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BUILDING COLLABORATIVE CREATIVITY THROUGH AN ITERATIVE APPROACH

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ABSTRACT

Instilling a creative mind is the foundation to prepare future architecture students. University educators can adopt an iterative approach in which students go through cycles of learning. This paper reports student experiences on a three-cycle team project in an architecture course that was part of a master program. This consisted of the group development of a single design proposal to build a large prototype on the roof in the School of Architecture building. Students had to self-select which solution to go forward with, starting with four teams of two in the first cycle, then two teams of four in the second cycle, and one final team of eight in the third cycle. Students needed to reflect on their individual experience and role within the team in a reflective cycle research model that was intended to enable independent and collaborative learning from a given action-based experience. Individual reports were analysed, and the students commonly showed learning through making mistakes and experienced collective efforts by all team members in the process of collaborative creativity.

KEYWORDS

Architectural Education, Creativity, Iterative Approach, Collaborative Learning

1. INTRODUCTION

Architectural educators create a learning environment that draws students' talents and imagination because these students will create landscapes for future generations. According to the charter of the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the International Union of Architects (UIA) for architectural education, one of the core skills in architectural education is the 'ability to work in collaboration with other architects and members of interdisciplinary teams' (p.6). Educators play a significant role in marking student performance, and students experience negativity when a group of tutors provide different critiques as an educational experiment on design studio pedagogy (Ciravoğlu, 2014). A transformative pedagogy adopted in architectural education is studio pedagogy that aims to break down the social relationships of hierarchy between educator and learners and competition between learners (Dutton, 1987). Students as designers have opportunities to sharpen their critical thinking skills, build confidence in taking a stand and be able to communicate their points verbally, or present their work in written format with visual illustrations (Hadjiyanni, 2008). The studio setting allows students to take responsibility to make critiques between one another, and the teaching professor provides guidance on the creative thought processes. Students take active roles in problem analysis and solution justification to work on an authentic local design project with the participatory process (Kowaltowski *et al.*, 2007).

Creativity is one of the core competences that student architects need to acquire in the journey of becoming professional architects. Creativity is not a unitary process but requires conscious and unconscious information processing (Dietrich, 2007). A variety of strategies can be adopted, including critical analysis, imagery, habit breaking, relationship seeking and interpersonal interactions (Smith, 1998). 'Imagery alone cannot be sufficient to improve an idea, and good representational skills [that] are crucial in the developmental phases' of design (Hasirci and Demirkan, 2007: 269). Creativity through interpersonal strategy can enable team members to stimulate one another through building on peer ideas, where each member has veto power in the process of decision making.

Using computer software to generate solutions has been widely adopted in architecture and the construction industry, with 50 percent of the construction industry in North America have adopting building information modelling (BIM) for 3D model-based processing (Becerik-Gerber and Rice, 2010). An iterative approach in architectural design with modelling is deployed that may speed up preliminary safety analysis of automotive systems to allow rapid adoption in the development cycle in the real world (Rupanov *et al.*, 2014). This paper will explore the learning experiences of an advanced architectural design studio that adopts an iterative approach to providing students with rigorous expertise in the concepts, architectural design and design development of working with real-time structural performance simulation engines as a design tool. In addition, it will introduce students to methods for procedural design, digital modelling, digital fabrication, and robotic fabrication. They are expected to develop competence in using the technical tools in order to extend and advance the use of new tools and technologies into architectural design for contemporary practice.

2. STUDIO 'FORCE MATTER 2: CALIBRATION'

Studio 'Force Matter 2: Calibration' takes the high density of Hong Kong's built environment and the lack of available space for new construction as the challenging starting point to advocate lightweight additive architecture. Existing podium and tower structures are used as a substrate for the integration of additional public programs within high-performing structural additions. Weight constraints and limitations from proximity to build fabric become drivers for non-standard architectural design interventions. Students have to learn how to work with geometry, form, performance, materiality and materialization in the context of architectural design addition to a high-density built environment.

Setting up workflows that rely on feedback between material experimentation and notational design with digital design tools, students may experience the complexity of creating a one-tenth scale model to build a large-scale physical manifestation while exploring model making. Iterative design processes are set up that allow for interaction between the numerous factors that define a project. The main tools used in this setup are virtual real-time physics simulation engines, and students are expected to use them to do digital fabrication. They are required to produce a 3D digital design model and all usual architectural drawings to test programmatic requirements and response to site conditions. Apart from learning about principles of modelling (both computational and physical) at various scales to iteratively develop and transform a medium into large-scale intervention, they have to create a full-scale physical model in which a combination is sought between conventional structural systems and lightweight tectonics using bending-active structures to explore the non-standard spatial possibilities for large span areas with minimal live loads.

Each student submits a short critical reflective report on their individual experience with the project and role within the team, supported by evidence of that contribution (e.g. imagery, screenshots, drawings and pictures) to reflect on the action-based experience.

2.1 Creating a 1:10 Prototype in the First Cycle

Among the eight students, a team of two was formed with one student, who had taken the foundation elective course, taking a leading role paired with someone who took a supporting role. The lead teammate would be familiar with the digital tools that were used in the initial design prototype. This meant that it would be a good opportunity for the lead member to teach the supporting member as a form of peer learning in the first cycle.

Students were set to be familiarized with design and physical model construction systems for the development of structurally high-performing geometry setups. Each team used digital physics simulation engines that served as a test basis for the physical model making. Bamboo sticks were used to build a 1:10 scale model. By the end of the first cycle, the paired teams were required to make a PowerPoint presentation that included a time-lapse video of the model construction and to show the first one-tenth scale model. Afterwards, individual students cast their votes as to which two design concepts most involved architectural experimentation and innovation with structurally high-performing systems. Models of the top two votes were selected for the second cycle, a scale-up development. Members of the other two teams would join the selected teams to form two teams of four.

2.1.1 Starting with Errors

Even working with a prototype in the first cycle, students working in creative fields often make errors, and this was observed in their reflections:

> ‘This is the first time we tested out Kangaroo with singularity, one of the fatal mistakes that we have made in the design is that we have inserted too many anchor points at the base to pull the desired shape and as a result the grid distorted more than 40mm. We underestimated the difficulties when we tried to bend the bamboo strips from the cover to form the column, strips went chaotic and hard to manage. So we failed to achieve our ideal double-column structure…we placed four anchor points in the skylight to hold up the skylight in position. As a result, the skylight was rectangular in shape instead of circular.’ – student D
>
> ‘I did struggle in doing simulation with Kangaroo. I failed several times because of the incorrect structural grid as well as the location and amount of anchor point setting. Though I have generated some successful simulations at last, I didn’t really understand the failure part from every case I did.’ – student O

2.1.2 Evidence of Teamwork

In the first cycle, teaming students with a foundation elective meant that they needed good teamwork, with one playing a leading role and the other a supporting role (with no prior experience in using software for model design and digital fabrication):

> ‘I prepared the drawings and diagrams while my teammate combined the PowerPoint, and together we tried to figure out reasons that led to failure.’ – student T
>
> ‘With the help of my teammate, I could be able to understand the system and help to do some model design using Kangaroo.’ – student F
>
> ’In phase 1, design experimentation was implemented as teamwork…. I learned a lot about grasshopper scripting from the discussions with my teammate. I did benefit a lot from the knowledge exchange between the peers throughout the entire phase. I put most of my effort and contribution in the assembly of the physical model while picking up the computation design method.’ – student O

2.1.3 Solving Problems by Students

Students were expected to demonstrate architectural applications of recently developed digital design and fabrication tools. They would certainly encounter problems and needed to learn to solve problems by themselves.

> ‘Professor has provided a grasshopper tool for generating diagonal grid, but this method must fix the singularity points by ourselves. – student N
>
> ‘We did figure out a new way to generate a structural grid by using diamond grid component in Lunchbox plug-in software.’– student O

2.2 Creating a 1:5 Prototype in the Second Cycle

In the second cycle, the two teams of four students needed to develop and refine their designs into projects that incorporated all material and force behaviour, restrictions and opportunities in a symbiotic manner into a single well-resolved architectural production. The teams used bamboo sticks to create a 1:5 scale model in the second iteration, knowing that only the best model design would be selected for the rooftop construction. All students joined in voting for the best project.

2.2.1 New Team, New Roles

Forming new teams could invite more opportunities to try out new tasks. However, the collective wisdom would take time to function.

> ‘I participated in both digital and physical model work in the first cycle. I took a role in preparing the material and model making in the second cycle. I made the wooden base bench for the 1 to 5 scale mock-up model…double checking in between the digital 3d model and physical model.’ – student D
>
> ‘Together as a team we marked and trimmed the bamboo lengths and tried to divide the whole fabrication into two parts (the column and the skylight). I was responsible for helping the skylight

part, but it was not smooth in the beginning as we went too fast and connected too many intersections. In the end, we were too confused and had to redo. It was a challenge later, even with a 1:5 model. We got difficulties merging the parts together because of the height and numbering problem.' – student T

'Although I know I would not be selected by the designer, I became more confident and wanted to make more contributions to the team. So I designed a series of simulations in the computer based on Lonhin's modeling file for more selections.' – student F

'I extrapolated the grid into 2D drawings for assembly and mainly assisted to build the scale model.' – student P

2.2.2 Lesson Learned

Using the same materials as in the first cycle, errors experienced in the first cycle could be avoided in the second, with new teammates' experience made the second cycle smoother than the previous one.

'I had ensured that the bamboo strips we used still contained enough moisture and bend well' [failed working out in the first cycle] – student D

'The failure in the first stage gave me a lot of lessons for the later process. I found a method to build the column rapidly.' – student F

'To prevent grid distortion [happened in cycle 1], we tried fewer anchor points with curve pull, and trimmed the ground part for grids that distorted the most and tried to tune the same rest length in the script. In Round 2, things went smoother as we had shared the lesson from failure with new teammates.' – student T

2.3 Creating a 1:1 Construction in the Third Cycle

All students worked together to implement the final design proposal. Construction detailing needed to be developed and tested through small-scale prototypes. Implementation strategies needed to be tried, coordinated, and realized. In the third cycle, students were set to construct a large-scale physical model to demonstrate the appropriate application of the selected tectonic systems, amplify its potential and incorporate its limitations. Instead of using bamboo sticks, new materials were used including PVC pipes with a different degrees of tensile strength to fit between joints, together with an estimate of how the whole structure might be created and mounted on a plywood base so that the full-scale construction could stand exposed to the weather on the rooftop of the School of Architecture. During the final review, the entire process and the end product were comprehensively presented. The team of eight was split into two sub-teams at the initial stage; one team was responsible for digital rhino modelling and documentation, and the second team took charge of material sourcing, design and testing. Nevertheless, the full-scale construction required more human resources and time to construct, and new materials and scale presented new challenges and unanticipated errors.

2.3.1 Role Shifting

After two rounds of competition, team members might have experienced different roles. However, the team process differed from the two cycles. Initially two sub-teams were formed to prepare for full-scale production.

'I was also responsible for searching for materials and ordering PVC pipes, screws, plywood board, zip ties and various tools fast in order to quickly test the trial design details…responsible for fixing the pipes with the base according to the anchor point markings…took role to do the documentation and drawings preparation…selecting the most representative photos and editing them through Photoshop.' – student D

'The third cycle brought me so many troubles during the computational process to come up with an ideal form for the bending-active shell structure for building on the roof, and I prepared the digital fabrication files, like the numbering and the length of the pipes, the wooden baseplate and the fixing point.' – student R

'I was in the sub-team for sourcing materials and testing initially. Later I was involved in digital documentation, including photo and video-taking and editing...kept track of all expenses.' – student P

2.3.2 More Errors

After two cycles of applying digital design and fabrication and making smaller-scale prototypes in the indoor environment, new challenges emerged because the materials used, ways of connection between materials and making anchors were all different.

> ‘At the beginning, we suffered from the different rest length of each grid, and the shape of the model is out of control.’ – student R
>
> ‘Some material was bad quality or did not fit our use…the PVC pipes ordered were slightly thinner than the original ones, weaker in strength so more easily broken after we bent them and easier to collapse after exposure to sunlight.’ – student D
>
> ‘We ordered the rubber rings and iron nails from the internet for cheaper cost. However, the size of inner radius written in the description was a bit smaller than our original sample.’ – student P
>
> ‘Not all of us were present in the briefing for the tasks when we figured out ways to number the tubes. Sometimes, the tubes were marked wrongly, with confusing starting points adding to the construction time to cut the zip ties and shift the grids again.’ – student T
>
> ‘In the process of assembling the skylight part, we didn’t check the connection carefully enough and found a lot of joints were connected incorrectly. Hence we spent extra time in redoing the skylight part.’ – student O
>
> ‘We made wrong calculations of the numbers for grid distance, wrong measurements of extensions at end points, wrong counts of the numbers of rubber rings, and loss of marking traces when moving the rubber rings to expected spots. All these issues showed up.’ - student W

2.3.3 Testing and Fixing

In preparing for the full-scale construction with new materials and methods of connecting pipes and the plywood base, testing with software and the actual materials was needed beforehand.

> ‘The pulling force was too much for the Kangaroo to keep the rest length remaining the same, and the whole model distorted. In order to solve this problem, we extended the flat grid to a larger one and reduced the number of pulling forces for it. It turned out to be a pretty good result.’ – student R
>
> ‘We tested the connection details for 1:1 construction, including the connection joints between pipe and wood base, pipe-to-pipe joints, a fixing method for the wood base to the ground on site.’ – student O
>
> ‘I offered a proposal that we can try to heat the pipe until it was soft and then quickly connect another pipe with it…It took several minutes to get some typical failures. Gradually I found the principle and tested the connection at three scales: the connection only, pipes of short length and pipes of full length. I was responsible to connecting pipes and repairing the broken pipe connections with heat. Then I tried to use the rainspout to fix the iron wire, and it succeeded.’ – student F
>
> ‘Before we built the scale model, we also built part of the column at full scale to test the pipes…After that, we did some mock-up and tested the feasibility of the connection details. Although the ground-fixing method seemed to work, the professor suggested a better solution. After more testing, we decided to adopt his solution.’ – student P
>
> ‘Quality of the pipes was not as good as our original sample. As we screwed at the overlapping part, the holes became the weak point and broke easily. Therefore, we bought PVC glue and solved the problem…. We did not prepare the edge profile pipe to the length measured with the intersection points in the digital model. We broke the bundle in half to form two arches for better and more stable support of the edge.’ – student P

2.3.4 Unfolding Challenges

Although tests were conducted, mounting different materials required much more planning and coordination.

> ‘The most difficult part was erecting the column at the beginning of construction. After forming the grid and then a loop, we had to hang the column down from one storey above and opened up the pipes like a flower. After we popped the structure up, it was difficult for us to work on the highest point of the edge.’ – student P
>
> ‘We ran out of screws and zip ties during the assembly process.’ – student O

> 'The pop-up process was the most difficult stage as we did not expect that the form would turn out to be this floppy. Pipes we chose were heavy and yet not stiff enough to support themselves. We tried diagonal wires, cables and boundary outlines to stiffen the opening of the structure, but results were not satisfactory. Since the stiffness I applied in Kangaroo simulation was high, the pipe material system did not fit in as well as bamboo did in previous models. Pipes were more fragile than we had expected, and we were certainly not aware of how they might react when exposed to strong sunlight and sudden rains. I think lack of testing the new material is another reason that the structure ended up being floppy' – student W

3. DISCUSSION

The course aimed to engage students through critically investigating and evaluating theoretical concepts and drivers behind evolving architectural design while tackling novel situations and ill-defined problems. The three-cycle project presented different challenges, including software to generate geometric solutions, do experiments with materials, calculate the cost of production, build a full-scale model and take and edit video footage of the production process. The iteration process enabled students to work in teams and experience the principles of modelling (both computational and physical) at different scales to iteratively develop and transform a medium into large-scale intervention.

It was characteristic that mutually agreed roles were taken up by different teammates in the three cycles. These students readily took up leadership, support, design, sourcing, documentation and workmanship roles in different cycles. Higher student learning efficiency can be manifested because there are opportunities for students to discuss and share knowledge and experiences (Ruengtam, 2013). During the process, students were working hard to learn about the potential and strengths of themselves and their teammates for each specific role. Each member performed varied roles in different cycles while functioning effectively and efficiently to construct a full-size model. They needed to perform as a team rather than as smart individuals.

This trial-and-error method was the common strategy used in solving problems. Throughout the process, students made different kinds of mistake and varied attempts to look for solutions. They learned either by themselves, or from advice by peers, technical staff and the professor, as indicated in their reflections, and during the peer-group comments in each cycle of presentation. However, the third cycle seemed to present most challenges to the whole team, from sourcing materials and testing connections to the process of mounting and reinforcing the edge. They should have conducted more material testing, because the weight and flexibility of the pipes were so different from bamboo sticks. Eventually, they can train to think like architects constructing real-size projects through the reality-based studio as a chance to experience a kind of apprenticeship to their future professional life (Tokman and Yamacli, 2007).

4. CONCLUSION

Dynamic processes in studio are the cornerstone of architectural education. Instead of working independently or each team competes with one another, students are explored through teamwork as new ways to represent architectural concepts verbally, graphically and by means of physical models. This requires a high level of careful planning, implementation and modification to make every step accurate and complete to achieve final success in the team project collectively. The iteration process can surely be replicable in different disciplines as team projects. Students can be actively engaged when working in pairs and scaling up to four and eight as a team with a component of competition. However, the final project needs to be designed in such a way that every member can fairly contribute to different aspects. The collective learning experience aims to build a range of essential skills for being future architects, because their next task is to work on individual project. This study, based as it is on a master program with eight students, worked well with mature students who already knew each other well and could thus work collaboratively as a team. Further research can be made on professional competence and practices through the iteration process in a design studio.

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