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Pavilions in Architecture Studio—Assessment of Design-Build Approach in Architecture Education

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Abstract: Pavilion construction projects are an emergent paradigm in architecture education. Nevertheless, their efficiency has not yet been assessed in terms of their added contribution to learning experience and pedagogical outcomes. This paper reviews the development, challenges and learning outcomes of the ‘Element Pavilion’ projects for Year One undergraduate architecture students and offers a quantitative and qualitative assessment over their impact on learning. A systematic analysis on students’ perceived learning outcomes using psychometric evaluation is presented here for the first time. The paper introduces a *hypothetical pavilion project pedagogy model* (HPPP model) which can be used and developed further by architects and educators. Analysis results and the model identify four aspects that students perceive as critical factors in pavilion design-build learning experience: construction, design process, engagement and participation, and teamwork.

Keywords: architecture pedagogy; design-build; design studio; teaching evaluation; student perception; learning outcomes



Citation: Gutai, M.; Palaialogou, G. Pavilions in Architecture Studio—Assessment of Design-Build Approach in Architecture Education. *Architecture* **2021**, *1*, 38–55. <https://doi.org/10.3390/architecture1010005>

Academic Editor: Avi Friedman

Received: 13 July 2021

Accepted: 3 September 2021

Published: 9 September 2021

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1. Introduction

Pavilion architecture is an emerging paradigm in architecture education that offers a wide range of opportunities for experimentation, from digital architecture to traditional craftsmanship. The design-build teaching method has been often linked with the Bauhaus educational approach because of its workshop-based learning activities that integrated design and craftsmanship [1]. The origins of design-build teaching activities can be traced back to John Ruskin, who worked on a road construction with his students at Ferry Hinksley near Oxford as a community project [2], or the student construction projects at Tuskegee University in Alabama, which were initiated by Booker T. Washington in exchange of students paying fees to complete their studies [3]. After the first student-led design-build projects, a new form of design pedagogy emerged in the 1950s in the United States, which challenged the design education norms of the Ecole des Beaux-Arts. The group was led by Colin Rowe, John Hejduk, Bernard Hoesly and Robert Slutzky, who introduced a critical and formal approach to architecture education. These new ideas inspired a novel concept for design studio, which initiated several design-build projects [4]. Design-build learning was also promoted later in ‘A Study of Education for Environmental Design’, also known as Princeton Report, which presented a change in pedagogical thinking in design studio and “highlighted the need to broaden the scope of architectural education to the design of the entire built environment and to engage students in solving community related problems” [5] (p. 282). In the past seven decades of history following their emergence, design-build projects shared typical features such as: separated design and construction phases, collaboration between university and external stakeholders (community, non-profit organisation) and combined effort of local volunteers, students and academics. The integration of design-build studio in the teaching curriculum, however, shows great variety [6].

Pavilions became a vehicle for design-build projects in design studios, in the last two decades, to experiment with parametric design and digital fabrication—for example, the pavilion construction project as part of design studio at Architectural Association [7,8]. Other examples are the pavilion projects by Institute of Computational Design in Stuttgart led by Achim Menges, which are mostly known as result of advanced structural research while some of them are student projects like the Aggregate Pavilion [9]. A similar approach is implemented at The University of Tokyo where emergent structural investigations by Jun Sato [10] are undertaken in design projects focusing on Japanese tradition and which include contemporary tea houses built by students of Kengo Kuma Lab [11,12]; or the pavilions of Yusuke Obuchi Lab's students [13,14], which intertwine tools, craftsmanship and digital fabrication in design-led research and construction projects. Furthermore, pavilion projects take up the challenge to link different fields of science with architecture design, i.e., the Studio One at UC Berkeley, which combines biomimetic research with design and construction [15]. With the advancement of computational design and the penetration of digital fabrication tools and technology in university labs, the number and complexity of student-built projects is increasing. The number of student-led design-build projects at universities globally was estimated to be about 60 in 2005 [16] and over 100 in 2010 [17]. Based on the number of project submissions for the student Design-Build Pavilion Competition organised by popular architecture website ArchDaily, design-build projects by students have at least doubled by 2017 and are increasing, showing “almost 100” submissions in 2015 and several “hundreds of projects” in 2017. (Popular architecture website, ArchDaily opened call for pavilion projects in 2015, 2016 and 2017. The number of submissions showed a significant (at least 200%) increase each year. The Best Student Work Worldwide: ArchDaily Readers Show Us their Studio Projects Available online: <https://www.archdaily.com/771146/the-best-student-work-worldwide-archdaily-readers-show-us-their-studio-projects> (accessed on 1 July 2021). The Best Student Design-Build Projects Worldwide 2017 Available online: <https://www.archdaily.com/875689/the-best-student-design-build-projects-worldwide-2017> (accessed on 20 July 2021)).

This development is also pointed out by Jori Erdman and Robert Weddle in their discussion on emerging full-scale student-led design-build exercises in architecture schools across the United States [18]. Their article, which concluded the findings of a conference they organised on that topic in 2001, aims to reflect on the fact that “design-build activities continue to resist theorizing and critical discourse,” [18] (p. 175). From a pedagogical perspective, this leads to two important disadvantages: the benefits of the exercise are often viewed as self-evident and the focus shifts from the process to the product itself, which hinders efforts to “integrate pedagogy with process” (ibid).

Corser and Gore present that design-build projects follow two possible methods: (i) constructing larger houses (with investigation of construction, i.e., modular systems), or (ii) exploration of new materials and processes. Although they acknowledge the significance and novelty of these two approaches compared to a traditional design studio teaching, Corser and Gore question the approaches' potential of offering a new alternative in practice—especially in terms of open-ended speculation for the first and being too reliant on individual student talents for the second. They propose an alternative and third approach, which they coin as “‘guerrilla architecture,’ defined as ‘small-scale interventions in in the social and urban landscape’” and present a case study for New Orleans [19] (p. 32).

With student-led design-build projects gaining popularity [20], it is becoming important to develop a way for evaluation of their pedagogical impact, especially considering that these projects are becoming part of standard architecture teaching curriculum. Pedagogical evaluation can address several critical aspects which currently lack attention. Firstly, the intended learning outcomes (ILOs) and their efficiency for a pavilion project is becoming an important factor: building a pavilion is clearly a bigger challenge for students than preparing design drawings for a project but it also requires significantly more resources from the school as well. The increased load on staff and resources should be justified with the higher impact of the project.

Secondly, student-led design-build projects include multiple stages, i.e., design, fabrication and construction, which have different learning outcomes for students. A typical project has all these stages and students are involved in each step of the process. While the advantage of student involvement is clear in the fact that students take ownership of the design, it is not established whether all these stages have equal importance in learning experience-especially, if the design process is managed by a smaller group rather than the total number of students involved in the construction. Speculation about the comparative contribution of the various phases of design-build projects raises a question on whether the exercise would have been equally or more effective if the students were to only construct a built structure that has already been designed-namely, having students focusing only on the build experience.

Finally, student-led design-build projects have not yet been compared with traditional teaching methods in the classroom to understand the difference in impact or the potential novel aspects in learning. A construction project is indeed an important challenge and requires an extended consideration of design-related aspects. However, it can be argued that making of physical models or large-scale detail models can have similar impact with less demanding learning environment for student, teacher, and the school. Therefore, the differential impacts of design-build projects need to be assessed to justify the higher demand in resource.

In light of their increasing popularity as a pedagogical vehicle, this paper evaluates the learning impact of student-led design-build pavilion projects by using psychometric assessment and quantitative analysis. The study involves an online questionnaire distributed to undergraduate architecture students at Loughborough University who were involved in student-built pavilion projects which took place in the first year of architecture undergraduate study. The aim of the research is to address current gaps in evidence-based assessment of the pedagogical benefits and shortcomings of design-build pavilion projects in architecture education. The paper examines the following research questions:

- What are students' perceived learning outcomes from design-build pavilion projects?
- Do aspects such as students' level of involvement and the project outcome have an impact on students' views?
- What are the theoretical and practical implications about pavilion project pedagogy that can be identified by the input from students' views?

In what follows, 'Materials and Methods' presents the research design and reasoning behind the selected types of analyses, including their description and limitations. 'Results' presents the findings from the analysis of the questionnaire data and 'Discussion of Findings' offers a reflection on the learnings and implications of the study findings considered against the wider pedagogical context in architecture education. Overall, the paper presents an evaluation of pedagogical impact of student-led design-build pavilion projects, which to our knowledge has not been attempted before on such scale. From this evaluation, a theoretical model for pavilion project pedagogy is proposed as a basis for future research.

2. Materials and Methods

This section describes the materials and methods used in this study to investigate students' perception of learning outcomes achieved by the student-led design-build pavilion project which takes place during the first year of the undergraduate architecture degree in Loughborough University. The project is part of the regular Design Studio and is a mandatory assignment, which asks the whole Year One student cohort to design and construct a pavilion together. The research examines students' views from three student cohorts in relation to three student-led pavilion projects accordingly: Perspectives Pavilion by the 2017–2018 cohort, Transformer Pavilion in 2018–2019 and Seed Bomb Pavilion in 2019–2020 (shown in Figure 1). The research design is primarily quantitative, using descriptive and exploratory statistical analysis. The main instrument used to measure the perceived learning experience is an online questionnaire titled 'Pavilion Project in Design

Studio A' which was distributed to Loughborough Architecture students in June 2020. Prior to the start, the research obtained ethical approval from Loughborough University's Ethics Approvals (Human Participants) Sub-Committee (2020-1509-1310).



Figure 1. Element Pavilions built by First Year architecture students. **Left:** Perspectives Pavilion, 2018 (element: paper cone); **centre:** Transformer Pavilion, 2019 (element: plywood polygon); **right:** Seed Bomb Pavilion, 2020 (element: bent aluminium triangle).

2.1. Research Design

2.1.1. Questionnaire Design

The questionnaire is divided into two parts and was designed to examine three main aspects associated with the student-led pavilion project: (1) learning outcomes achieved according to students' views; (2) relative assessment of the pavilion project compared to other learning activities (e.g., making construction detail models or models for their building design); and (3) the potential role of level of involvement and year of participation in influencing students' views. The first part (Part I) of the questionnaire addresses Aspects 1 and 2 and the second part (Part II) collects information on Aspect 3 (see Table A1 in the Appendix A). To confirm the validity of questionnaire items, the questionnaire was reviewed by an expert from the Centre for Academic Practice in Loughborough University. The expert's review focused on the theoretical constructs linked to the general categories of intended learning outcomes, the items measuring these constructs, and the accessibility of the chosen language.

In Part I, the majority of questionnaire items were composed in a seven-point Likert scale from Level 1: strongly disagree to Level 7: strongly agree. Given the relatively small population size (130 students), the seven-point scale offered a better option to achieve higher degree of insight into perceptions compared to the less nuanced five-point scale. The theoretical approach for the questionnaire design and scale development follows academic and practice-informed pedagogical approaches for categorising and defining intended learning outcomes (ILOs), which are established in the UK higher-education and professional context. First, Likert scale sections were identified to reflect the pedagogical categories defined by the university ILOs specification—i.e., knowledge and understanding (KU), intellectual abilities (IA), practical skills (PS), general and transferable skills (GS). To these initial categories, two sections were added to assess personal development (PD) and the overall experience (OE). Following, the research utilised the General Professional Criteria of the Royal Institute of British Architects (RIBA) to evaluate the perceived learning impact of the Pavilion Construction Exercise (see Table A1 in the Appendix A). The criteria are used by the Architects Registration Board in the United Kingdom (ARB) and RIBA to assess UK-based architecture education. This evaluation framework offers an objective reference for assessment and comparison with teaching exercises that have similar intended learning impact for students, such as digital 3D modelling of a design, making physical models of proposed designs, and building models and construction details of an existing building. The Likert scale items were specified following thorough mapping of the pavilion project ILOs against the RIBA learning criteria. Where necessary, the RIBA criteria wording was modified to be more accessible to undergraduate students. Finally, non-Likert scale items in Part I include a ranking question which asked students to rank comparatively the significance of a set of design studio activities on their learning; a question asking students to identify RIBA criteria relevant to the pavilion project; and a qualitative question where students were asked to provide five keywords on the benefits and five on the disadvantages from the pavilion project.

Part II was brief, with questions aiming to profile students in terms of the year and pavilion project they participated in, as well as in terms of their level of involvement—i.e., low (1 day or less), medium (2 days), intensive (4–5 days), do not remember/prefer not to say. The study year and pavilion project in which students were involved is of significance because of the different success levels of each pavilion project in terms of the final construction outcome, as discussed later in this section.

2.1.2. Participants

The online survey was distributed to 130 undergraduate students in Loughborough Architecture (total number of students at the time when this research was conducted). It returned 78 completed questionnaires which equals a 60% response rate. Participants are proportionately distributed across the school cohorts, with 15 students from the 2017–2018 academic year, representing 52% of their cohort (29 students in total) and 19% of the studied sample; 24 students from 2018–2019, representing 60% of their cohort (40 students in total) and 31% of the studied sample; and 39 students from 2019–2020, representing 64% of their cohort (61 students) and exactly half of the studied sample (50%). Overall, there is good representation from all three cohorts, with over half of each year's cohort being represented.

The first page of the online questionnaire informed participants about the aims, purpose, data collection and data treatment aspects of the research, in line with Loughborough University's 'Code of Practice on Investigations involving Human Participants'. Following, participants were asked to confirm their agreement with an informed consent form before proceeding to the next step of answering the questionnaire items.

2.1.3. Statistical Analysis

The Statistical Package for the Social Science (SPSS) version 23.0 was used to analyse collected data. The analysis involves a first stage of examining the dataset via descriptive statistics. Descriptive statistics are used to report on the overall profile of students' assessment of the pavilion project and to respond to the first and second research questions. In addition, inferential one-way analysis of variance (ANOVA) parametric tests were applied to assess whether there is statistical evidence that the population means for the Likert scale items are significantly different depending on students' level of involvement and year of participation. Although the use of parametric tests, such as ANOVA, to analyse Likert scale data are debated extensively in academic research, it has been argued that there is enough evidence to support the application of ANOVA when analysing the summations [21,22].

In the second stage of the analysis, exploratory factor analysis (EFA) was conducted on the Likert scale items to identify the underlying factorial structure to respond to the third research question. EFA investigates the possible underlying relationships of the measured items without imposing a predefined structure. In other words, the data are examined to reveal evidence-informed dimensions of the examined construct (in this case, pavilion project pedagogy), instead of applying a preconceived theoretical interpretation of the relationships that define the construct. Furthermore, EFA helps to identify items with poor psychometric reliability and thus to reduce the number of scale items and avoid measurement redundancy. EFA is typically used as the first step in developing reliable psychometric questionnaires before conducting confirmatory factor analysis (CFA). In pedagogical research, factor analysis has been deployed to develop instruments for assessing both teachers' e.g., [23,24] and students' perceptions, e.g., [25,26] of pedagogical approaches and experiences.

A principal axis factor analysis (FA) was conducted on the 29 scale items (sections KU, IA, PS, GS, PD, OE; see Table 1) with oblique rotation (direct oblimin). The sampling adequacy was verified by the Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) measure, KMO = 0.866. In addition, the KMO statistic for individual variables at the diagonal elements of the anti-image correlation matrix were well above the acceptable limit of 0.5 [27]. After extraction, we retained four factors using the following criteria: (i) factors with eigenvalues >1 (Kaiser's criterion); and (ii) indicators with factor loadings of absolute

values > 0.5. All four identified factors show high internal reliability, with Cronbach's α values ranging between 0.861 and 0.910 (see Table 5 in Results).

Table 1. Overview of Likert scale items for the Pavilion Project questionnaire, before EFA (Stage 1—analysis) and after (Stage 2).

Questionnaire Sections and Items	Factors (F)	Rotated Factor Loadings
Section 1—Knowledge and Understanding		
KU1 The Pavilion Project helped me to understand the possibilities of architectural language to satisfy both aesthetic and technical requirements.	F2—Design Process	0.515
KU2 The Pavilion Project helped me to understand the importance of construction strategy for the design and building process.	Removed during EFA	-
KU3 The Pavilion Project helped me to understand tectonics (structural stability, load-bearing capacity, etc.).	F1—Construction	0.620
KU4 The Pavilion Project helped me to understand the physical characteristics of building materials, components and systems.	F1—Construction	0.534
KU5 The Pavilion Project helped me to understand the role of users and context in the design process (e.g., students or exhibition visitors as users, campus as context).	F2—Design Process	0.678
Section 2—Intellectual Abilities		
IA1 The Pavilion Project developed my ability to create a design concept.	F2—Design Process	0.858
IA2 The Pavilion Project developed my ability to solve design problems.	Removed during EFA	-
IA3 The Pavilion Project developed my ability to apply cost assessment as part of the design process.	Removed during EFA	-
IA4 The Pavilion Project developed my ability to integrate knowledge of structural principles and construction techniques.	F1—Construction	0.751
IA5 The Pavilion Project developed my ability to assess and respond to design constraints (e.g., user needs, site and context).	Removed during EFA	-
IA6 The Pavilion Project developed my ability to appraise design solutions and their potential effectiveness.	Removed during EFA	-
Section 3—Practical Skills		
PS1 The Pavilion Project encouraged me to use scaled models to explore, prepare and present a design concept.	F3—Engagement and participation (removed during reliability analysis)	0.572
PS2 The Pavilion Project encouraged me to use freehand sketches and technical drawings in the design process.	F2—Design Process	0.652
PS3 The Pavilion Project developed my ability to communicate design concepts effectively using oral and visual methods.	Removed during EFA	-
PS4 The Pavilion Project developed my ability to apply research skills and collect information on design precedents.	F2—Design Process	0.684
PS5 The Pavilion Project encouraged me to use the labs (modelling workshop) and handcraft tools.	Removed during EFA	-
Section 4—General Transferable Skills		
GS1 The Pavilion Project developed my time management skills.	Removed during EFA	-
GS2 The Pavilion Project developed my ability to work as part of a team.	F4—Team Working	−0.797
GS3 The Pavilion Project developed my leadership skills.	F4—Team Working	−0.738
GS4 The Pavilion Project developed my interpersonal skills.	F4—Team Working	−0.867
GS5 The Pavilion Project developed my skills on how to pitch my ideas in a group.	F4—Team Working	−0.823
Section 5—Personal Development		
PD1 The Pavilion Project helped me to achieve better performance on the home project (design studio project).	F2—Design Process	0.706
PD2 The Pavilion Project helped me to engage more with the studio and my peers.	F3—Engagement and participation	0.683
PD3 The Pavilion Project motivated me to attend extra-curricular 'design and build' activities (e.g., summer school).	Removed during EFA	-
PD4 The Pavilion Project grew my interest in architecture.	Removed during EFA	-
Section 6—Overall Experience		
OE1 The Pavilion Project made a valuable contribution to my learning.	Removed during EFA	-
OE2 I am eager to participate in a 'design and build' project again.	F3—engagement and participation	0.837
OE3 I would be eager to participate more often in 'design and build' projects as part of my degree.	F3—engagement and participation	0.859
OE4 The Pavilion Project has been the most valuable academic experience to date.	Removed during EFA	-

Results from EFA introduce a hypothetical Pavilion Project pedagogy model which can be used in future research as a starting point for measuring the ILOs of pavilion projects in architecture education.

2.1.4. Limitations

The research design presents a number of limitations which, however, do not compromise the value of its contributions. First, the questionnaire was distributed at the same time to all three cohorts. This suggests that each cohort had a different perspective in terms of the time distance from the actual events examined (i.e., the pavilion project). However, as discussed later in the results section, time distance from the event did not appear to correlate with their judgement; although, each cohort had distinct views on the learning outcomes, these do not appear to be time dependent—with the cohorts 2017–2018 and 2019–2020 showing similar results and cohort 2018–2019 being the outlier. Second, the representation of each cohort is not evenly distributed within the sample; this limitation is because each cohort size is different and, in reality, it reflects the population structure. Difference in representation across students' cohorts has been mitigated by achieving participation from over half of the population in each cohort. Third, the sample size ($N = 78$) is below the recommended threshold of 100 participants for exploratory factor analysis. However, extant research has questioned the argument on the unreliability of small sample sizes by demonstrating that good factor recovery can be achieved even with small N s [28].

Finally, a couple of limitations should be noted regarding the theoretical framing of the initial questionnaire. First, as previously explained, the theoretical premise of the questionnaire was formulated by integrating ILO categories which are typical in UK higher education with learning criteria which are used to validate architectural education in the UK. While the UK/RIBA educational model is adopted in universities internationally, we acknowledge that it does not reflect all possible pedagogical frameworks for the subject of architecture and other researchers might wish to tailor the questionnaire towards their specific pedagogical approaches. Second, the pedagogical aspects of the Element Pavilion Project as a design studio brief were created and curated independently of the questionnaire design. However, we do acknowledge that the effectiveness of the brief might have an impact on the way participants responded to the questions.

2.2. Case Study: Element Pavilion Project

The Element Project is a design exercise taught for undergraduate architecture students as part of the First Year Design Studio at Loughborough University. The project consists of three stages. The first is the individual stage where students are asked to develop their own design proposal for a shelter. The second stage builds on the learning outcome of this experience and asks students to design and construct a new pavilion together as a cohort. The third stage is constructing the pavilion in 1:1 scale.

2.2.1. Design-Build Stages

Stage 1: Individual design of element and shelter. The project is titled Element because the students are asked to design a building component first that can be tessellated and mass-customised or mass-produced for the shelter. In the first stage, each student develops their own element and designs their shelter. The aim of the exercise is for the students to explore the potential of building components in controlling key aspects of a building envelope, including permeability, structural performance and volume or form. Each of these aspects need to be manipulated by either slightly changing the element (i.e., increasing its porosity and thereby translucency) or the way the elements are joined (i.e., increasing the gap between them which would affect load-bearing capacity and translucency). The first stage ends with a review for which the students are asked to prepare design drawings and physical models in 1:50 scale of their individual design. In addition to considerations on materiality, structure and assembly, the students are asked to explore the design potential of their element (e.g., controlling porosity of building envelope, relationship with user, site, etc.) and to present a conceptual idea and function that underpins their design. The jury selects one element 'with the most potential', which will be used for the second stage.

Stage 2: cohort-based design of pavilion. The second stage of the project is to design a pavilion together as a cohort. All students are asked to develop proposals by building

models using the selected element. The students build their first model individually and team up in consecutive stages. As the teams grow, the number of proposals drop. The process continues until the number of designs go down to three to four proposals when the students can choose one of the designs with a vote. This cohort-based design process is titled Design Pyramid and was developed by the first author.

After the design is selected, the cohort is divided into smaller groups. Each group focuses on a specific design problem of the project—i.e., (1) final design for the form, (2) manufacture and materiality, (3) joint details, (4) final element variations (size, perforation, colour and finish), (5) documentation and (6) assembly, and finally (7) user engagement (function of the pavilion, event and promotional material). Each team was asked to develop alternatives for their specific focus which helped the cohort to finalise the design. This stage ended with two cohort meetings. The first was used for each group to present their initial ideas and to receive feedback from the cohort and the teachers. The second meeting was used to vote on the options and finalize the design. The groups also had to work together on issues that were no group specific, e.g., consider that the pavilion is to be used in a short period, should be easy to assemble and be sustainable (easy to disassemble with minimal waste and high recycled content).

Stage 3: pavilion construction. The final stage of the project is to manufacture the elements and construct the pavilion in five days. The work is led by student volunteers who act as group leads. The cohort is divided into new groups and work together in different stages of the manufacturing and construction process. The whole cohort is engaged in manufacturing and construction for the full period of the five-days process. The key goal of the time plan (managed by the Assembly Team) is to lead a work allocation that gives a diverse construction experience for the students.

The construction process takes five days during which the students working on the Pavilion full time. The first two days are typically spent with mass production of the elements and preparation of the site. The third and fourth day is used for assembly of the pavilion. The last day is for finalising details of the building (i.e., preparing furniture and preparing the site for the public) and organise the opening.

It should be noted that although the cohort is divided into groups during Stage 2 and 3, the exercise overall incorporates steps to make sure that the overall learning outcome is the same for every student. During Stage 2, this happens through presentation sessions when each group presents their process and findings to the whole cohort and decisions on the design are made together. In case of Stage 3, the students are moved between groups each day to make sure that they are not working on the same step throughout the week. This is possible because these groups are established to increase the efficiency of the cohort and not to provide different learning outcomes or experiences.

2.2.2. Pavilion Projects

The School of Architecture at Loughborough University built three pavilions so far between 2018–2020, which are shown in Figure 1. The three buildings show a continuous growth in challenge in terms of design, manufacturing, and construction. The first project (Perspectives Pavilion, 2018) used paper cones, the second (Transformer Pavilion, 2019) plywood polygons and the third (Seed Bomb Pavilion, 2020) bent aluminium triangles. In terms of design the project became more complex by shifting from an indoor installation (2018) to an outdoor project with an actual function (2020) because the Seed Bomb Pavilion was used for a charity sale that supported Australian Firefighters. In terms of manufacturing, the techniques used for the paper structure (2018) were the simplest as the elements were practically glued and pinned together. In case of later pavilions, the joints were tied (2019) and riveted (2020), which gave more strength and control for construction. In case of the second project, titled Transformer (2019), the project was challenged by the utilised materials and joint method and structure did not stand as long on its own (24 h). After its collapse, the pavilion needed additional bracings to stand again, which (as results show) had an impact on students' perception. In contrast, the latest project (2020) was

an important milestone because it was the first time that the building was built outside and not within an exhibition space. This was clearly an important step because students had to consider multiple aspects of design, including weather or public engagement with the building.

It should be noted that although the three buildings were somewhat different, the projects run with the same budget, allocated time and coursework brief each year. This gave us the opportunity to involve the three cohorts in the assessment of the exercise (BArch Years 1–3).

Additionally, the comparison of the three projects showed a continuous development, which is worth mentioning. There is a significant added value in repeating the project in consecutive years, which showed increasing impact with the same investment of resources (budget and staff time allocation).

3. Results from Descriptive and Inferential Analysis

3.1. Students' Views on Learning Outcomes from Pavilion Projects

The psychometric assessment (Likert scale items) of students' views on the learning outcomes from the pavilion project returned generally positive results. The overall mean score across all Likert scale items is 5.3 (standard deviation SD = 0.915). Similarly, the mean score for five out of six Likert scale sections is above five, with only personal development (PD) scoring 4.9 (SD = 1.199) (see the last row in Table 3). Based on the seven-point Likert scale, a score of five equals the 'somewhat agree' value. The chart in Figure 2 illustrates the percentage distribution of negative, neutral and positive responses for individual Likert scale items. General and transferable skills is the section of learning outcomes that has received the highest score on average, followed by practical skills and knowledge and understanding.

Students were also asked to rank the significance of the pavilion project against other learning activities taking place in Design Studio during the first year of their studies. Because the pavilion project process includes some of the other activities (e.g., model making), to avoid confusion, only the construction aspect of the pavilion project was considered in this ranking question. Results in Table 2 show that students ranked first model making for design projects followed by 'digital 3D modelling'. The pavilion project (construction only) ranked third, ahead of construction details and lab experiments.

Table 2. Students' ranking of learning activities in first year in architecture education ¹.

Learning Activity	Mean	Std. Deviation (SD)
Model making for design projects	5.71	1.280
Construction details	4.15	1.571
Lab experiments (e.g., in tectonics)	3.77	1.376
Digital 3D modelling (building projects in virtual environments)	5.05	1.750
Pavilion project (construction only)	4.41	1.670

¹ Participant sample N = 78.

The questionnaire also asked students to evaluate the pavilion exercise based on RIBA learning criteria by selecting the most relevant ones from a list. The strongest ones were design related: ability to create structural designs, understanding the relationship between people and buildings were highly relevant in students' perception. Criteria related to understanding were a bit lower but still relevant: 'understanding the methods of investigation for a design project' and 'understanding the structural design, construction and engineering problems. Knowledge based skills showed the lowest link in students' perception, which were: 'necessary design skills to meet users' requirements within the constraints of cost factors', understanding of the profession of architecture and the role of architect in society' and 'adequate knowledge of physical problems of technologies and the

function of buildings to provide them with comfort and protection against climate'. This order of relevance makes sense considering that only the last pavilion was built outside and for a specific function (charity sale) while the others were installations for exhibition. This result points out the importance engaging with a client/community, working on pavilion with function and exposed to elements as these considerations lead to higher impact. It should be noted that each criterion had sufficient relevance in students' perception by marking 44–93%.

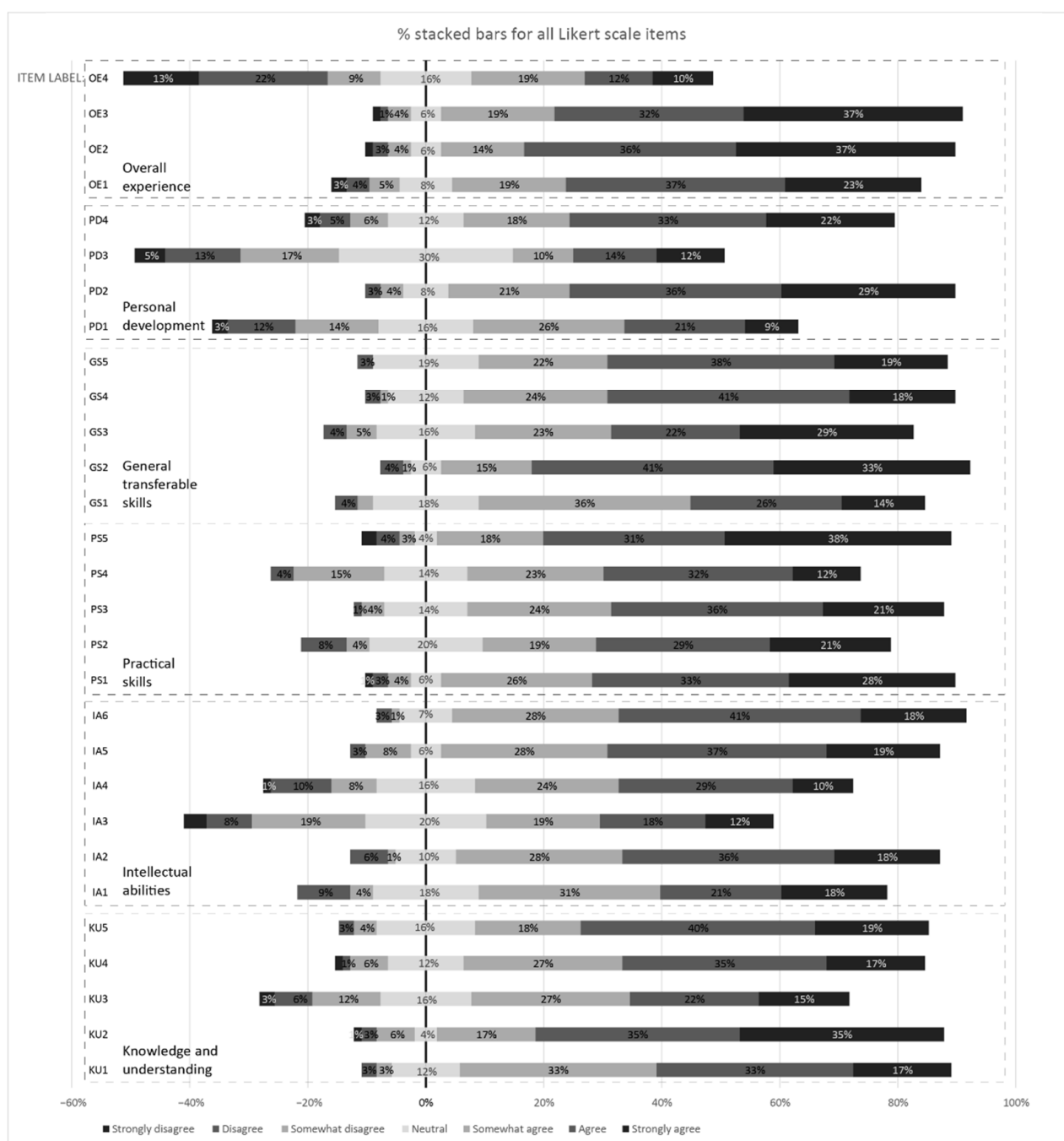


Figure 2. Percentage distribution of negative, neutral and positive responses for individual Likert scale items.

Inferential statistics returned varying results with regards to the statistical significance of the difference in students' views based on students' level of involvement and pavilion project/year of study. According to the one-way ANOVA test which considers the p-

values below 0.05 to be statistically significant, the probability of difference based on level of involvement (Table 3) is highly significant for learning outcomes relating to general and transferable skills. Significant probability of difference is also observed for personal development learning outcomes as well as for the overall assessment of the pavilion project learning experience (for all Likert scale items). As anticipated, the least positive scores on average are given by the ‘low involvement’ and ‘do not remember/prefer not to say’ groups. Students with medium involvement appear to give the highest scores on average amongst the three groups for all four out of six sections besides general and transferable skills and overall experience. The overall experience section has received highest scores on average from students with intense involvement. These results suggest that students with intensive involvement have been more critical in their assessment of the learning outcomes compared to students with medium level of involvement (see also ‘All items’ in Table 3); however, they have also been more appreciative of the overall experience and would be keener to engage again in design and build projects.

Table 3. Level of involvement impact on perceived learning outcomes.

Level of Involvement	KU		IA		PS		GS ***		PD *		OE		All Items *.1	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low (1 day or less), N = 1;	4.6000	.	4.6667	.	5.6000	.	5.8000	.	5.2500	.	4.5000	.	5.0690	.
Medium (2 days), N = 10;	5.6200	0.9773	5.4500	1.1001	5.6400	1.0658	5.5000	0.9298	5.2750	1.0438	5.2000	1.1414	5.4621	0.9448
Intensive (4–5 days), N = 58;	5.4517	1.0154	5.1667	0.9985	5.5034	0.9345	5.7034	0.9323	4.9914	1.1297	5.3578	1.2714	5.3686	0.8692
I do not remember/prefer not to say, N = 9;	4.5778	0.9718	4.5370	1.0266	4.6444	0.6692	4.2444	0.9475	3.8889	1.4583	4.5556	1.3450	4.4253	0.8691
Total, N = 78	5.3615	1.0330	5.1239	1.0233	5.4231	0.9529	5.5103	1.0267	4.9038	1.1994	5.2340	1.2686	5.2679	0.9155

¹ Participant sample N = 78. One-way ANOVA; * $p < 0.05$; ** $p < 0.01$; *** $p \leq 0.001$.

One-way ANOVA results for the three pavilion projects (Perspectives, 2018–2018; Transformer, 2018–2019; and Seed Bombs, 2019–2020) show statistical significance across all sections and for the overall assessment (for all Likert scale items) in terms of the probability of these three groups in explaining difference in students’ views (see Table 4). More specifically, the highest scores on average are systematically given by the 2019–2020 cohort for the Seed Bombs pavilion, followed by the 2017–2018 cohort for the Perspectives Pavilion. The 2018–2019 cohort gave the least positive scores on average across all sections and overall. This is a particularly interesting finding considering that the Transformer Pavilion is the only one out of the three which was not successfully completed, with the pavilion collapsing very soon after its installation. This result suggests the potential cognitive impact that the build outcome might have on the student experience and on the perception of valuable learning contribution.

Table 4. Pavilion project (and year of study) impact on perceived learning outcomes.

Level of Involvement	KU ***		IA *		PS **		GS *		PD *		OE **		All Items ***,1	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Perspectives, 2017–2018, N = 15;	5.1733	0.9437	5.0444	0.7223	5.4667	0.8200	5.6933	0.6798	5.0833	1.0635	5.1333	0.8176	5.2690	0.5322
Transformer, 2018–2019, N = 24;	4.7167	1.1095	4.7292	0.9790	4.9083	0.9362	5.0500	1.0168	4.3646	1.1252	4.5625	1.3757	4.7399	0.9432
Seed bombs, 2019–2020, N = 39;	5.8308	0.7658	5.3974	1.0826	5.7231	0.8951	5.7231	1.0708	5.1667	1.2103	5.6859	1.1708	5.5924	0.8782
Total, N = 78.	5.3615	1.0330	5.1239	1.0233	5.4231	0.9529	5.5103	1.0267	4.9038	1.1994	5.2340	1.2686	5.2679	0.9155

¹ Participant sample N = 78. One-way ANOVA; * $p < 0.05$; ** $p < 0.01$; *** $p \leq 0.001$.

Finally, the analysis of keywords confirms the central role of construction and the hands-on engagement as positive aspects of the pavilion project experience. Nevertheless, negative factors highlight organisational and teamworking challenges associated with pavilion projects, especially when these are student-led. These observations appear to identify risks from having students to lead the design and build process. Keywords suggest time management, high workload and uneven students’ contribution as prominent issues as shown in Figure 3.

for further research and validation by architecture educators. The questions presented in Figure 4 can be used by architecture schools, educators and design tutors as a basis for a questionnaire to assess pavilion projects by students, thus offering valuable feedback and possibility to tailor future pedagogical pavilion projects according to the target group in respect of the course, year of study and other specifications.

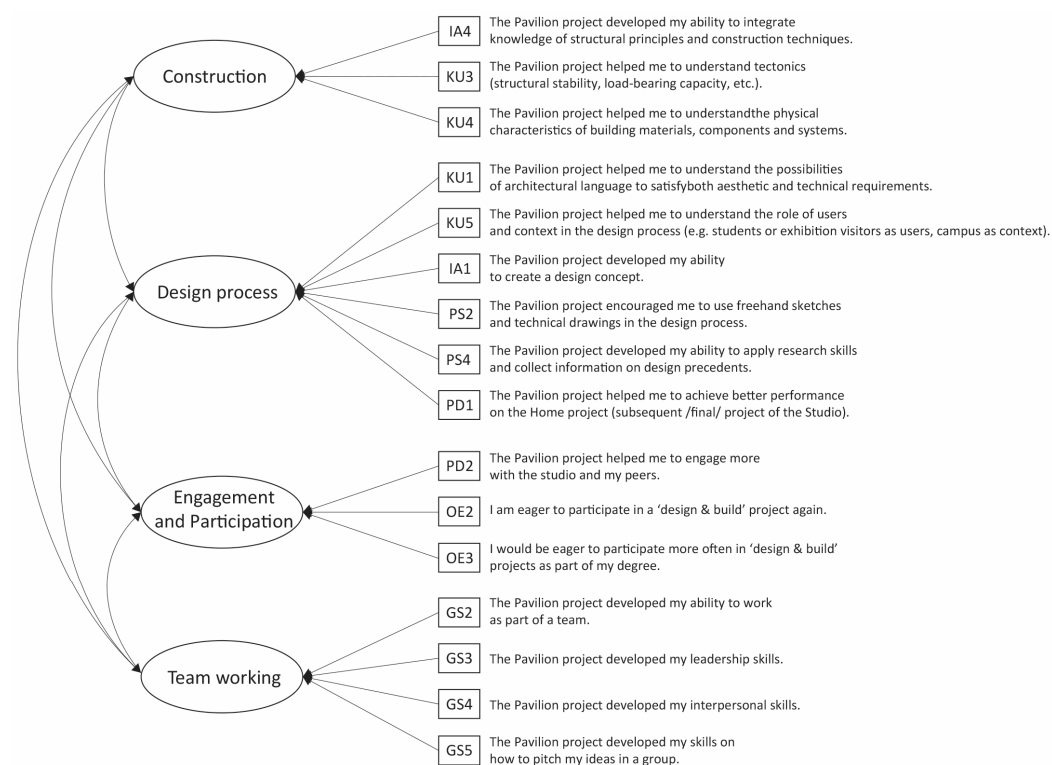


Figure 4. Hypothetical Pavilion Project Pedagogy (HPPP) model, showing the most important four impact groups of student-led design-build exercises based on students' perception.

4. Discussion

The research presents a psychometric assessment of a student-led design-build pavilion project and translates the results into a hypothetical Pavilion Project pedagogy model, which can be used as a tool to develop and assess similar educational projects.

Beyond its novelty, the research is important because of multiple factors. Firstly, as Erdman has argued, with the increasing possibilities in student 'hands-on' constructions, it is important to get a better understanding of the learning impact of student-led design-build project [3], especially considering the different activities and stages involved in the project. Assessment of learning impact can highlight unique aspects that other learning exercises cannot offer or other strengths that the pedagogical approach should focus on to maximise impact. The psychometric assessment contributes to existing reflections on 'hands-on' pedagogy offering a more nuanced understanding of the student perspective and the value and challenges which students experience in these projects, mapped against learning criteria and intended learning outcomes. Furthermore, the HPPP model offers an evidence-based entry point for the development of design-build focused pedagogical theorisation which is an observed gap in architecture education discourse [17,18].

Secondly, an effective evaluation of student-led design-build projects can improve the efficiency of design-build projects not only in terms of learning outcomes but also their planning and implementation. In general, an effective evaluation can support comparative understanding of the benefits and challenges associated with including such projects in standard architectural teaching curriculum, which would eventually improve student experience and learning environment while minimising negative impacts on school and staff. Assessment and improvement of the pedagogical performance and delivery of design-

build learning could help to mitigate what Canizaro identifies as ‘collegial resistance’ and ‘administrative and institutional’ resistance [17] (pp. 31–32). In response, the aim of the authors is not to discourage student-led construction projects in education, but rather the opposite: presenting an evaluation framework that offers an objective assessment on the impact of such projects, which would support student-led projects to take their place as part of standard architecture education and enable more students to access hands-on experience in design and construction.

With regards to the results and benefits of HPPP, the model suggests a few speculative ways to use it in architecture education, especially if the design-build exercise is embedded in standard design studio class where time and resources are limited. Firstly, students’ perception suggests a justified emphasis on construction and the significance of the ‘building’ process in design-build educational projects. This outcome begs further discussion about the meaning and value of ‘build’ in an architectural curriculum, which is particularly timely considering the current context of online learning [29,30]. The significance of the construction phase could be reflected upon when the design-build exercise is planned overall: sufficient time and resources allocated for the construction stage is essential, especially if intended learning outcomes for design can be covered by other projects within the module. The impact of the construction factor explains that construction success emerges as a critical element of the learning experience, which is also evidenced in both ‘positive’ and ‘negative’ keywords used by the students (success and failure). This means that the positive learning outcomes of the project should be clearly communicated to the participants especially regarding lessons learned that are independent from construction because students appear to perceive success as equal to learning outcome. It also aligns with research in design-build education which suggests the central role of the educator in managing confusion and facilitating the learnings of uncertainty and its resolution to come through [31]. A caveat to be noted is that the questionnaire distinguished between the design and construction questionnaire items and included no questions regarding design in the construction phase, whereas it can be argued that design decisions continued to take place during construction.

The second observation is that the engagement and participation factor and teamwork factor are confirmed as critical elements for students’ perception, therefore, the management of students’ teams and tasks should focus on achieving collaboration: the tasks should be designed in a manner to offer diverse participation for the students instead of making them responsible for a specific task of the project (as it would happen in a typical professional construction project). In general, higher involvement leads to more positive acknowledgement of learning outcomes, which means that the exercise should be designed with monitoring on attendance and participation. Overall, the results show positive outcomes with high satisfaction for teamworking, which makes student-led design-build exercises a strong option for collaboration projects in architecture education.

Considerations for Future Research

The questionnaire items should be seen as a basic assessment framework which needs to be further validated by applying it to similar student pavilion projects. Validation via new projects and datasets will reveal whether the model can explain student perceptions for other cases of pavilion projects, which could result in additional refinements of the model before its theoretical confirmation.

The resulting HPPP model suggests that the construction stage reflects most of the learning impact perceived by students, which could indicate that pre-designed projects may have similar impact to student-led design-build pavilion projects. This aspect needs further exploration and may have significant implications in terms of future directions of design-build projects—on the one hand, emphasising the learning value of the construction experience and, on the other hand, promoting less emphasis on the design phase; and with resulting implications on resources required from schools and the debate on hands-on versus online design education. Overall, a closer consideration of the multifarious

impacts of design-build pedagogy measured against its challenges is an area that requires further research to uncover whether the multifarious benefits outweigh the costs in labour and resource. Future research could also focus on different typologies of design-build projects—e.g., in terms of scale, year of study, educational scope and project timeline and their respective and comparative learning impact.

Finally, the model and the questionnaire in its current state does not reflect on differentiation between design-build projects and other activities in terms design experience. Since design studio projects are time constrained, the time allocated for design stage is often shorter and much of the efforts are reserved from resolving construction-based problems and project delivery. While design elements scored high in the current assessment, it should be acknowledged that design here can be understood in a broader aspect as simply designing a building. Establishing such distinction may present further understanding in learning outcome of design-build projects, especially in relation to other design works in studio.

5. Conclusions

The research presented an overall assessment of students' perception on student-led design-build projects, focusing specifically on pavilion projects. The significance of the study was to offer a comprehensive evaluation on the intended learning outcomes of the exercise in design studio pedagogy. Such assessment has not been presented to date and is relevant to architecture education because design-build projects require much higher resource and effort investment from both students and school, whilst they are increasingly becoming part of standard architecture education—which is also the case for our study project (Element Pavilion at Loughborough University). An additional consideration was the timing of the project in education since Element Pavilion is for Year One BArch students and having a student-led design-build project at this early stage is very rare.

The results show that the pavilion exercise was seen by the students as a positive experience overall. The benefits in learning have been acknowledged by the participants both in terms of ARB/RIBA learning criteria and overall assessment of educational framework used by universities in the UK (knowledge and understanding, intellectual abilities, practical skills, general transferable skills, personal development and overall experience). The comparison of the pavilion project with other exercises has been perceived positively as well, following digital and physical modelmaking. However, it needs to be mentioned that further consideration is needed to understand how the scale and complexity of design-build exercises compares to standard design studio learning activities.

The statistical analysis of the data showed further advantages of student-led design-build projects, especially considering construction and teamwork. The analysis translated the results into four critical domains: construction, design process, engagement and participation, and teamworking. These four domains served as a framework for a hypothetical pavilion project pedagogy model, which can be used for theorisation, design and analysis of further student-led design-build projects in the future. However, the results show that the impact and eigenvalues of the construction factor (13.228) is much higher than the design process (2.703), engagement and participation (1.801) and team working (1.346) factors. This result would suggest that a construction-only project could also be viable exercise because it appears more influential compared to the remaining three domains that together present considerable part of the pavilion project. This is relevant especially for courses where the ILOs of design process are covered elsewhere in the design studio curriculum. This assumption, however, needs further study and sufficient comparative analysis.

Finally, it should be noted that this study was limited only to analysing the perception of students. While students' perception is an important part of the learning process and should be always acknowledged, it is important to point out that students' views should also be critically reflected upon and both the limitations of student evaluations of teaching (SET) should be acknowledged alongside the contributions [32]. For example, students failed to acknowledge the pedagogical value of failure itself and perceived success as being equal to learning. This is of course not the case, since there is inherent value in trials and

attempts, especially when considering materiality and construction. Indeed, in their study of design-build education, Nicholas and Oak argue that the resolution of ‘frictions’ is “in fact central to the pedagogical model of design-build education” [31] (p. 50).

Author Contributions: Conceptualization, M.G.; methodology, M.G. and G.P.; software, G.P.; validation, M.G. and G.P.; formal analysis, G.P.; investigation, M.G. and G.P.; resources, M.G. and G.P.; data curation, M.G. and G.P.; writing—original draft preparation, M.G. and G.P.; writing—review and editing, M.G. and G.P.; visualization, M.G. and G.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethical Approvals (Human Participants) Sub-Committee of Loughborough University (proposal 2020-1509-1310, date of approval 26 May 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Project datasets available via Loughborough University Repository: (1) data supporting reported results can be found at ‘Pavilion Project in Design Studio A: Questionnaire Survey’ <https://doi.org/10.17028/rd.lboro.12676688> (accessed on 2 September 2021); (2) the students survey questionnaire can be found at ‘Pavilion Project in Design Studio A: Questionnaire Survey’ <https://doi.org/10.17028/rd.lboro.12682307> (accessed on 2 September 2021).

Acknowledgments: The authors are grateful to our colleagues Sarah Turner and Simon Richards for providing their feedback to the questionnaire design. We are also grateful to our students for their participation in this research. No funding has been received by the authors to conduct this research.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Mapping of questionnaire items against the ARB/RIBA Criteria at Part 1.

Questionnaire Sections and Items	ARB/RIBA Criteria at Part 1 ^{1,2}
Section 1—Knowledge and Understanding	
KU1 The Pavilion Project helped me to understand the possibilities of architectural language to satisfy both aesthetic and technical requirements.	GC1
KU2 The Pavilion Project helped me to understand the importance of construction strategy for the design and building process.	GC8
KU3 The Pavilion Project helped me to understand tectonics (structural stability, load-bearing capacity, etc.).	GC8
KU4 The Pavilion Project helped me to understand the physical characteristics of building materials, components and systems.	GC8
KU5 The Pavilion Project helped me to understand the role of users and context in the design process (e.g., students or exhibition visitors as users, campus as context).	GC5
Section 2—Intellectual Abilities	
IA1 The Pavilion Project developed my ability to create a design concept.	GC1
IA2 The Pavilion Project developed my ability to solve design problems.	GC1
IA3 The Pavilion Project developed my ability to apply cost assessment as part of the design process.	GC10
IA4 The Pavilion Project developed my ability to integrate knowledge of structural principles and construction techniques.	GC8
IA5 The Pavilion Project developed my ability to assess and respond to design constraints (e.g., user needs, site and context).	GC5
IA6 The Pavilion Project developed my ability to appraise design solutions and their potential effectiveness.	GC7

Table A1. Cont.

Questionnaire Sections and Items	ARB/RIBA Criteria at Part 1 ^{1,2}
Section 3—Practical Skills	
PS1 The Pavilion Project encouraged me to use scaled models to explore, prepare and present a design concept.	GC1
PS2 The Pavilion Project encouraged me to use freehand sketches and technical drawings in the design process.	GC1
PS3 The Pavilion Project developed my ability to communicate design concepts effectively using oral and visual methods.	GC1
PS4 The Pavilion Project developed my ability to apply research skills and collect information on design precedents.	GC7
PS5 The Pavilion Project encouraged me to use the labs (modelling workshop) and handcraft tools.	GC1
Section 4—General Transferable Skills	
GS1 The Pavilion Project developed my time management skills.	GC6
GS2 The Pavilion Project developed my ability to work as part of a team.	GC6
GS3 The Pavilion Project developed my leadership skills.	GC6
GS4 The Pavilion Project developed my interpersonal skills.	GC6
GS5 The Pavilion Project developed my skills on how to pitch my ideas in a group.	GC6
Section 5—Personal Development	
PD1 The Pavilion Project helped me to achieve better performance on the home project (design studio project).	GC1
PD2 The Pavilion Project helped me to engage more with the studio and my peers.	GC6
PD3 The Pavilion Project motivated me to attend extra-curricular ‘design and build’ activities (e.g., summer school).	n/a
PD4 The Pavilion Project grew my interest in architecture.	n/a
Section 6—Overall Experience	
OE1 The Pavilion Project made a valuable contribution to my learning.	n/a
OE2 I am eager to participate in a ‘design and build’ project again.	n/a
OE3 I would be eager to participate more often in ‘design and build’ projects as part of my degree.	n/a
OE4 The Pavilion Project has been the most valuable academic experience to date.	n/a

¹ GC1—Ability to create architectural designs that satisfy both aesthetic and technical requirements; GC5—understanding of the relationship between people and buildings, and between buildings and their environment, and the need to relate buildings and the spaces between them to human needs and scale; GC6—understanding of the profession of architecture and the role of the architect in society, in particular in preparing briefs that take account of social factors; GC7—understanding of the methods of investigation and preparation of the brief for a design project; GC8—understanding of the structural design, constructional and engineering problems associated with building design; GC9—adequate knowledge of physical problems and technologies and the function of buildings so as to provide them with internal conditions of comfort and protection against the climate; GC10—the necessary design skills to meet building users’ requirements within the constraints imposed by cost factors and building regulations. ² The full list and breakdown of the criteria is available at: https://arb.org.uk/wp-content/uploads/2016/05/ARB_Criteria_pt1.pdf (accessed on 1 September 2021).

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