and their colleagues’ designs as a complete cluster of contributions [19]. This related to earlier research into design studios based on the same principle, in which media were applied outside their normal pre-described purposes, and innovative design methods were deployed by interplaying digital media and design explorations [8].

With the employment of parametric software that allowed students to experience the dependencies and rules of the various individual contributions spatially, as well as the overall common proposals, the design could be communicated using tangible interfaces or digitally controlled devices. The generated design data could then be linked in a variety of ways to extract or generate new geometric forms and understandings. These descriptions could then be used directly in the manufacture of objects by means of, for example, digitally controlled devices [20].

Each of the components was an essential part of the overall process of design creation. Each addressed and expressed certain distinct aspects of the process. This enabled a holistic discussion about design, form, function, and development, which is significant not only within architectural education, but also in all other dialogues involving spatial representations. This follows the tradition of artists and designers, who have always pushed creativity to new definitions of both their artworks themselves and of their cultural contexts.

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Spatial Simulations with Cognitive and Design Agents

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