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Enhancing Students' Competency and Learning Experience in Structural Engineering through Collaborative Building Design Practices

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Abstract: The field of the built environment is evolving, whereby the involvement of a multi-disciplinary team in the project becomes necessary. Complexities of issues keep challenging the industry of Architecture, Engineering and Construction (AEC) and address the importance of skills in collaborative work to deliver a great building design. A building that is not only aesthetic but also durable, sturdy, sustainable, and has positive influences on the surroundings. That said, collaboration skills become essential for students in the field of AEC. Concerning this current need in the industry, it becomes necessary for the educators as well as the undergraduate programs, especially in the field of AEC, to facilitate the students with exposure to a multi-disciplinary environment, to enhance the readiness of their graduates in the industry. The current pandemic makes the efforts harder. This study presents a case study-based research on enhancing the competency and learning experience of students through an international and multi-disciplinary collaborative environment in the form of joint studio assignments involving students of architecture and civil engineering. Both qualitative and quantitative approaches through triangulation methodology were used in the study. Results showed that students could enhance their knowledge as well as their skill to collaborate, especially in the design process.

Keywords: joint studio; collaborative learning; architecture; structural engineering; collaborative design

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1. Introduction

Practically, students are generally exposed to the internal and silo learning environment within their field during their study [1,2]. In some study programs and countries, students in architecture are heavily given the principles of art and design; although they also learn about structural engineering, it is at the most basic level. Conversely, students in civil engineering are focused to learn the maths and physics of structures. It cannot be doubted that this practice may lead to conflict for the students as well as the graduates from both programs since they have limited knowledge of the substance and the thinking process. With the developing and emerging challenges in the field of the built environment, collaboration skills become vital.

The development of issues, needs, and technology in the industry always challenges graduates to enhance their skills to match and satisfy the demand. On the other side, the educators and study programs are also challenged to support their students with the proper and suitable facilities to produce high demand graduates with a full skillset that satisfies the necessities in the industry. High competence in collaborative works is essential to produce a common goal [3], which is integrating the aspects of aesthetics with safety, reliability, and performance in a building design. Despite the utilisation of Building Information Modelling (BIM) to technically facilitate the multi-disciplinary design process, collaboration skills appear as essential factors to support the making of the best building design [4]. Thus, facilitating students to enhance their collaboration skills becomes necessary [5,6].

Some approaches are proposed as solutions to enhancing the competency of students, such as internship programs [7] as well as lecture exchange, students exchange, scholar exchange, and research exchange activities [8]. Each program has pros and cons, whereby the main issue that is frequently faced by the undergraduate study programs is the responsibility to find suitable spots for students that can enhance the desired competencies as well as satisfy course learning outcome (CLO) at the same time. Uncertainty in the current pandemic also becomes another major obstacle to providing a better facility for students, especially for large-sized classes [9]. Virtual joint studio assignment is one of the applicable solutions [10], which can be flexibly parked under suitable weekly topics inside the courses. Furthermore, it will be more convenient to be implemented for multi-disciplinary students with different backgrounds. For example, in the built environment field of study, students in architecture, civil engineering, and environmental engineering can be put together in one assignment to design a building.

The course coordinators can design the questions to satisfy the necessary competency of each program that is involved. In this case, students are simulated with the actual condition in the AEC industry, where they need to collaborate to develop a building design. Students will be able to enhance their skills in communication, negotiation, group decision making, and other soft skills that support collaboration. In addition, students are also imposed to enhance their skills in the virtual collaboration process. This study aims to investigate the role of virtual joint studio assignments in enhancing the competency of students in architecture with structural engineering and materials durability, also the competency of students in civil engineering with the design concept and process. In addition, this study also investigates the learning experience of students from different fields of study, universities, as well as nationalities to improve their competency of collaboration skills. Triangulation methodology was applied by combining both qualitative and quantitative approaches sequentially and simultaneously.

2. Conceptual Framework

Reviews of previous studies that are related to strategies to enhance students' competency, factors that support virtual joint studio, as well as collaborative learning were performed to develop the conceptual framework.

2.1. Competency Enhancement Strategies

Students in architectural education are exposed to a highly stressful learning environment since they have an intensive schedule of design studios and lecture courses every semester. These lead to long hours of learning periods with a huge workload on assignments. In addition, it is also found that one of the causes of stress is academic inadequacy [11]. Architecture students who have a deficiency of knowledge in material and structural engineering tend to play safe and produce unattractive/artless designs, which will generate an unfavourable score in the evaluation. According to this matter, Sgambi et al. [12] and Lam et al. [13] concluded that an active teaching strategy is very important to be implemented in architecture, especially for improving the competency of students through technical-based courses, such as structural engineering. Herr [14] conducted observation research in the practices and academia in China and found that education that facilitates the cross-disciplinary collaboration of architecture and civil (structural) engineering students is important for the next generation. In line with this, Iulo [15] also found that interaction among many disciplines is necessary for educating future architects in the United States of America. The importance of collaborative team-based learning for architectural education is also highlighted by [16,17]. The result of collaborative design may prevent failures in architectural design, especially in the principles of structure and the responses to disaster [18]. Table 1 shows the summary of strategies to enhance the students' competency and learning experience.

Table 1. Strategies to enhance students' competency and learning experience.

Strategies to Enhance the Students' Competency	Justifications	Sources
Active learning strategy	To put students in a real situation, which is a collaborative design process in construction, will effectively enhance the learning process.	[12,13]
Cross-disciplinary collaboration	To engage students to achieve one common goal in a diverse environment, in such a way, that everyone can learn from the communications, the construction of ideas/alternatives, and also the decision-making process.	[14,15]
Team-based learning	To facilitate the learning process of students with complex issues, where students have to collaborate with others to find possible solutions.	[16]
Interaction in a multi-discipline environment	To equip students with experiences in a knowledge exchange environment to enhance competency.	[17]

2.2. Virtual Joint Studio

The studio-based class can be found in all architecture programs, and it is designed to facilitate students in gaining competencies in design. Physically, it is usually equipped with drafting tables and computers where students are required to be in this class for half-day and twice a week to develop their design according to the given project's questions. Project and case-based learning are implemented in this studio-based class. The COVID-19 outbreak and the ongoing pandemic are challenging all architecture programs to conduct the studio classes virtually, which is not an easy practice [19]. Megahed and Hassan [20] proposed blended learning strategies for online studios in Architecture. Aside from the emersion of doubts from academics about the effectiveness of online or virtual classes, Wooten [21] highlighted online activities have the capability to enhance the learning process of students.

Kulal and Nayak [22] stated that achieving effectiveness in online classes is very challenging, but Ceylan et al. [23] and Shahriar et al. [24] found that the effectiveness can be achieved with facilities as well as the technology literacy of students. Moreover, on the technological support, the provision of the AR/VR model enhances the communication and the online studio [25,26]. In addition to supporting the technological factors, skills in architectural design communication, such as the ability to utilise effective communication through proper selection of language, handcrafts, and also sketches or technical drawings, are also vital in conducting successful online engagement [27,28]. Communication is one of the social skills that intensifies the efficacy of online studios [29]. In different circumstances, the effectiveness of online studios can be supported by integrating the studio class with the technologically based courses [10,16].

Other factors that can have positive influences in online classes are attitude, motivation, and training [30]. Chakraborty and Nafukho [31] also concluded primary factors for online engagement that are creating and maintaining a positive learning environment, building a learning community, promptly giving consistent feedback, and utilising the right technology to deliver the right content. These supporting factors appeared as results of the fundamental requirements in developing impactful engagements; thus, the facilitators need to have structured instruction for both the project and learning process [32]. Table 2 presents the factors supporting virtual joint studios.

Table 2. Factors supporting virtual joint studio.

Factors Supporting Virtual Joint Studio	Justifications	Sources
Blended learning strategy	To utilise mixed approaches and platforms to increase the engagement of students with the learning process, especially in the virtual and collaborative manners.	[20]
Microlearning strategy	• To divide big class (huge number of students) into small/micro-groups. • To prepare specific or micro contents.	[33]
Technology	The effectiveness of the virtual joint studio can be achieved through: • Strengthen the literacy of technology. • The utilisation of technology-based communication.	[23–26,28]
Communication	Technical communication: • Use impactful language (specific/technical terminologies may appear during the communication). • Communicate ideas through sketches, drawings, and 3D mock-ups (handcrafts). • Social communication: • Motivation. • Positive environment. • Clear, supporting, and consistent feedback. Other supporting factors: • Structured instructions. • Training.	[27,30–32,34]

2.3. Collaborative Learning and Collaboration Skills

The AEC industry is still suffering from successful integration between multi-discipline, although already started to utilise BIM [35]. Collaborative-based learning enhances the experiences of students/graduates to integrate with other disciplines [36]. Collaborative learning is an effective learning activity that facilitates students to learn both the context of material and social aspects [37]. Collaboration across cultures may enhance the learning process of professional collaboration [38]. AL-Rawahi et al. [39] demonstrated that an international setting in virtual collaborative project-based learning leads to a positive impact on students' competencies, especially in their communication skills. Table 3 presents the summary of the importance of collaborative learning.

Collaborative learning is capable of easing the knowledge-building and intensifying the interactions and participation of students, especially in the virtual environment [40]. The essential of collaboration skills and collaborative learning in higher education cannot be doubted. Wieser and Seeler [41] noticed that higher education is still facing difficulties in finding the best practice to facilitate collaborative learning. It is quite challenging to construct a platform for students to collaborate that reduces any feelings of social isolation, furthermore in the online environment. While it is not the easiest nor the fastest approach, the self-directed work team can have a positive impact on the result of collaborative learning [42].

Table 3. The importance of collaborative learning.

The Importance	Sources
• To gain new perspective and knowledge through a wide-scale learning experience setting.	[36,40]
• To enhance knowledge building by strengthening the interactions and participation of students.	[36,40]
• To improve the effectiveness in facilitating the learning process of context and social aspect.	[37]
• To gain a new soft skill, which is collaboration across cultures, especially in the international setting.	[38,39]

3. Methodology

Figure 1 illustrates the research flow with the details of the strategies on approaches used for attaining and analysing the data. A case study is used as a strategy for the research, and triangulation is applied as the methodology in the research that comprises both qualitative and quantitative approaches sequentially and simultaneously. The research was started with the development of a conceptual research framework through grounded theory. Through the grounded theory, the conceptual framework of this research was formed by simultaneously synthesising the data gained from the observation of empirical conditions and findings from the literature review. Data of empirical conditions, including the combined CLOs and also the technical and social competencies that are needed to be achieved, are constructed. The literature review was conducted to find and formulate the key factors and strategies to be used to build the research variables and materials. The results of the grounded theory are presented in Tables 1–3. Furthermore, the conceptual framework is used as a foundation to establish the research materials and equipment through focus group discussion to be tested in a case in the form of a joint studio assignment. In order to strengthen the result of the study, the research continued with a quantitative approach to study the experience of the students during the joint studio. Lastly, the results were then validated qualitatively through focus group discussion.

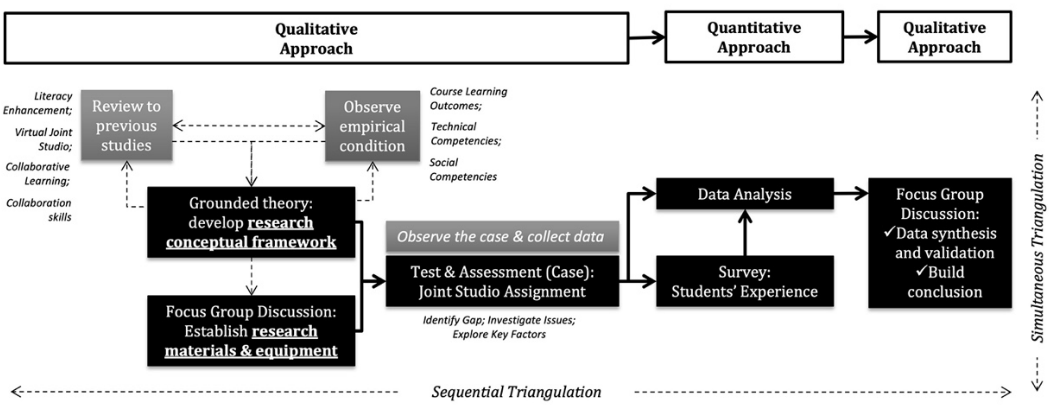

Figure 1. Illustration of research methodology and flow.

3.1. Sample of the Study

The joint studio assignment involved students from different programs and universities across countries. In order to enhance the competency of material and structural engineering, students of architecture who were in their first year and taking the course of principles of structure were facilitated to learn the materials in a collaborative learning setting with students of civil engineering who were in their second year and taking the course of civil engineering materials. Students from both courses are merged and grouped into 9 groups. In total, there are 110 undergraduate students from two different universities and programs across the country, which are from Indonesia and Malaysia, involved in the study. The students were grouped into 9 groups, where each group consisted of students of architecture and civil engineering. Nine senior students from architecture were also involved to respectively assist the collaboration process between students in each group to finish the assignment. The senior students were in their second or third years and already had experience and passed with excellent score (A/A−) on a similar course in their first year. Although the seniors already have experience, they also were briefed a few weeks prior to the joint assignment starting. The briefing did not only contain technical matters on the necessary knowledge and information about the assignment but also social matters related to characteristics, cultures, behaviours, and the collaboration model of the students. The joint studio assignment was facilitated by five lecturers from both universities with expertise in architectural design, structure, construction materials and construction management.

3.2. Research Materials and Equipment

Strategies as a result of grounded theory are presented in Table 4. In order to enhance the competency and learning experience of students, it is necessary to involve students with different programs and universities in an international manner, which is also involving different countries. The details of students, courses, and programs for the virtual joint studio are presented in Table 5. To better gain the benefits, the joint studio assignment was conducted towards the end of the class/semester, whereby students had already matured with their understanding of the materials inside the class they were taking, respectively. Both departments have different duration of study in each semester. Students of architecture have 16 weeks of learning time before final exam, while students of civil engineering have 12 weeks of learning time. This made the joint studio assignment cannot be executed in a similar week, but all students experienced it towards the end of the semester.

Table 4. Strategies for the implementation of joint studio assignment.

Goals	Necessities	Strategies/Solutions (Material/Equipment to Be Provided)
• Enhance the technical competencies: knowledge of students in structure, materials, and design. • Enhance the social competencies: collaboration skills.	• Cross-disciplinary collaboration. • Team-based learning. • Multi-discipline environment.	• Involving students from different programs and different universities across countries, which have suitable CLOs to be achieved in the assignment. • Suitable blended CLOs. • Enhancing the maturity of the students' knowledge (prepare students to be ready for collaborative learning).
• Enhance the virtual collaborative learning experience.	• Blended learning. • Active learning. • Active interaction • Technical and social communication. • Microlearning. • Positive environment. • Feedbacks and motivation.	
	• Readiness of students with technology and materials.	• Training. • The assignment was given towards the end of the semester. • The details were given one week before the joint studio was rolled.

Table 5. Details of program, participants, schedule, and CLO.

Program	Details of Students	Schedule and CLOs
Undergraduate Program in Architecture. Location of Campus: Yogyakarta Indonesia.	• Origin of students: Indonesia. • Class level: 1. First-year first semester. 2. Nine students are seniors (second and third year), as students' buddies, assisting the collaborate-on process inside each group.	• Schedule of the joint studio assignment in class: Week 14–15 • Course: Principles of Structure. • CLOs in the joint studio assignment: 1. Demonstrate the principles of stability in the structure. 2. Recognise the impacts of forces, loads, and moments on structural systems of elements. 3. Analyse and compare the characteristics and performance of materials in supporting the structural integrity of a design.
Undergraduate Program in Civil and Environmental Engineering. Location of Campus: Perak Darul Ridzuan, Malaysia.	• Origin of students: Malaysia, Kenya, Indonesia. • Class level: Second-year first semester.	• Schedule of the joint studio assignment in class: Week 11–12. • Course: Civil Engineering Materials • CLOs in the joint studio assignment: 1. Explain the nature and performance of civil engineering materials. 2. Identify the strength and durability characteristics of concrete, asphalt, timber, and steel.

Based on reviews of previous studies as well as the grounded theory that has been carried out, there are some concerns to be used as fundamental in developing strategies to better facilitate virtual collaborative learning, as formulated in Table 4. As for the strategies, the facilitators prepared guided open-ended questions that are related to the blended CLO, a rubric of evaluation, and also supporting systems and instruction. The question is presented in Figure 2, and the rubric of evaluation is presented in Table 6. Each design/result was evaluated based on three main criteria, which are aesthetic and structural stability, analysis of the durability of materials, and presentation of results. The design needs to be aesthetic and satisfy the structural stability that is shown by its resistance of the form/design to the given loads on certain tests. The design also needs to consider the durability of materials that is shown through the analysis of weather resistance, compliance to the environment, as well as its resistance to possible loads. For the presentation, each group must concisely present their design and analysis within the given duration of a maximum of 3 min. It may harm the whole session of evaluation if the presentation is more than 3 min.

Table 6. Rubric of evaluation.

Program	Evaluation		
	Poor	Acceptable	Excellent
A. Design: Attractiveness, stability, and durability (40%)	• Unsafe and unattractive design/model that is also not in compliance with the environment. • The model is unable to safely stand.	• Safe and acceptable design/model that is not in compliance with the environment. • The model can safely stand before being given some tests.	• Creative and attractive design that also considers and satisfies the criteria of safety, stability, and durability. • Follow the requirement. • The model perfectly stood out and successfully passed some tests.

Table 6. *Cont.*

Program	Evaluation		
	Poor	Acceptable	Excellent
B. Selection and conceptual analysis of the designs and materials (30%)	Insufficient conceptual analysis for the designs and materials and not supported with references.	Sufficient conceptual analysis for the designs and materials and loosely supported by references.	Excellent conceptual analysis for the designs and materials supported by references.
C. Presentation (30%)	• Sloppy contents and difficult to be recognised. • The duration is 3 min or less. • Lack of necessary sketches, explanations, and photos.	• Good content and easy to be recognised. • The duration is 3 min or less. • Presented with sufficient sketches and supported with a good 3D model (mock-up).	• Excellent and attractive presentation with great impacts for building the understanding of the audience. • The duration is 3 min or less. • Excellently presented with excellent and complete sketches/drawings and supported with an excellent 3D model (mock-up).

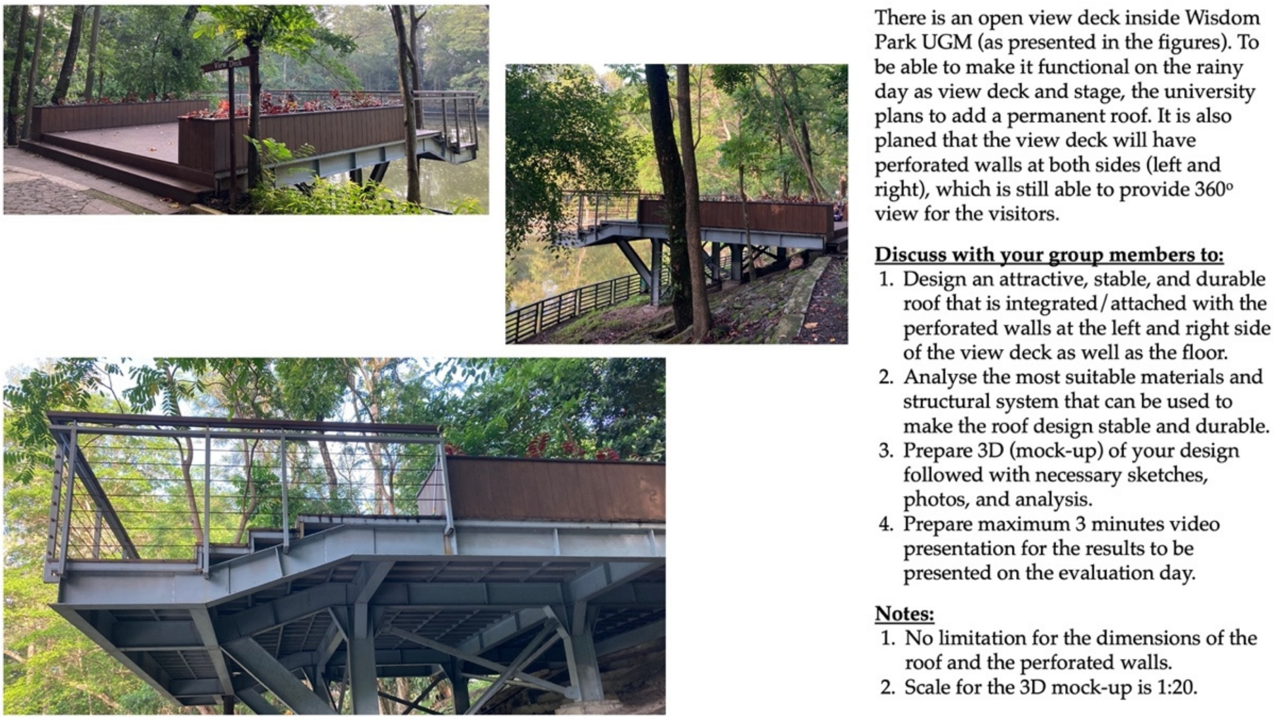

Figure 2. Questions of The Joint Studio Assignment.

4. Result and Discussion

The joint studio assignment was broken down into two sessions. The first session is the workshop, and the second session is the presentation and evaluation. The second session was set to be passing the weekend; thus, the students could continue the work on the assignment over the weekend before evaluation. Based on the question, students are required to design a roof for a viewing deck. On the design requirements, the roof should perform well the value of aesthetic, structural integrity, and durability. To demonstrate the achievement of the requirements, students must integrate their knowledge and capability into the required design. Furthermore, they need to turn the design into a mock-up for the visualisation of the three-dimensional design and the structural testing. As a complement, students were also required to prepare supporting drawings and analyses of the design.

Several platforms were used for the collaboration. Students used hand sketches, SketchUp, and Google Docs for the technical communication that included drawings, references, and analysis. For the discussion and social communication, students were equipped with WhatsApp group, zoom, and Google Meet. The WhatsApp groups were developed a few days before the workshop started with the intention of ice-breaking and introduction. Students introduced each other through the platform. During this period, students were building perceptions of the environment they would need to deal with. This moment will ease the collaboration process on day one, and it expedites the grouping process [43].

4.1. Activities on Day One: The Workshop

The workshop was conducted on the first day for 4 h. All students collaborated with their colleagues inside the group to start creating the design by following the guidance and instructions given, as proposed by [44] on the importance of structured instructions in collaborative learning. It has been demonstrated that clear and structured instruction supports the effectiveness and efficiency of virtual collaboration. Both were achieved by the support of the arrangement of specific contents and microlearning groups [33]. The workshop started with an opening, briefing and explanation of the assignment, then followed the workshop. The micro-groups completed their workshop inside their virtual room (breakout rooms provided), respectively. The students' buddies become the timekeeper and assist their members inside the group by following the instruction as well. Since the students were still in their first and second years, they had not been explained with design phases yet; thus, the structured activities and instructions were vital to guide them with the intention that students would practice learning by performing the multi-discipline design process. The activities inside the micro-groups are presented in Table 7.

Table 7. Research findings and details of activities.

<table>
<tr><th colspan="4">During the Workshop (Utilised Virtual Meeting Platform)</th></tr>
<tr><th>Activity</th><th>Duration</th><th>Purpose</th><th>Findings</th></tr>
<tr><td>1. Introducing members in the group</td><td>15 min</td><td>To determine the group's norm.</td><td rowspan="6">Some factors supporting collaboration:
• The role of facilitators and buddies.
• Clear and structured instructions.
• Motivations.
• Literacy in utilising the technology.
• Ability to communicate technically and socially.
• Readiness and maturity on the contents (materials).</td></tr>
<tr><td>2. Explaining questions and conducting a desktop study</td><td>30–40 min</td><td>To find case studies and inspirations for the design.</td></tr>
<tr><td>3. Brainstorming</td><td>45–60 min</td><td>• Discussing findings and possible/potential solutions/design.
• Developing alternatives.</td></tr>
<tr><td>4. Concluding</td><td>30–40 min</td><td>Discussion to select the best possible alternative for the design.</td></tr>
<tr><td>5. Coordinating</td><td>15 min</td><td>Distributing tasks among members in the group for the presentation packs.</td></tr>
<tr><td>6. Closing</td><td>Remaining time</td><td>• Preparation of the presentation, theme, etc.
• Mingle session.</td></tr>
</table>

Table 7. *Cont.*

Outside the Workshop (Utilised Messaging App)			
Activity	**Duration**	**Purpose**	**Findings**
1. Reporting progress	60–120 min	To check the progress that has been performed by each member.	Some factors supporting collaboration: • The role of facilitators and buddies. • Motivation. • Technical and technological literacy. • Social and technical communication.
2. Investigating and analysing design	60–120 min	• To test and analyse the design. • To solve in case issues were found.	

Figure 3 presents the process of collaboration inside the micro-groups. Students collaboratively discover the issue, investigate and criticise possible/potential solutions, analyse and develop a suitable design, and finally propose the most suitable design as the solution. During the workshop, students utilised a virtual whiteboard to sketch their idea, shared photos/pictures and used annotation tools. Some groups also tried to build their digital model using SketchUp. During the 4 h workshop, students demonstrated the form-finding of suitable design that satisfies the aspects of aesthetic, durability, and structural stability. They also finalised the basic/main idea for the design in the workshop.

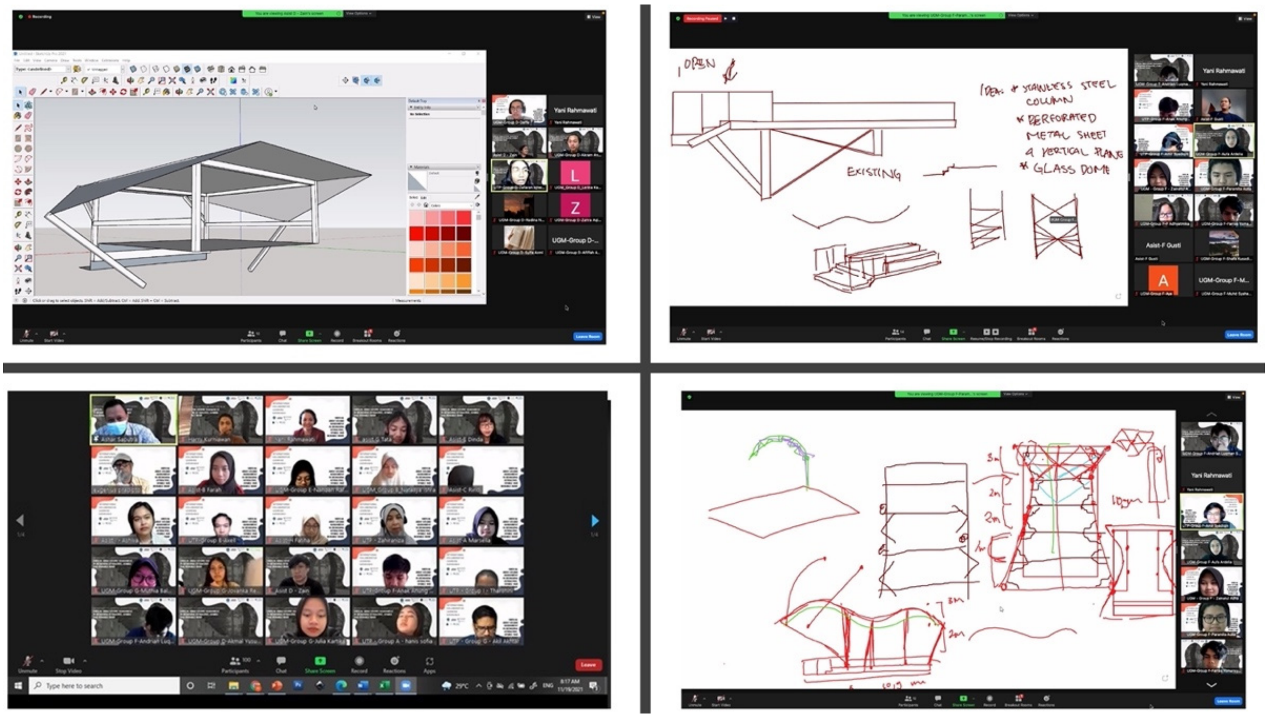

Figure 3. Photos of collaborative learning process during workshop on day one.

The details of the design, i.e., the structural analysis, structural stability tests, principles of aesthetic and durability, details of drawings, as well as a 3D mock-up, were performed outside the workshop (over the weekend). The communications were continued by using a messaging app (WhatsApp), as presented in Figure 4. All groups were required to submit their poster and video clip presenting the result one day prior to the presentation and evaluation. It was found that the role of Buddies in the activities outside the workshop was also necessary, whereby they motivated the members and facilitated the supportive social environment inside the micro-groups. Thus, it is necessary to train and brief the buddies to prepare them before the activities start, as suggested by [30,34].

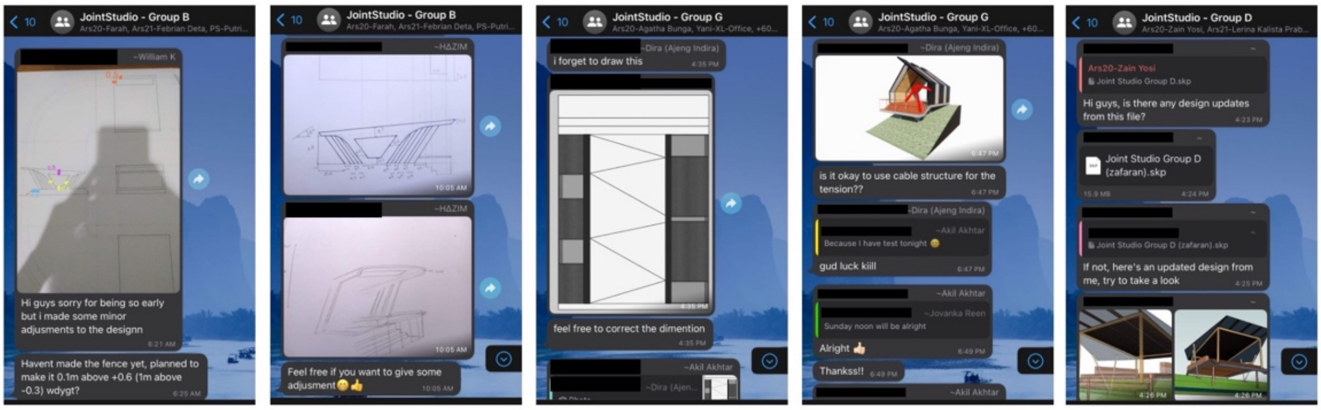

Figure 4. Photos of collaborative learning process outside the workshop.

During the workshop, it was also discovered that both students of architecture and civil engineering were able to gain new knowledge. Each group of students were willing to share their expertise or knowledge with their counterparts. During the form-finding in the design process, all students were able to learn the reasons behind the forms in their model as well as the selection of materials. It was also observed that with guidance and motivation, the positive dynamics of the groups were formed naturally and led to positive outcomes in enhancing the level of understanding of the students. In the beginning, each group needed time to outstretch the group performance; however, it did not take much time since all groups were guided and well prepared, as findings shared by [20]. Equip students with sufficient literacy [23] is also verified to be the supporting factor of the group performance; thus, the joint studio assignment was held toward the end of the semester. It is also confirmed that the technical capability of students can be enhanced by interactions in a multi-discipline environment [16,17] as well as cross-disciplinary collaboration [15].

In enhancing their technical capability, students performed well in the technical communication practices. They utilised sketches, illustrations, pictures, and mock-ups to communicate their ideas through virtual meeting platforms and a messaging app. Both groups of students also have the capability of delivering their idea in simple language manners using simple/general terminologies. Here, this study also verified suggestions from [24,27]. During the practice, some groups indeed need the facilitators to fill the gap in the technical communication since the students usually use different technical terminologies. Despite the enhancement of technical capability, students were also able to gain their soft skills in social communication. Students of civil engineering were also able to recognise how students of architecture work and communicate their idea, and vice versa, with the experiences gained by students of architecture. The environment of multi-disciplines and cultures can give insight into their future working environment.

4.2. Activities on Day Two: Presentation and Evaluation

It was investigated that feedback is crucial for the effectiveness of collaborative learning [31]; thus, the evaluation session was embedded inside the activity on day two. Each group presented the result of their collaborative work in developing the design and then continued with the evaluation by the facilitators. The facilitators are required to give feedback and correct it in case there are mistakes in the analysis or any other content in the presentation. All students/groups attended the session and followed the whole agenda on day two; therefore, they could learn from other members/groups as well. Figure 5 presents the photos of the presentation and evaluation on day two. All results are presented in Appendix A, and the scores are presented in Table 8.

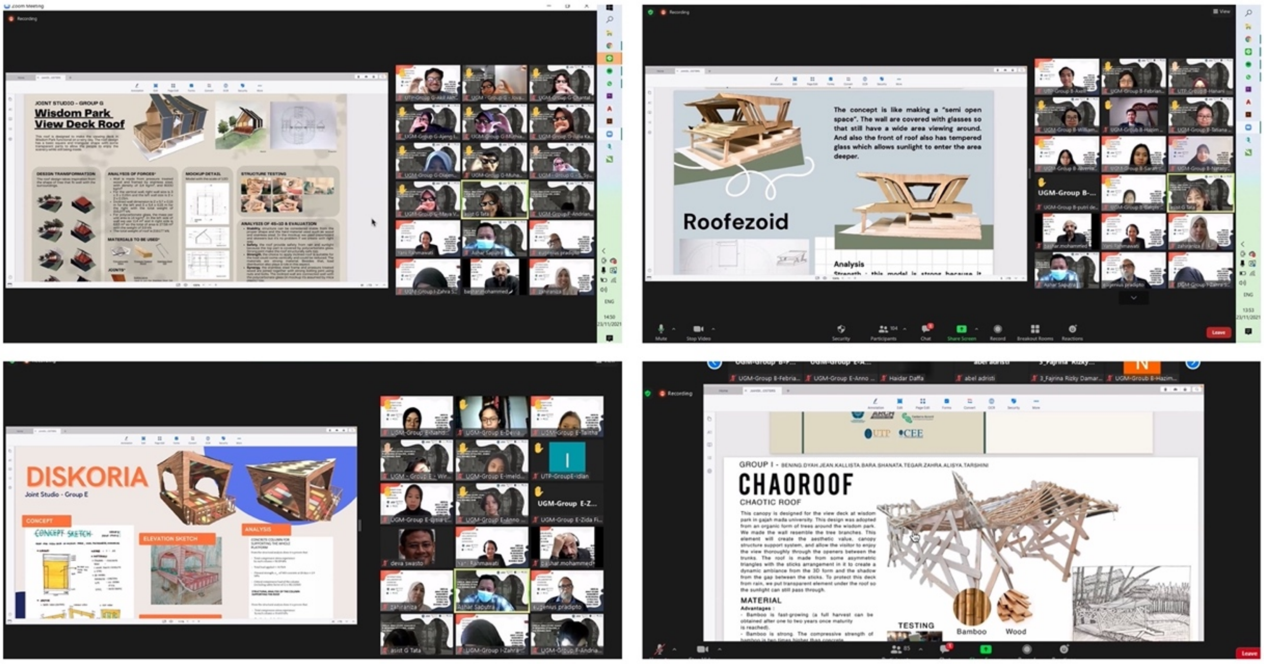

Figure 5. Photos of presentation and evaluation on day two.

Table 8. Research findings and details of activities.

Group	Scores				Notes
	Design (Architectural and Structural)	Analysis of Materials	Presentation	Total	
A	31. 67	21	26	78.67	The strength and stability of the scaled model do not represent the real condition.
B	31. 67	26	25. 33	83.00	The design is too structural and less aesthetic. Need more optimisation on both aspects, structural and architectural.
C	34	26	25	85.00	Appropriate material selection and the structural arches form
D	28.67	27. 33	23. 67	79.67	Need to put more lateral stability on the design.
E	32. 33	26	24	82.33	The material used for the wall is not clear.
F	35	24.67	26	85.67	Nice design. Has an issue with the detailing.
G	32. 67	25	23. 33	81.00	Has issue with roof stability.
H	35	23. 67	24	82.67	Too wide on roof support, the roof material will be difficult to be provided.
I	34. 67	25. 67	23	82.83	Has an issue with the detailing.

Based on the presentation by all groups and the evaluations, it can be concluded that the students were able to improve their knowledge and their social capability through the joint studio assignment. As [36,40] concluded, it is vital to expose students to collaborative learning to enhance their knowledge or technical competency effectively and efficiently. Students of architecture improve their basic understanding of structural stability and the durability of materials in a design, as well as students of civil engineering who enhance their skills in the implementation of structural systems as well as the use of durable construction materials in a design. The enhancement of technical capability can be observed from the results. Each group presented a design that considered the aesthetic, structural stability, as well as durability of materials. The presentation was strengthened with analysis and tests. Each student inside the group was able to learn collaboratively.

Despite the technical capability, the finding proposed by [37] is also confirmed in this study, which is the enhancement of social capability can be achieved through a collaborative learning setting. Apart from their technical capability becoming enhanced, the students also enhanced their social capability, whereby they were able to evolve themselves as individuals and as members of diverse groups. The individuals started to evolve themselves at the ice-breaking in forming the group. The ice-breaking continued and became stronger during the workshop on the first day. The collaborations evolved into the performing phase since all the groups were able to integrate their thoughts to find the solutions and decide the best alternative at the workshop. The performance of the evolving collaboration of each group was then continued outside the workshop until the evaluation day. On the evaluation day, it can be observed that students already know their role inside the group; thus, on the question-and-answer session, they were able to support each other in defending their results. Observing the limitation of time on the joint studio assignment as well as the time needed for every individual to reach the performing phase in the group, Haruna et al. [45] found that adding competition through a gamification system may expedite the grouping process. The competition may enhance the sense of belonging of individuals in the group, as well studied by [46,47]. As an improvement, the concept of competition or gamification can be added to the joint studio assignment.

4.3. The Learning Experiences

Questionnaires were distributed to all participants of the joint studio assignment to survey the experience of students for the collaborative learning process and the enhancement of their capability throughout all the provided activities. Figure 6 presents one of the results from the survey, which is the satisfaction of students with the event. It can be concluded that almost all students were satisfied with the event; this result is also strengthened by the result shown in Figure 7, showing students are excited to join a similar event to enhance their knowledge in a collaborative environment manner.

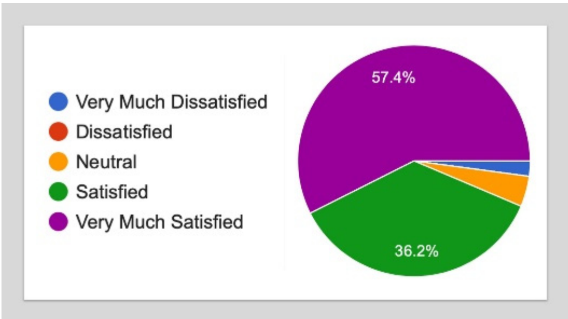

Figure 6. Satisfaction of students with the event.

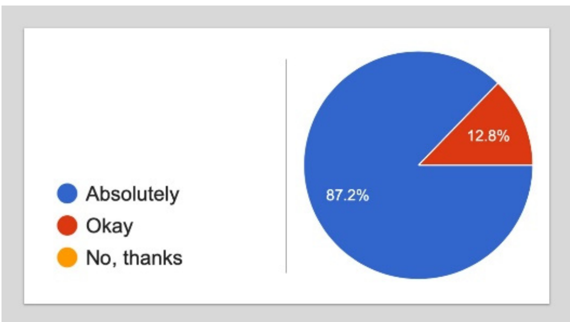

Figure 7. Willingness of students to join other similar event.

The main finding from this study with other similar previous studies [36,37,40] has been confirmed through the survey, and the result is presented in Figure 8. It can be concluded that, indeed, collaborative learning has a huge role in enhancing the competency of students, especially in cross-disciplines or multi-disciplines. Apart from the surprising results of the assignments, this finding is also strengthened by the result from the survey presented in Figure 9. It is found that students are aware of the benefits of the joint studio assignment in enhancing their technical capabilities in the application of the knowledge they have as well as the enhancement of the competency of structural engineering for students of architecture. It was also revealed that collaborative learning supports the enhancement of the students' social capability, especially in communication.

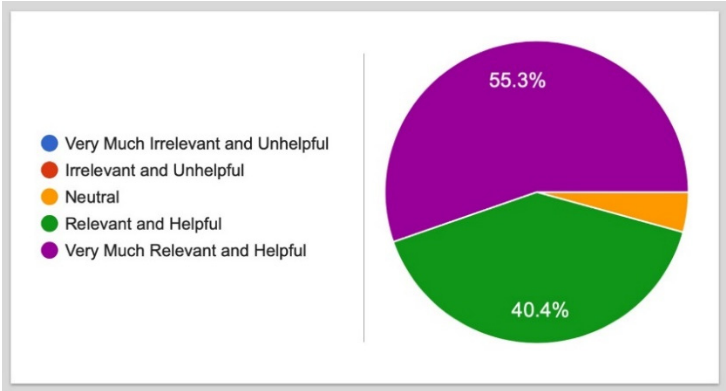

Figure 8. Relevancy and support of the event in enhancing the knowledge of students.

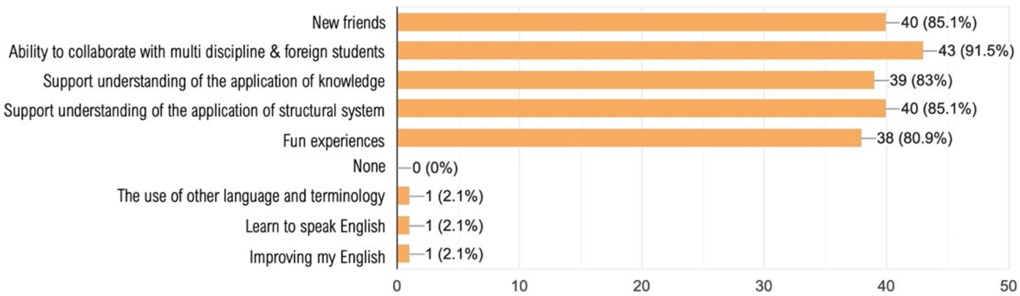

Figure 9. Benefits from joint studio assignment.

Through the survey, it can also be concluded that students were satisfied with the facilities provided for collaborative learning, as shown in Figure 10. The study was then continued with focus group discussion, where selected participants were involved in validating the result from the survey as well as from the observations during the event. From the interviews, it can be highlighted that students had fun and interesting experience in their learning process. They were able to learn how to integrate ideas into solutions, although some of the students faced difficulties at the beginning in communicating their ideas since the use of different terminologies and the need to achieve mutual understanding under different technical and social communication manners. The issue also has been highlighted by previous studies [44,48], especially in a multi-discipline environment in the AEC industry. It was also validated that all facilities provided in the event were beneficial to supporting the virtual collaborative learning process. One main factor suggested to be improved is the time-setting, where some students felt it was too short.

4.4. Retrospective: Challenges and Lessons Learned

Despite the findings revealed in Table 7, there were also challenges found during the implementation of the joint studio assignment. The brainstorming sessions ran smoothly because of the roles of the buddies and the facilitators. During that session, buddies and facilitators did not only observe the practices of presentations, discussions, negotiations, and the decision making by students in the group but also assisted when issues, glitches, or mistakes appeared. One of the issues was the different technical terminology used by students of both architecture and civil engineering on the architectural and structural elements. Although the students were independently able to explain by using their sketches or showing pictures, in some cases, it was found that some students struggled to deliver their idea since their counterparts could not understand. The facilitators interrupted to explain to both parties the meaning of the terminologies. The interruption became efficient to save students' limited time on developing alternatives for the design. This challenge and solution were also discussed by [49]. This finding leads to the improvement of the activity. As proposed by [30,34], training is necessary; thus, the facilitators need to train the buddies and students prior to the event. The facilitators can also introduce the terminologies in their lectures to enrich the students' vocabularies on constructions. The challenge may also appear because the activity involved students in their first and second year, whereby they have not explored yet the technical terms used by other disciplines.

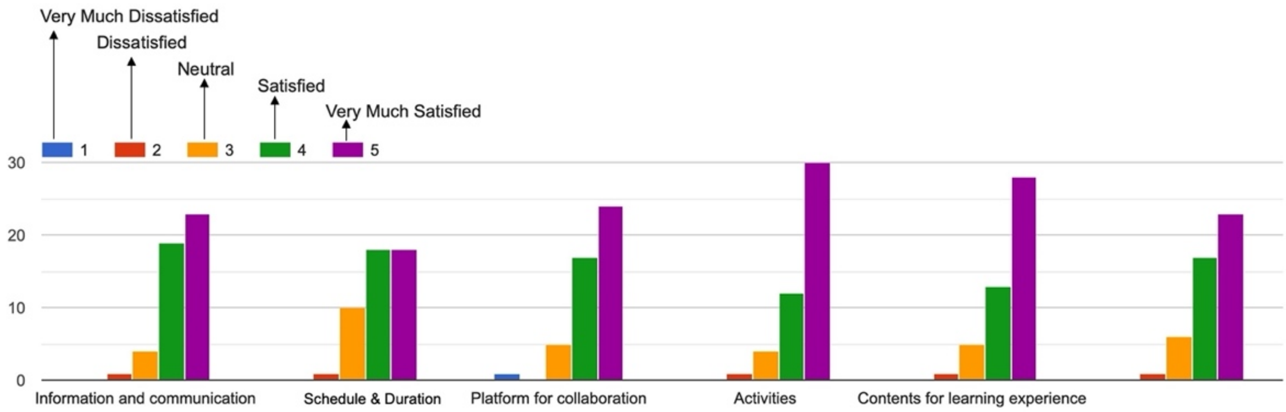

Figure 10. Satisfaction of students with the facilities.

The other challenge was the timing and schedule for the joint studio assignment. Based on data received, some students felt that the duration of one week with twice official virtual meetings through workshop and evaluation was too short. Although it was short, most of the students felt that the sessions were compendious and structured. Thus, within a short period, the students were able to complete their assignments and grasp the addressed experience and knowledge from the activities. The solution of providing structured instructions in the assignment was also proposed by [30,34]. Conceptually, the joint studio assignment was placed toward the end of the semester with the intention that all students were already given the basic knowledge; hence they would be able to apply their knowledge in the assignment. Practically, the timing also challenged the students since they also faced tests and submissions of assignments from other subjects/classes. Therefore, for the improvement, it is necessary to plan the timing and schedule of the activities by considering the general schedule of the students. Through their study, Wang et al. [50] revealed that intrinsic learning motivation and prosocial motivation are needed to gain better outcomes in the learning process of students. This finding was also found in the practice of joint studio assignment, whereby the motivation given by the facilitators and buddies kept the students' activities on track, especially for the ice-breaking session and the activities performed outside the workshop. Inside the messaging app, some groups were motivated by buddies and facilitators with greetings, asking about their feeling and how were the students doing, asking about the progress of the assignment, and sending examples of case studies related to the assignment. In other groups, students were able to actively discuss the assignment without the assistance of buddies and facilitators.

An interesting finding has been revealed by Bedon and Mattei [51] related to the role of facial expression or human reactions in enhancing the building design, especially in the selection of structural components and architectural design, as well as satisfying the criteria of human comfort. Throughout the joint studio assignment, the participants rarely considered the expression of their colleagues or counterpart in the decision making of a design. The effort on this was quite challenging since they all worked in a virtual environment within a short duration of the collaboration. Observing the importance of the human reaction and with the purpose to enhance the design, it is necessary to consider the related criteria to be facilitated in the future program, especially in providing the e-collaboration platforms that can capture and analyse the criteria. The criteria can also be embedded in the evaluation; thus, the students need to observe and understand well their colleagues/counterparts in making a design decision.

5. Conclusions

With the evolving need in the AEC industry on the complexities and the requirement of having the capability to work in a collaborative environment, collaborative learning through virtual joint assignment appears as one of the substantial approaches to prepare and facilitate students to cope with the industry's demand. The technical competency and the social capability of students are validated and can be achieved by engaging students with different backgrounds in a supportive environment manner. Structured instructions, motivations, roles of facilitators and buddies, training, and also capabilities in technical and social communication are found to be essential factors to carry out a successful collaborative learning experience for the students.

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Appendix A. Results of the Joint Studio Assignment

The compilation of the short video presentation can be watched through the link: ugm.id/JointStudioResult2021 (accessed on 1 March 2022).

Figure A1. Under the leaf.

Figure A2. Bambooring.

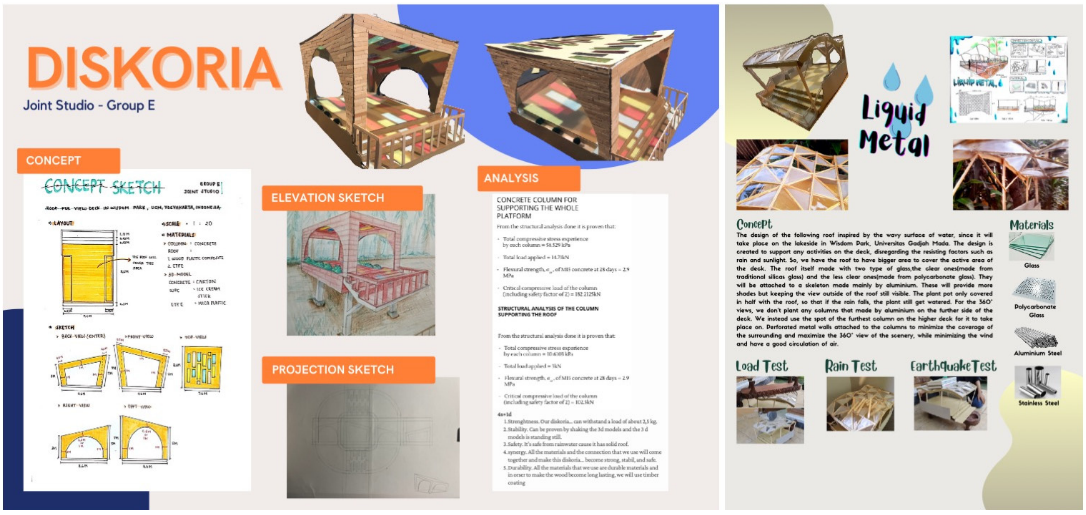

Figure A3. DISKORIA.

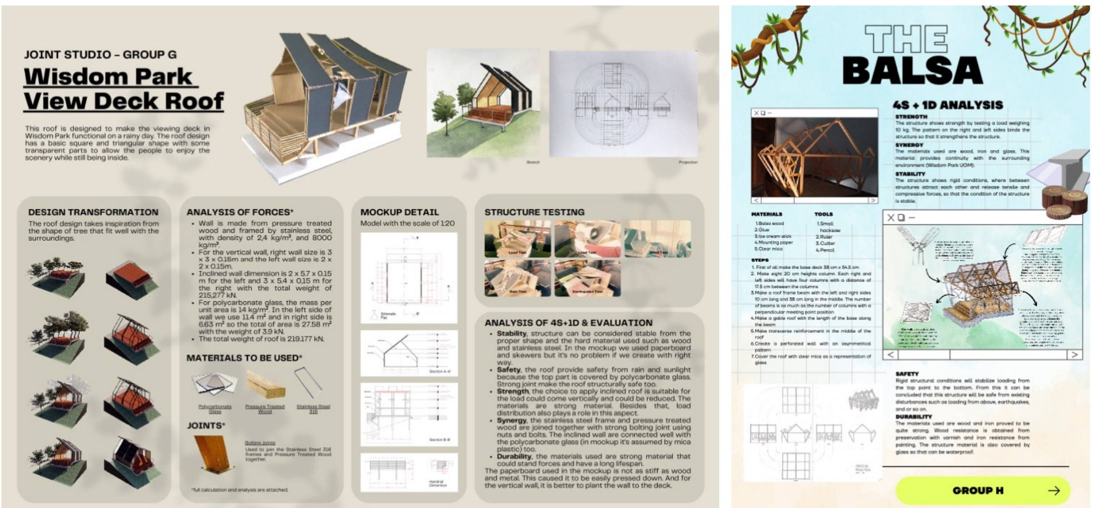

Figure A4. Deck roof.

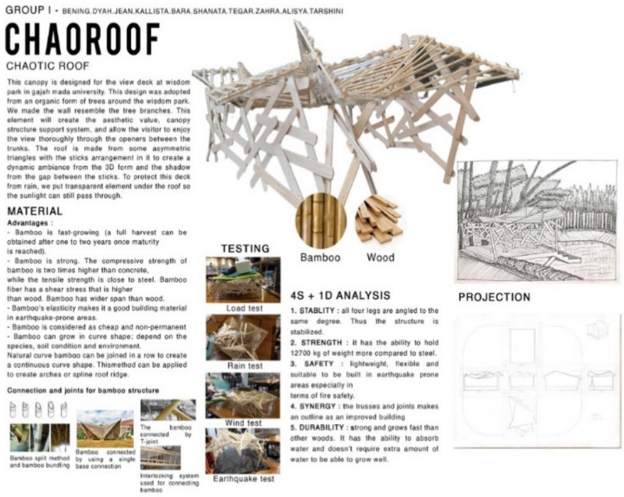

Figure A5. Chaoroof.

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