Investigating the Arch RSU Parametric Design Studio

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Abstract

The Faculty of Architecture at Rangsit University, Arch RSU, has taught architectural design using traditional methods since it was founded in 1988. 2016 was the first academic year that the school transitioned from teaching in traditional architectural design classes to vertical design studios. This paper presents the learning process and learning outcome from the Parametric Design Studio, which was set up at Rangsit University. This was the first time the school had integrated parametric design into the studio projects. Therefore, the following research questions were asked: (1) How will parametric design be taught? and (2) What will the students' learning outcome be? The objective of this paper is to improve the learning process in the RSU parametric design studio. The following four-step process for teaching parametric design was introduced to investigate the teaching and learning processes: (1) parametric design books (2) introductory workshops, (3) the development of parametric design skills and (4) the integration of parametric design into the design. The students' design outcomes were observed then two 2nd year, five 3rd year students and two lecturers were interviewed to gather feedback. The results show that the students were mostly satisfied with the outcome and they were more than likely to continue studying in the design studio next semester. However, some drawbacks were identified, which will allow for improvements next semester such as better class management, strengthening students' parametric design skills, and further integration of the parametric design software course into the design studio course.

Keywords**:** *vertical design studio, parametric design, architectural education*

1. Introduction

The Faculty of Architecture at Rangsit University (Arch RSU) has been teaching architectural design using traditional methods since it was founded in 1988. In the Horizontal Design Studio, tasks were assigned to students who were in the same year and lecturers had to follow the same subject matter, teaching processes and guidelines. The subject matter used to be, for example, vertical homes (2nd year), high-rise buildings (3rd year), and ASEAN projects (4th year). 2016 was the first academic year that the school transitioned from traditional architectural design studios to vertical design studios. Vertical design studios allow students of multiple levels and sometimes of different disciplines to study design courses together (Youssef, 2014). Leading architectural schools that use vertical design studios include:

- The Architectural Association School of Architecture, London (AA, 2018),
- The Bartlett School of Architecture, London (Bartlett, 2018),
- and The Institute of Architecture, University of Applied Arts Vienna (Die Angewandte, 2018).

The following architectural schools have published research on vertical design studios:

- The University of Science and Technology (NTNU) and the National University of Singapore (NUS) (Liem, 2009),
- The Department of Architecture (DA), King Abdulaziz University, Saudi Arabia (Youssef, 2014),
- The School of Architecture, University of Texas, Austin (The University of Texas at Austin School of Architecture, 2017),
- and The Welsh School of Architecture, Cardiff University (Welsh School of Architecture, 2018).

The existing studios at RSU were converted into nine new vertical studios, i.e. New Edge, Design Lab, Flex, Professional, SOS, Spatial design, Parametric design, Eno, and SIA, based on the lecturers' expertise and interests.

This paper presents the learning process and learning outcome from the Parametric Design Studio at RSU. Parametric design software (Rhino and Grasshopper) was introduced to the syllabus in 2014 and then taught again in 2016. However, this was the first time that it had been studied in the vertical design studio. Therefore, the following research questions were asked: (1) How will parametric design be taught? and (2) What will the students' learning outcome be?

Researchers have explored the use of parametric design tools in the design studio. Schnabel (2007) investigated the gap between skills training and the application of knowledge in the studio. The students were trained to develop parametric thinking early in the semester so that they could apply it in the design studio later. Some researchers have created their own approach to parametric design. Lecourtois & Guéna (2012) from the School of Architecture in Paris La-Villette (ARIAM-LAREA) proposed that the students develop parametric design methods based on the school's theoretical approach, known as Architecturology. Other researchers have explored digital fabrication in parametric design studios. Holzer (2008) asked the students at RMIT to investigate the "aesthetics of performance" of the design by going back and forth between physical and digital models. Ikeda, Toyoda & Takenaka (2016) integrated a problem-based project where students designed and built full-scale mock-ups of a small structure.

2. Objectives

The objective of this research is to improve the learning process in the parametric design studio at RSU.

3. Materials and Methods

A four-step process for teaching parametric design was introduced to investigate the teaching and learning process. Then, the students' design outcomes were observed and seven students (two second year and five third year) were interviewed to gather feedback.

4. Investigation of the Arch RSU Parametric Design Studio

4.1 The vertical studio

Each studio had to accommodate 2nd, 3rd, 4th and 5th year (thesis) students. Initially, 800 students attended an introduction in a large auditorium. The next day, the students had to select studios in order of preference then submit their profiles to the lecturers for consideration. The parametric design studio lecturers decided to select only 2nd and 3rd-year students. Finally, ten 2nd-year students and twenty-five 3rd-year students were accepted by three lecturers. The second-year students' task was to redesign the facade of a building on the campus (studio theme). The facade had to correspond to the identity of the faculty in the building (horizontal theme). The third-year students' task was to design a Museum of Art on a piece of land of their choice (studio theme), which had to be a public building of not more than 23 meters high (horizontal theme). The 2nd and 3rd-year students were expected to study on the same parametric design tool course. However, as the course did not open, the only linkage between the two studios was design reviews.

4.2 How is Parametric Design taught?

Schnabel (2008) addressed the gap between skill and application in a parametric urban design studio. From the beginning of the semester a series of compact workshops, seminars, and lectures were arranged at appropriate times. This meant that they could apply what they had learned to their work in the design studio. This approach exposes students to the concepts of parametric design at an early stage in their education. Therefore, it is suitable for use as a pedagogical framework. Based on this framework, the following four-step process was proposed for teaching parametric design:

1. Parametric design books.
2. Introductory workshops.
3. The development of parametric design skills.
4. The integration of parametric design into the design projects.

4.2.1 Parametric design books

A Thai language parametric design book was written by an RSU lecturer in 2017 (Nakapan, 2017). The book introduces parametric design to students in a structured way and outlines basic theory. This is helpful because important questions such as what is parametric design? what can parametric design do? and how is a building created using parametric design? are answered in the book. Digital fabrication within the context of parametric design is also explored. The book is useful for Thai students because all the existing literature on parametric design has been published in other languages. In addition, it allows teachers and students to communicate using the same set of keywords such as form finding, materialization, simulation, iteration and digital fabrication.

4.2.2 Introductory workshops

The first Weaving Structure and Interactive Space Workshop was held from September 26th to October 5th, 2017 at the RSU Chinese-Thai Institute. Students from three campuses: RSU, Tsinghua University (Beijing) and National Yunlin University of Science and Technology (YunTech, Taiwan) worked together to build a 3.59 meter x 4.14 meter structure using PE pipes and fibre rods. The goal of the workshop was to give second-year students (ARC 224 Architectural Design 1) a basic understanding of parametric design, digital fabrication techniques and interactive space. They learned how a three-dimensional structure could be modelled using parametric design software and how structural force could be simulated using Tsinghua University software (Huang, Yan, Luo, & Li, 2016). As a result, structural members were measured precisely then cut for assembly and interactive LED flashing lights were programmed to make the space more lively and interactive (Chang, Jiang, Chen, & Datta, 2012).

Figure 1 RSU X Tsinghua X YunTech - weaving structure and interactive space workshop held from Tuesday, September 26, 2017 - Thursday, October 5, 2017 at the RSU Chinese-Thai Institute

4.2.3 The development of parametric design software skills

Students who become familiar with parametric design software before they attend the design studio are more likely to have successful outcomes. However, at the beginning of the semester, many students had not joined the course. A parametric tool class was organised in parallel; however, the students did not enrol. Therefore, tutorials were organised in the design studio when appropriate skills were required. For example, form finding had been taught by the time they had finished studying architectural programming and started creating building forms. The 2nd-year students' parametric skills were not formally tested. The learning process was objective based. The students had to learn independently by finding definitions on the internet then teachers gave feedback during design reviews as to whether the objectives had been met or not. The 3rd year students' parametric software skills were tested at midterm (designing a parametric pavilion) to ensure they had enough knowledge to continue working in the studio.

4.2.4 The integration of parametric design into the students' design

Doyle and Senske (2016) addressed bridging the gap between design education and digital technology education; there is a challenge demonstrating the impact of such intervention upon design outcomes, which are not easily measured or quantified. The task is burdensome and unreliable, therefore, there is no accepted pedagogical model for digital design education. What is more important is that the developed skill should allow technology to be used expansively and in unique ways rather than reductively and repetitively. Following this argument, students in their studio had the liberty to use parametric design anyway they wanted.

To categorise the students' parametric design use, three levels of parametric design integration were identified. The first level is when the students do not use parametric design in their designs at all. The second level is when students use minimal parametric design in their designs. At the third level, students use parametric design normally in their designs. The second and the third levels have been further defined in terms of the students' parametric design use.

- *Form finding*: using parametric design to create a desired form.
- *Iteration*: using parametric design to create a loop that generates different forms or solutions.
- *Materialization*: using parametric design to create new effects on materials such as patterns on walls or roofs.
- *Simulation*: using plugins (such as Ladybug) to analyse the impact of the environment on the building such as sunlight, heat gain, wind flow and structural analysis.
- *Digital fabrication*: sending digital files to fabrication machines (laser cutters, 3d printers) to make 3-dimensional models.

Table 1. shows the number of 2nd-year students who used parametric design at each level of integration.

Table 1 Levels of parametric design integration in the 2nd year studio

Level of integration	Number of students					
Level 1: Students not using parametric design at all	1	form finding	iteration	materialization	simulation	digital fabrication
Level 2: Students using minimal parametric design	4	4	-	4	4	-
Level 3: Students using parametric design normally	5	5	-	5	5	2
Total	10	9	0	9	9	2

- One student did not use parametric design at all.
- Four students used minimal parametric design. All of them used parametric design for materialization, simulation and form finding. However, they found the shape of the facade then applied a pattern to it without considering the suitability of the pattern.
- Five students used parametric design normally. All of them used parametric design for form finding, materialization, and simulation. They created facades with patterns that were appropriate for the interior and the environment (figure 2).
- None of the students used parametric design for iteration.
- Two students used digital fabrication to make 3d models.

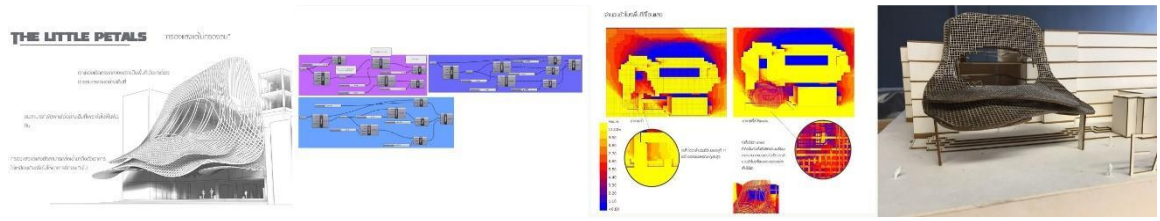

Figure 2 Example of students' work that used parametric design normally
(form finding, materialization, simulation, and digital fabrication)

Table 2 Levels of parametric design integration in the 3rd year studio

Level of integration		Number of students				
Level 1: Students not using parametric design at all	2	form finding	iteration	materiali zation	simulation	digital fabrication
Level 2: Students using minimal parametric design	5	5	-	1	-	1
Level 3: Students using parametric design normally	18	14	4	6	-	5
Total	25	19	4	7	0	6

- Two students did not use parametric design at all (figure 3: 1).
- Five students used minimal parametric design in their designs (figure 3: 2-3-4). All of them used parametric design for form finding. Four of them put double curved roofs on their buildings (form finding), which did not integrate well with the design, one of them created a double curved ceiling in the entrance hall and another student used parametric design for materialization, i.e. making a pattern for the roof.
- Eighteen students used parametric design normally. Among them, fourteen used parametric design for form finding. They used scripts to create shapes that matched the original shapes they had in mind (figure 4). Four students used parametric design for iteration. Beginning with a script, they experimented with different values to create design choices (figure 5). Six students used parametric design for materialization, five of them created linear patterns on the facade while one student used parametric design to find a colourful pattern for the facade (figure 6).
- Six students used digital fabrication to make 3d models (figure 7). The fabrication techniques used were slicing and unroll surface. A laser was used to cut the pieces. Some students used a 3D printer because they had designed complex forms.

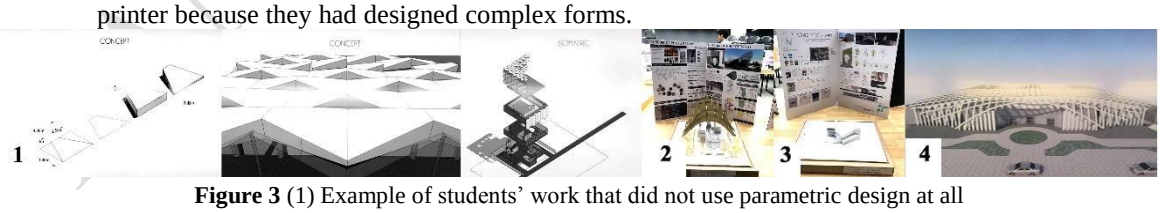

Figure 3 (1) Example of students' work that did not use parametric design at all
Example of students' work that had minimal parametric design integration (2-3-4)

Figure 4 Example of students' work that used parametric scripts to find shapes that matched the original shapes they had in mind

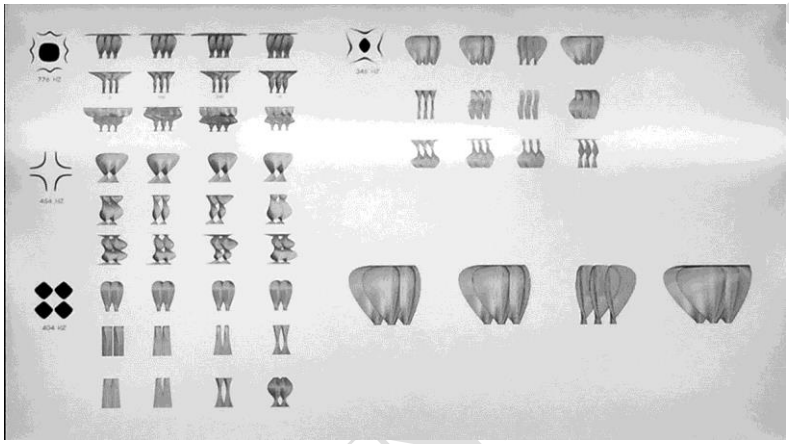

Figure 5 Example of students' work that used iteration to experiment with different values to create design choices

Figure 6 Example of students' work that used parametric design to find colourful patterns on the facade

Figure 7 Example of students' work that used digital fabrication

Analysis of results

The results show that the students mostly used parametric design for form finding. However, the students who used minimal parametric design tended to create double curved roofs over the buildings they designed. One student (The Makeup Museum – cf. figure 6) used parametric design to create a colourful pattern (materialization), which was appreciated because it demonstrated another potential use of

parametric design to the junior students. The students that used parametric design for simulation were all from the second-year. They used software plugins, such as Ladybug, to perform a sunlight hour analysis on the facades they designed. Unfortunately, some of the students did not fully understand the simulation procedure; they used a template created by a classmate without further analyses of the result. Unfortunately, as the third year had a more complex project, they did not have time to run the simulation.

5. Results

The effectiveness of the pedagogical framework and the four-step process (books, introductory workshops, the development of parametric design skill, and the integration of parametric design into the design) need to be measured. First, drawbacks from observing the students' design outcomes are identified. Then, the feedback from the survey and interview conducted with the students and lecturers is given.

5.1 Drawbacks identified

The following drawbacks were identified by observing the students' design outcomes.

1. Books: parametric design books were given to the students; however, it is uncertain whether they found them useful or not.

2. Skills: many students lacked parametric design skills because they did not enrol in the parametric design tool course.

3. Level of integration: a few students did not use parametric design at all. Some students used only minimal parametric design just to say they had experienced it. Surprisingly, the 2nd year students used parametric design for environmental simulation.

4. Design and production software: Many students used SketchUp, which caused limitations because the files were too large to be processed.

5. Digital Fabrication: only a few students used digital fabrication techniques to make physical models at the end of the semester.

6. Vertical linkage: the only vertical linkage between the studios was a cross design review. The 1st and 2nd-year students should be encouraged to learn together more frequently.

5.2 Feedback from the students and lecturers

Preliminary survey

The objective of the preliminary survey was to identify drawbacks, which could be used to formulate interview questions. Seven students (two 2nd year and five 3rd-year students) participated in the survey. The questions that were asked and the answers that were given are as follows.

- Books: did you find the book useful? All the students (100%) found the book useful.
- Skills: did you enrol in the parametric design tool course? None of the students (0%) enrolled in the course.
- Level of integration: have you used parametric design in your design? Five out of seven students (71.4%) had used parametric design. One student had not used it at all.
- Production software: what software did you use for the design? From seven students, six used Rhino-Grasshopper (85.7%), three used ArchiCAD (42.9%) and three used SketchUp (42.9%).
- Digital fabrication: did you use digital fabrication? Four out of seven students (57.1%) used digital fabrication.

Interview with the students

The objective of the interview was to discover the reasons for the drawbacks. Two 2nd year and five 3rd year students were interviewed to find the answers to the following questions.

- Books: what do you think of the parametric design book?
- Skills: why did you not enrol in the parametric design tool course?
- Level of integration: according to your design outcome, why did you use parametric design in such a way? and are you satisfied with the design outcome? Those students who did not use parametric design were also asked why they did not investigate the technology.

  The 2nd year students were asked what they thought of the environmental simulation.

- Production software: what software did you use for the design and why?
- Digital fabrication: did you use digital fabrication and why?
- General comments: do you have any suggestions that will improve the parametric design studio?

The 2nd year students were asked one additional question.

- Did you find the workshop useful?

1. Books: all the students interviewed found the book useful, for example, they could find and select appropriate case studies. One student said that when they needed inspiration they could flip through the book to get ideas. However, some students did not spend enough time reading the book.

2. The parametric design course: most of the students did not enrol in the parametric design tool course due to a scheduling conflict. Those who did not enrol in the course found that it affected their work significantly. One student wanted to further develop their design; however because they lacked software skills the result was compromised. Those who were proficient in parametric design had learned by themselves using online tutorials.

3. Level of integration: the students used parametric design in ways that made them feel comfortable. Those who did not use any parametric design at all said that it was because they did not enrol in the parametric design course; therefore, they were lacking in parametric design skills. Those who used parametric design in a minimal way said that they were running out of time so they had to come up with a quick solution. Some students could not progress as quickly as others because they could not finish the architectural programming. One student mentioned that they had to come up with something that looked parametric. One student, who was dissatisfied with the design outcome, stated that there was not enough time to learn and experiment because the tools were new. One 2nd-year student was satisfied with the parametric simulation tools because they helped to visualise the effects that the environment had on the building. One 3rd year student remarked that they wanted to run an environmental simulation like the 2nd year students; however, they did not have enough time.

4. Design and production software: the 2nd-year students had fewer problems with the software because they worked on a smaller scale project. They could both design and draw using Rhino and Grasshopper. However, many 3rd year students attempted to use SketchUp, which resulted in design limitations. One student thought that SketchUp was better for designing curved forms and ArchiCAD was less flexible. One student had problems converting files from one format to another.

5. Digital fabrication: only a few students used digital fabrication in their designs. Most of them made traditional paper models. One student attempted to use a 3D printer; however, they were unsuccessful because the design was a complex form, which had many voids. They experimented by using three different ways to cover the void; however, the printed models did not come out well. The school did not provide fabrication machinery and the students could not afford to purchase any.

6. Introductory workshop: the students found the workshop beneficial. It helped them to understand the fundamentals of parametric design and gave them hands-on experience. One 2nd-year student commented that they enjoyed the workshop because it broadened their horizons.

7. General comments: the general comments were focused on improving the students' parametric design skills. Most of the students said that they would enrol in the parametric design tool class next semester. They would also like to see a software solution implemented for design and production.

<u>Interview with the lecturers</u>

The lecturers' comments focused on class management issues such as how weekly design reviews could be more effective. They also wanted to expand the vertical structure with more linkage to strengthen the identity of the studio.

6. Conclusion and Discussion

The results show the effectiveness of the four-step process for teaching parametric design. The students were mostly satisfied with the outcome and they were more than likely to continue studying in the design studio next semester. Drawbacks relating to class management, the students lack of parametric design skills, and the integration of parametric design software course into the design studio course will be taken into consideration next semester.

1. Books: the book should be updated at least once per year to ensure it contains relevant resources.

2. Parametric design course: lecturers should check students' enrolment plans and schedules well in advance to solve course scheduling conflicts. Ideally, the parametric design tool course should be integrated with the design studio course.

3. Integrating parametric design into the students' designs: the students' level of parametric design integration is dependent upon their design tool skills. Better integration could be achieved if they enrolled on the parametric design tool course.

Some improvements to the level of integration, that could be considered, as areas for future of research, are as follows.

- Many students who designed interesting free forms used parametric design to find the shapes they had in mind. They did not use the full potential of parametric design, which allows for unexpected outcomes (Chien and Yeh, 2012).
- The students who used iteration to experiment with different forms did it manually.
- 3rd-year students should also run an environmental analysis using the parametric design tools.

4. Design and production software: design and production software should be made available to the students. SketchUp should not be used.

5. Digital fabrication: more resources and tutorials on digital fabrication should be provided.

6. General suggestions: the site selection and architectural programming process should be shortened to give students more time to focus on their designs and advanced analysis techniques such as iteration and environmental simulation. This was the first semester that students from both the 2nd and 3rd year had studied parametric design in the design studio concurrently. Therefore, it is worth comparing the learning outcomes. The 2nd year students' task (redesigning a facade of an existing building) was less complex and more suitable as an introduction to parametric design. The students had enough time to join the introductory workshop and explore advanced parametric design tools such as environmental simulation. However, the 3rd year students' task required multi-faceted analysis because it involved designing a project from scratch. This meant they did not have enough time to explore all the tools because the task was more complicated.

- More vertical linkage could be achieved, for example, by allowing the 2nd year and 3rd year students to study together in the same studio at the same time. In terms of policy, the staff should work together to strengthen the studio's identity by increasing vertical linkage. In the future, hopefully, the architectural school at RSU will run a vertical studio where students from different levels (2nd, 3rd, 4th, and 5th year) can participate in the same projects.

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