ITU A|Z • Vol 20 No 2 • July 2023 • 281-297

Competition-based digital design studio experience

Orkan Zeynel GÜZELCİ[1], Derya Güleç ÖZER[2*], İnanç ŞENCAN[3]
[1] guzelci@itu.edu.tr • Department of Interior Architecture, Faculty of Architecture, Istanbul Technical University, Istanbul, Turkey
[2] dgulec@itu.edu.tr • Department of Architecture, Faculty of Architecture, Istanbul Technical University, Istanbul, Turkey
[3] sencani@itu.edu.tr • Department of Architecture, Faculty of Architecture, Istanbul Technical University, Istanbul, Turkey

**Corresponding author*
Received: June 2022 • Final Acceptance: January 2023

Abstract
This study presents a competition-based digital design studio experience through the use of an updated structure for a graduate-level digital design and modeling course. In the Digital Architectural Design and Modelling (DADM) course, 24 students (in groups) were asked to design a playground for a location in Warsaw. This assignment was given in response to a competition brief organized by UNI.xyz. The course was restructured to function as a design studio and was organized to allow four integrated phases namely: analysis, design, modeling, and fabrication. A total of six student groups succeeded in participating in the competition (week 11). During the final submission (week 15), the students and jury members evaluated the completed projects according to 12 sub-criteria that were applied to the 4 main phases. The competition jury awarded various prizes to four of the projects developed during the semester. The course jury members observed that the biggest deficiencies occurred during the fabrication phase, the students regarded the design-related criteria as the major problem area. As the competition jury had no predefined evaluation criteria, they mostly drew attention to the projects' conceptual, spatial, construction, and material issues. This study proposes a project-based framework that combines computer-aided architectural design as a methodology, distance education as a type of communication, playground design as an architectural program, and participation in international competition as a means of motivation.

Keywords
Computational design pedagogy, CAAD teaching, Design competition, Playground design, CAM.

doi: 10.58278/0.2023.7

1. Introduction

The widespread adoption of digital technologies has a significant impact on architectural education and practice. The use of digital design, modeling, and fabrication technologies has increased and transformed almost all stages of architectural education. The changing profile of an architecture student also affects the structure and strategies of computer-aided architectural design (CAAD) education (Koutamanis, 1996; Kokosalakis et al., 1997; Gross & Do, 1999). Beyond computer literacy, graduate-level architecture students, in particular, arrive at the courses with the skill to use multiple software as a representation tool (2-dimensional drawing and 3-dimensional modeling) in architectural design processes. Furthermore, the adoption of digital technologies has become a common skill for students (Hemsath, 2010), and it has become clear that computational design pedagogy should go beyond simply teaching how to use software and tools. Their use is expected when students are required to solve complex design problems, develop innovative design solutions and fabricate at various scales.

The integration of design studios and CAAD is not a new idea; it has been tested since the 1980s. As a contribution to the existing project-based CAAD frameworks, this paper proposes a competition-based framework that includes all components of a design studio as integrated phases (analysis, design, modeling, and fabrication), an architectural program, a real site, and a user profile specified in the brief.

The proposed framework is tested by updating the content and objectives of of a computational design course. Accordingly, this study describes and evaluates the process and outcomes of an updated graduate-level digital design and modeling course that underwent three major changes during its restructuring, namely:

- Reorganizing the course as a design studio instead of merely theoretical content.
- Requiring the students to design projects using computational methods and to participate in an international design competition.
- Requiring design projects to be produced (prototyped) using digital fabrication tools.

Design competitions are essential platforms for architecture students and recent graduates to develop their practice, increase their visibility, and become more competitive. By having competitions as course elements, the students are required to follow external briefs and deal with real-world problems such as site, climate, and user.

The course focuses on the investigation of design solutions in response to the competition brief, as well as how they can be modelled and materialized using computational design approaches, methodologies, and tools. Another goal of this study is to criticize the overall course structure and make suggestions for improvements based on the evaluations of projects by participating students and jury members. During the semester, the works developed in the studio were evaluated both qualitatively (by the competition jury) and quantitatively (by the guest jury members and peer reviewers). This feedback allowed the course to be evaluated (in terms of its process, content, and structure) and for further improvements to be made.

In terms of educational medium, distance learning, which was made mandatory during the pandemic, had both positive and negative educational effects. Unfortunately, face-to-face education has completely replaced this medium without properly appreciating its advantages. Given the course content and learning objectives, it is critical to reconsider course communication methods and apply hybrid alternatives. Although it was not required, distance learning was used in this study to evaluate its benefits, and the results are presented.

In the following parts of this study, Section 2 details the background of computer-aided architectural design pedagogies, distance education in computational design education, and playgrounds, playground design and related criteria. Section 3 introduces the course, the assignment, the development of the works, and the evaluations of the peer reviewers, the guest jury members, and the competition jury. The results of the evaluations and related findings are listed in Section 4. Finally, Section 5 discusses the positive (successful) and negative (unsuccessful) aspects of the proposed framework and highlights the necessary modifications to improve it.

2. Background

The project-based framework presented consists of three components: methodology, communication type, and architectural program. The methodology for the teaching experiment presented in this study was computer-aided architectural design (Section 2.1), distance education as the communication type (Section 2.2), and playground design as the architectural program (Section 2.3). Keeping in mind that these selected contents for the components are not fixed, the following subsections provide information about the selected contents for this particular teaching experience.

2.1. Computer-aided architectural design pedagogies

The transition from punched cards and big computers of the 1970s to affordable PCs and available commercial computer-aided design software accelerated computerization in architectural education (Asanowicz, 1989; Pittioni, 1992; Andia, 2002). Many studies have been conducted since the 1980s on how to teach computer-aided architectural design (CAAD) (Asanowicz, 1989; Koutamanis, 1996), how to integrate CAAD into existing curricula, or how to develop CAAD curricula (Asanowicz, 1998; Silva, 2000; Mark et al., 2001; Mark et al., 2003). Traditional CAAD education was a common criticism raised in these studies, which is discussed further below.

CAAD was traditionally taught as a standalone subject/discipline within the architectural curriculum and was attempted to teach in units (Asanowicz, 1998; Roberts & Forster, 1998). A limited number of software compatible with existing computers was taught in traditional CAAD education. Furthermore, rather than working with a computer, the work was limited to the features provided by the software to the user (Roberts & Forster, 1998). Pittioni (1992) defined such an approach as software-specific. The steps of identifying the requirements in the architectural design process, finding the appropriate software for this requirement, and learning how to use it were followed by the software-specific approach (Pittioni, 1992). Achten (1996) raised and discussed the difference between teaching CAAD principles and teaching CAAD principles in this context. Sliwinski (1996) also raised the issue of teaching CAAD by architecture rather than CAAD by architecture.

According to Flemming and Schmitt (1986), in the 1980s design studio, the computer was used to automate routine tasks and increase drawing productivity. The representation-oriented use of CAD in architecture education was more developed in the 1980s and early 1990s (Pittioni, 1992). Similarly, Andia (2002) asserted that between the mid-1970s and the mid-1980s, CAD was used for architectural documentation and visualization. Many researchers have criticized CAAD education for providing students with skills required in architectural practice, such as modeling and visualization (Roberts & Forster, 1998; Koutamanis, 1999; Pektaş, 2007). Another issue that traditional CAAD education caused was the focus of students and educators (CAAD on technology rather than design, and becoming computer technicians) (Koutamanis, 1996; Sliwinski, 1996; Koutamanis, 1999).

More than 30 years ago, Akin (1990) argued that changing the role of the computer in the design studio had to result in a change in design pedagogy. Since then, many pedagogies aimed at integrating CAAD into design studios have been developed (Flemming & Schmitt, 1986; Kokosalakis et al., 1997; Roberts & Forster, 1998; Koutamanis, 1999; Chiu et al., 2003; Duarte, 2007). According to Achten (2003), the ability to design is the primary subject that is attempted to be taught to architecture students. Since the design process has no specific formula, CAAD in the design process can concentrate on addressing complex design problems and creating innovative solutions (Roberts

& Forster, 1998; Achten, 2003; Duarte, 2007). However, the experiments in previous CAAD courses do not fully correspond to real-world projects. CAAD skills taught in separate courses are ineffective unless accompanied by applications, and the learned skills are only superficial (Pektaş, 2007; Covill et al., 2008). To address this issue, Pektaş (2007) proposes project-based CAAD education. Because the student who is confronted with a real project must apply the learned CAAD skills to the given context in order to produce higher-quality projects.

Over the last decade, project-based CAAD frameworks have been tested through furniture (bench) (Agirbas, 2020) and product (lamp) design (Lanzara, 2021). At the architectural scale, structures such as bridges (Stavric et al., 2019), gridshells (Naboni, 2016; Wallisser et al., 2019), and vaults (Sousa & Xavier, 2015) have been commonly included in educational approaches that include phases from design to construction.

2.2. Distance education for computer-aided architectural design

With the advancement of collaboration technologies and CAD literacy, researchers have contributed to the field of architectural education by developing new types of design studios such as virtual studios, web-based studios, and online studios (Andia, 2002; Pektaş, 2007). Due to the Covid-19 pandemic in 2020, many researchers had to experience distance education for all courses, regardless of their relationship to digital technologies (Yorgancıoğlu, 2020; Akçay Kavakoğlu et al., 2021; Alnusairat et al., 2021; Ceylan et al., 2021). According to Gelmez and Arkan (2022), a course with a specific focus on computer-aided design plays a distinct role in online education due to its technology, computer-based nature, and virtual medium.

In an online course conducted during the pandemic, Ostrowska-Wawryniuk et al. (2022) focused on teaching algorithmic thinking and the necessary skills to students for developing design solutions to abstract mathematical problems. In another online taught course, students were asked to design interventions for their own living space while keeping the live connection with augmented reality systems and software (Weissenböck, 2021). Another online teaching experiment by Goepel and Crolla (2021) uses mixed reality (MR) and photogrammetry technologies for collaborative clay modelling production without the necessity of physical presence.

There are also pedagogies that adopt the computational design method and continue with the computer-aided manufacturing of the designed products. In such cases, experiments with fabrication machines and materials are required in addition to the physical workshop space. Benabdallah et al. (2021) addressed the question of how digital fabrication can be taught in the lack of physical workshop spaces and fabrication equipment/machines and presented new possibilities such as producing at-home machines for fabrication tasks. Due to the Covid-19 pandemic, physical dimensions in courses that used computational design methods had to be partially or completely canceled for a time. Güzelci et al. (2022) responded to this situation by replacing the teaching of more digital tools for modeling and performance analysis for the fabrication phase of the process.

2.3. Playgrounds, playground design, and related criteria

Previous research has demonstrated that playground design is important for the development of children's social, cognitive, and physical abilities as it can enrich their experience and encourage better behavior. Furthermore, studies have been conducted to examine playground safety and risk minimization (Little & Eager, 2010), the development of social and physical skills (Barbour, 1999), and inclusive play strategies and design (Siu et al., 2017).

Creative playground design is an important aspect of children's social and cognitive development. The early work of Susa and Benedict (1994) analyzed the pretend play behavior of 80 children in two different playgrounds: contemporary and traditional. According to the findings of this study, the modern playground encourages more pretend play and greater creativity. Furthermore, a study developed for an undergraduate-level design course to raise awareness among students by Acar (2015) demonstrated how module design can be organized according to affordances in playgrounds.

On the manufacturing side, some global organizations support playground design and research. For example, the International Play Equipment Manufacturers Association (IPEMA, 2022) supports the "Voice of Play" initiative, which aims to improve the quality and quantity of children's play and playgrounds (Voice of Play, 2020). According to IPEMA 2020 research, public playgrounds play a significant role in fostering inclusiveness and play equity. In a survey of parents regarding the benefits of a playground, a majority stated that encouraging play between children of all abilities and improving physical fitness are two important aspects for playground design. Furthermore, during the Covid-19 pandemic, the majority of surveyed parents (87%) stated that play became more important than ever.

There are guidelines for creating a safe and creative environment when designing a playground (Moore et al., 1992). The main points of playground design, according to the Whole Building Design Guide (WBDG Whole Building Design Guide, 2017), are safety, design, materials, accessibility, and estimated costs. Besides that, the overall design parameters should include zones for age-appropriate equipment and activities, as well as quiet and noisy zones.

3. Teaching experiment

3.1. The digital design course

As one of the 5 compulsory graduate-level courses, Digital Architectural Design and Modelling (DADM) has been taught every fall semester within the Architectural Design Computing graduate program at Istanbul Technical University since 2008. The DADM course is taught by different tutors every year and the course is constantly improved through the contributions of professors. The duration of the course is 14 weeks, with 3 hours of class per week. According to the criteria of the European Credit Transfer and Accumulation System (ECTS), the ECTS of the DADM course is 7.5, which is approximately equal to 187.5 hours of study during a semester.

In the course catalog, the objectives of the course are given as 3-dimensional modeling and designing a building using solid modeling software. Considering the students' existing abilities in 3-dimensional modeling and their widespread use of solid modeling software, the tutors updated the course objectives of the course for the 2021-2022 fall semester. The teaching of solid modeling software was excluded in favor of a visual scripting environment (Grasshopper) and its plug-ins (i.e. Kangaroo 2, Ladybug, Lunchbox) to demonstrate the generative nature of modeling. The teaching methodology of the DADM course includes tutorials, lectures by tutors and guests, group work, critiques by tutors, and mid-term and final reviews with guest jury members.

The authors decided to update the DADM course based on their previous teaching experience in Digital Architectural Design Studio (DADS) (another compulsory course of the graduate program), which resulted in award-winning projects. For the 2021-2022 fall semester, the DADM course was redesigned as a project-based computational design course rather than a design and modeling course, as the title indicates. Under its new structure students are encouraged to accomplish the following:

- To use digital design and modeling as a methodology through a project development experiment, rather than learning digital design and modeling as a skill,
- To develop design solutions for a real-world problem with a specific site and user with the introduced methodology,
- To work on the materialization of their designs rather than exploring design solutions only in the digital environment.

While the course duration and the number of weeks remained unchanged in the fall semester of 2021-2022, the communication method of the class was changed to online (distance learning). In the fall semester of 2021-2022, the communication type of the courses was optional and determined by the tutors' preferences. The tutors decided to conduct the course remotely since one of the instructors was in another country and the other was in another city. Another reason for conducting the course remotely was to allow for jury meetings with international guests and to receive their feedback.

3.2. The assignment: International competition for a playground design

In the 2021-2022 fall semester, instead of planning a series of assignments, the students were asked to focus on the design problem given in the brief of an international design competition. The competition, which was selected by the tutors prior to the start of the semester, was organized by UNI.xyz. This brief was to create a play structure for children to be located in a public park. The project site given by the organization was Old Orchard Park in Zoliborz, a residential district of Warsaw, Poland. The park was full of fruit trees, a traditional playground for children, and paths for walking with benches. The site area was 693 square meters, however, the designs were limited to a maximum of 50 square meters, with a height constraint of 5 meters. Although the participants were not required to follow a fixed approach, they were expected to design a single structure (UNI.xyz, 2021).

As stated in the competition brief, the aim was to generate a healthy lifestyle within the playground, and to this end, the available activities must satisfy the physical, mental, and social requirements for the well-being of the children using it. The experiences of digital play are very common among children, but especially after the Covid-19 period, it has become very important that their opportunities for physical play are also engaging and attractive. The competition also demanded that the submitted designs allowed for multiple activities and also included qualities such as accessibility, security/safety, modularity, durability, and eco-friendliness (UNI.xyz, 2021). The reasons for the selection of the competition included in this study are as follows:

- The emphasis on a specific user and architectural program,
- The necessity for extensive research and analysis when designing a playground,
- The requirement to meet multiple architectural qualities such as tangible, modularity, structural durability, and constructability,
- The competition's schedule, which begins and ends within the academic term.

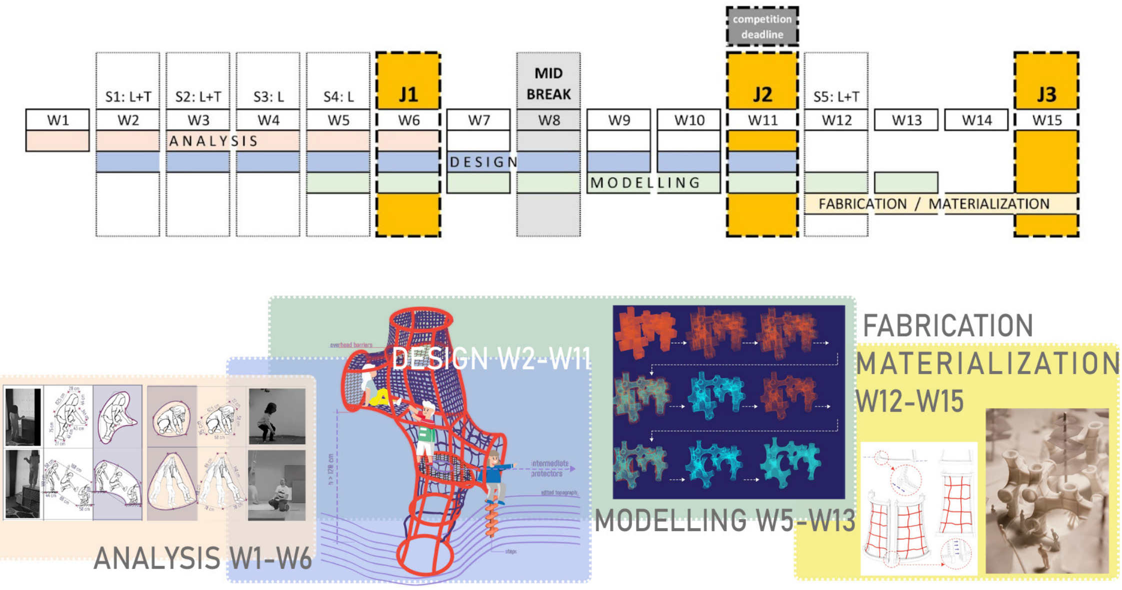

Figure 1. (Top) Course structure; (Bottom) Sample products for the phases (Group 5).

3.3. Development of the works

The 15-week DADM course (including a final jury day) is organized to allow 4 processes, namely analysis (A), design (D), modeling (M), and fabrication/materialization (F). These processes overlap as a result of the integrated and continuous nature of design studios. The course is also supported by seminars (S), lectures (L), and tutorials (T), and by jury evaluations (J) from students, guest jury members, and tutors (Figure 1).

3.3.1. Process of week 1 to 5

The student groups were formed in the first week. Thus, the groups started to develop their conceptual framework in parallel to the process of learning through the series of seminars. Over the following 4 weeks, 2 of the tutors and 2 guest lecturers gave seminarsto support the analysis, design, modeling, and fabrication processes. The first seminar dealt with form-finding strategies in architecture and was supplemented with a tutorial for real-time form exploration using physics engines. The goal of the second seminar was to explain the logic of the data structures necessary to work with a variety of data in the virtual scripting environment (VSE). The second seminar also included a short tutorial to demonstrate these data structures through basic 2-dimensional shapes and operations. A third seminar on environmental performance, sustainability, and Life Cycle Assessment (LCA) was given by a Polish architect and scholar familiar with the site, climate, and local materials of Warsaw. The third seminar also included a tutorial on solar analysis by using Ladybug plug-in. The subject of the final seminar was the materialization of complex forms through both analog and digital making techniques. The possible bio-based construction materials for the playground design were also discussed with the guest lecturer (Figure 1).

3.3.2. Process of week 6 to 11

The first jury (with the participation of guest jury members) was held on the 6th week. Each student group presented a flowchart as the route map they intended to follow during the semester (Figure 2). Since the design brief is both site- and user-specific, the students made intensive analyses regarding children's play, behaviors, and movements, as well as the specific site conditions. In addition, the students started to develop ideas for playground design and to test various digital modeling tools and methodologies to produce their intended design solutions.

For their analyses of the unfamiliar site, the students preferred to use the Ladybug plug-in of Grasshopper VSE. After the import of the necessary EnergyPlus Weather (EPW) data of the selected location from the related databases (https://www.ladybug.tools/epw-map/), Ladybug was used to generate solar and shading analysis for selected times or time periods within the year. The use of Ladybug during the analysis

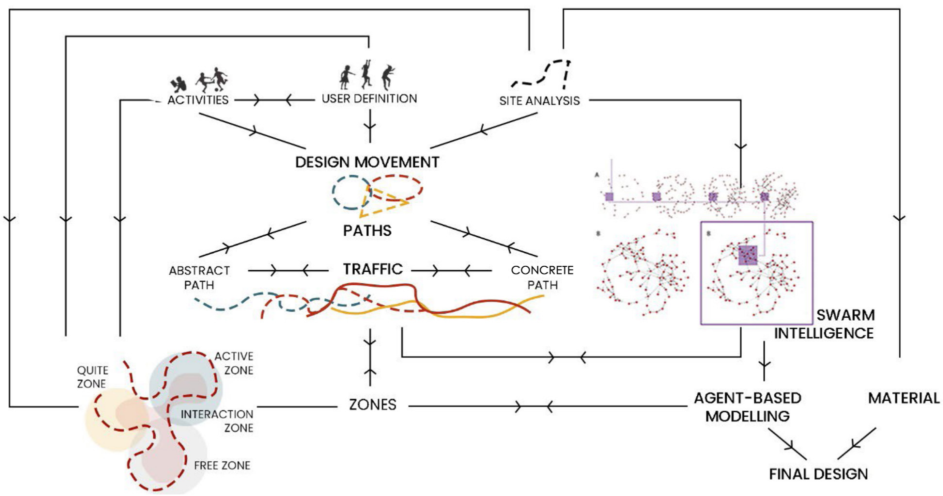

Figure 2. *Design flowchart by Group 3.*

phase was mostly associated with decisions regarding zoning. For instance, while Figure 3a illustrates the annual direct sun hours analysis by Group 1, Figure 3b shows the sunlight analysis of Group 2 for a definite time period which is between March and July. Similarly, Group 3 presented the solar analysis performed for the site (Figure 3c).

Generative design approaches were both used for analysis and design development. For instance, while swarm intelligence was used to analyze the individual and collective behavior of children, cellular automata were chosen for game design (Figure 3d). In the work of Group 7, Voronoi pattern was used for form finding for the task of layout design (Figure 3e). Last, the magnetic field diagram was used by Group 5 for form-finding on the site plan level (Figure 3f).

Additional research was also carried out to determine what effect the available materials may have on structures designed for use by children and on the life cycle assessments of the structures themselves. Since modularity was an important design criterion specified in the competition brief, experiments to combine the designed modules were conducted using 3D-printed models. Finally, the students presented their initial design solutions to be implemented at the site.

The 3 weeks between the first and

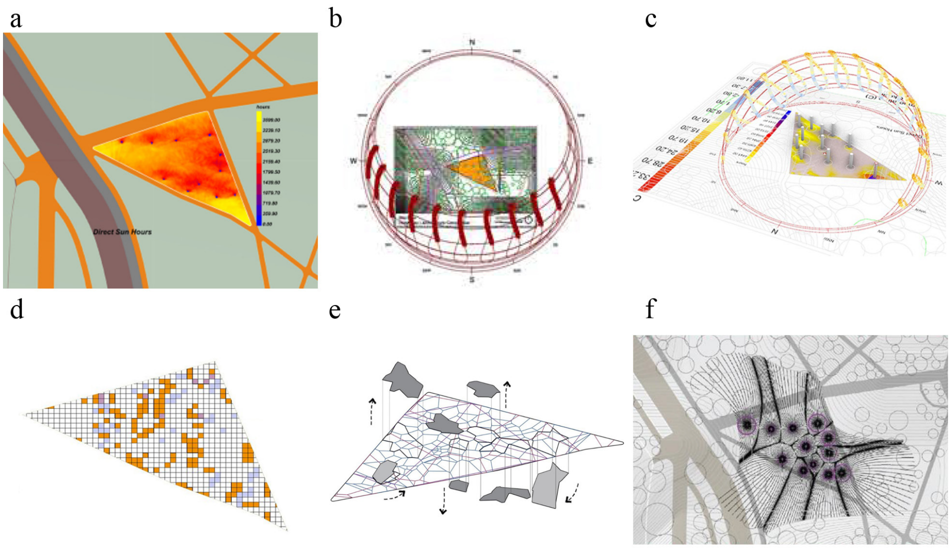

Figure 3. *Conducting environmental analysis and adaptation of generative approaches.*

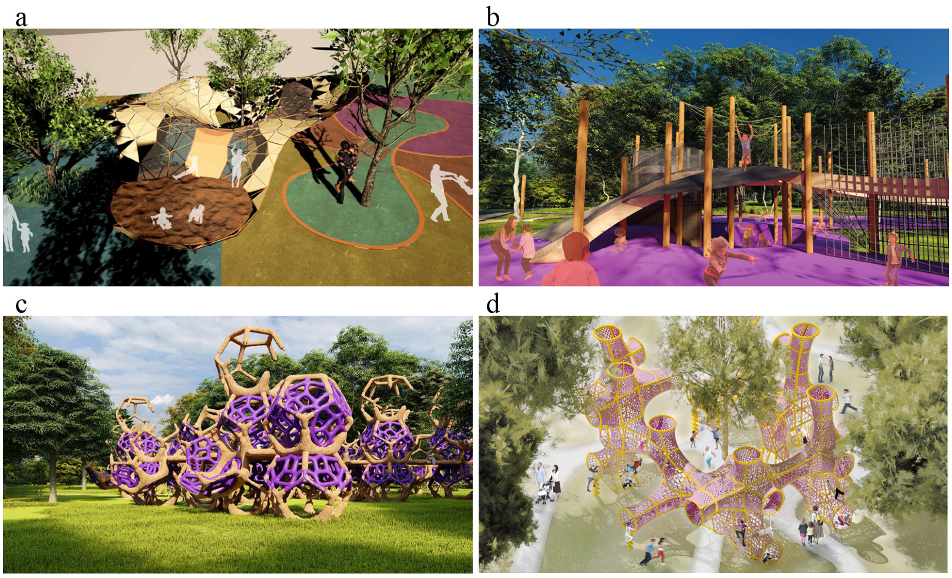

Figure 4. *Visuals from the final posters of (a) Group 1, (b) Group 3, (c) Group 4, (d) Group 5.*

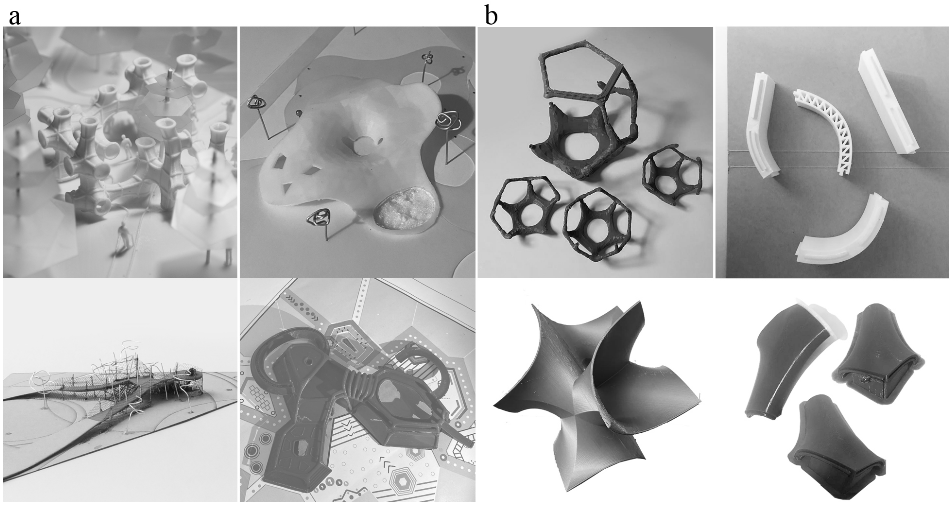

Figure 5. *Physical models (a) 1:100 scale models, (b) Detail models.*

second jury continued with design development through presentations, critiques, and discussions. However, the eleventh week, which was planned as the second jury week, overlapped with the submission deadline for the competition (15th December 2021). For this reason, the students participated in the second jury with their projects prepared in the specific format required by the competition. The following developments were observed in the projects submitted to the competition and evaluated by the second jury:

- The analyses of children's behavior and activities became more in-depth.
- The designs and their forms were developed in relation to the created/selected games and activities.
- The materials research resulted in definitive material selections.
- The components of the playground structure, as well as the details of their combination, were provided.
- The designs were implemented on the site and the areas not including the play structure were modeled to-scale with the master plan.

3.3.3. Process of week 12 to 15

Between the eleventh week (second jury and competition deadline) and the fifteenth week (third jury and final submission date), the students focused on the fabrication of their final designs. Since no physical models were requested by the competition, the students postponed the materialization and fabrication of their designs to the period between weeks 12-15. In the twelfth week, the tutors conducted face-to-face lectures and tutorials to introduce the students to the 3D printers and software necessary to fabricate the models of their designs. During the materialization and digital fabrication process, the students continued to develop their designs according to the critiques given by the second jury and presented their projects for the final jury review (Figure 4).

For their final submission (week 15), the groups presented posters and 1:100 scale physical models (Figure 5a); four of the eight groups also provided detail models at various scales. These detail models were made to clarify the assembly of playground parts or to show their structural principles (Figure 5b).

Table 1. *Design and evaluation criteria.*

Analysis			Design			Modelling			Fabrication/Materialization		
A1	A2	A3	D1	D2	D3	M1	M2	M3	F1	F2	F3
Ability to analyze children behaviour	Ability to analyze playgrounds and the activity of playing	Ability to analyze the site, environmental conditions, and program	Ability to develop a design problem in terms of innovative/computational approaches	Ability to develop appropriate design solution for children (scale, security etc.)	Ability to develop a sustainable design solution (Life Cycle Assessment, material selection etc.)	Ability to use parametric tools	Ability to use generative tools	Ability to integrate various data (climate, movement, material behavior etc.)	Ability to materialize the design with the proper material	Ability to use digital fabrication tools	Ability to develop design with digital fabrication solutions (trial-error etc.)

Table 2. *Evaluation results of the peer-reviewers and guest jury members.*

Peer Reviewers (S)	Ranked as Worst	Ranked as Best
S1	Group 2 (46)	Group 5 (55)
S2	Group 2 (50)	Group 4 (57)
S3	Group 2 (49)	Group 7 (59)
S4	Group 2 (51)	Group 7 (59)
S5	Group 8 (47)	Group 6 (60)
S6	Group 1 (50)	Group 4 (57) Group 6 (57)
S7	Group 8 (28)	Group 3 (53) Group 4 (53)
S8	Group 8 (50)	Group 1 (53) Group 7 (53)
S9	Group 4 (50)	Group 7 (55)
S10	Group 8 (51)	Group 4 (57) Group 7 (57)
S11	Group 7 (52) Group 2 (52)	Group 5 (55)
S12	Group 8 (49) Group 6 (49)	Group 2 (56)
S13	Group 6 (49)	Group 1 (55)
S14	Group 2 (54)	Group 5 (59)
S15	Group 6 (49)	Group 1 (55)
S16	Group 8 (47)	Group 1 (58)
S17	Group 8 (47)	Group 1 (58)
S18	Group 4 (52) Group 3 (52)	Group 5 (58)
S19	Group 7 (48)	Group 5 (57)
S20	Group 7 (43)	Group 1 (55) Group 5 (55)
S21	Group 2(48)	Group 1 (58) Group 8 (58)
S22	Group 8 (47)	Group 5 (58)
S23	Group 8 (46)	Group 5 (56)

Jury Members (J)	Ranked as Worst	Ranked as Best
J1	Group 1 (36)	Group 4 (60)
J2	Group 8 (31)	Group 3 (60)
J3	Group 2 (44)	Group 3(60) Group 5 (60) Group 6 (60)
J4	Group 8 (35) Group 2 (39)	Group 5 (50)
J5	Group 8 (39)	Group 5 (60) Group 6 (60)
J6	Group 8 (22)	Group 4 (52)
J7	Group 8 (35)	Group 4 (52)
J8	Group 8 (37)	Group 2 (54) Group 5 (54)
J9	Group 8 (42)	Group 6 (59)

Table 3. *Summary of the evaluations (overall).*

Project	Voted as Best by Jury Members	Voted as Worst by Jury Members	Voted as Best by Peer Reviewers	Voted as Worst by Peer Reviewers
Group 1	0	1	7	1
Group 2	1	2	1	7
Group 3	1	0	1	1
Group 4	3	0	4	2
Group 5	5	0	8	0
Group 6	3	0	2	3
Group 7	0	0	5	3
Group 8	0	7	1	9

*The number shows that how many people voted for the best/worse case.

During the modeling phase, digital models created with Rhino CAD software were exported in .STL or .3MF format for the 3D printing preparation process. Before the printing phase, the dimensions of the models were set to millimeters and scaled. The models were imported into CURA software and were then sliced to evaluate their 3D printability. Considering the printing capacities of the available 3D printers for the course, the majority of the 3D printing operations were performed using Fused Deposition Modeling (FDM) 3D printers (Creality Ender-3, Creality Ender-6, Ultimaker 3-Extended, and Creality CR10-S5) and PLA material supplied by the ITU Faculty of Architecture. However, the student groups were also free to use any 3D printers that they owned or had access to. Five student groups (Group 2, Group 4, Group 6, Group 7, and Group 8) used the facilities of the ITU Faculty of Architecture for the 3D printing of both their 1:100 scale project models and their detail models. During the 3D printing process, a trial-and-error approach was followed and most of the digital models had to be 3D printed more than once. The situations that commonly caused errors in the 3D printing process were as follows:

- Lack of necessary thickness: In each layer, the thinnest part of the model should be at least twice the thickness of the nozzle diameter. The 3D printers used for this project have a nozzle diameter of 0.4 mm. This means that the thinnest part of the models was required to measure at least 0.5 mm.
- Lack of adhesion surface: 3D printed objects require sufficient ground surface contact with the print bed for good adhesion. There are options to increase the first layer surface (brim, raft) to reduce the chance of 3D prints breaking off the print bed.
- Support material removal: Some of the models exceeded the maximum amount of overhangs that the 3D printers can support (around 60°). Support geometry was added to the models in order to achieve a successful print, but removing the support material after printing increased the risk of damage, especially for those models with thin parts.

For the final submission, except for that of Group 2, all the other models were successfully 3D printed. Due to the wire-frame nature of the Group 2 design, it was impossible to 3D print at a scale of 1:100 using the FDM method. The model was 3D printed using a stereolithography (SLA) machine after the final submission date with the permission and support of the tutors.

According to the competition brief, the size of the playground design was limited to 50 square meters. Therefore, the 1:100-scale version of each design solution was printable in a basic 3D printer as a single piece due to their small size. However, conventional model-making techniques were preferred for the construction of a 50x25 cm scale model of the site. For the physical model of the site and the existing elements in the park, students used various materials such as paper, foam

Table 4. Evaluation results of the peer-reviewers and guest jury members (phases and individual criterion).

Peer Reviewers (S)	Phase Rated as lowest	Criteri-a/on Rated as lowest
S1	D	D3
S2	M,F	F3
S3	M	D1
S4	F	D3, M3, F1, F3
S5	A	A1,A2,A3,D3,M1,M2,F1,F2
S6	D,F	D2,M1
S7	F	D1
S8	D	D1,M3
S9	D	D1,D2
S10	A	M3
S11	D	A2
S12	M	A1,M1
S13	M	M1
S14	D	D3
S15	M	M1
S16	D,M,F	M1
S17	D,M,F	M1
S18	D	D3
S19	D	D2
S20	A,D	A3,D2
S21	D	D2,D3,M3
S22	D	D3
S23	F	M3

Jury Members (J)	Phase Rated as lowest	Criteri-a/on Rated as lowest
J1	F	F1
J2	F	F3
J3	M	M2
J4	D	D1
J5	F	F1,F2,F3
J6	F	F1
J7	F	F2
J8	D, F	D3, F1
J9	M	M2

board, cardboard, net, metal stick, steel wire, miniature plants, and plexiglass.

3.4. Evaluation of the final work

For the final jury, a quantitative evaluation method was adopted. The tutors prepared an evaluation form containing three criteria to be rated under each main phase, namely analysis (A), design (D), modeling (M), and fabrication/materialization (F). The twelve evaluation criteria were extracted from the course catalog, the syllabus of the course, the competition brief, and the discussions that took place during the mid-term juries (Table 1).

On the final jury day, the same evaluation form was shared with the students for peer review and with the jury members for expert review. 23 of the 24 students who took the course and made their presentations in the final jury filled in the evaluation form and 9 out of the 10 jury members also completed their evaluations. The evaluation results of the peer reviewers and jury members are given in Table 2. Table 3 and Table 4 summarize both sets of evaluations for further analysis given in the following section.

3.5. Evaluation of the competition projects by the organization

The results of the competition were announced in February 2022. Four projects received awards: Winner (Group 6); People's Choice award (Group 4); and Editor's Choice awards (Group 3 and Group 7). In addition to the jury's evaluations of the projects, there were also valuable comments posted on the accompanying competition website. With regard to the winning Group 6 design, it was stated that the proposal is very interesting, conceptual, spatial, and has an interesting constructive logic that uses a module from which multiple possibilities and spaces can be created and which can be installed at various locations. It was also underlined that it was the best proposal as it quickly hooked into a simple and consistent idea and concept in line with playground design (Figure 6a). For Group 4, which received the People's Choice award, it was mentioned that although their project proposed a constructive logic with material possibilities, it did not present any new approaches to design or possible future explorations (Figure 6b). For Group 3 and Group 7, which received Editor's Choice awards, it was stated that the Group 3 project addressed the issue of being able to develop multiple spaces and uses, but that it lacked material development. It was recommended that the design avoid catwalks in favor of building everything from mesh to better define games (Figure 6c). For Group 7, the jury found it interesting how their project developed a section with all play opportunities but that it was chaotic in its overall design (Figure 6d).

4. Results and findings

This section presents the results of the evaluations given in Section 3.4 and Section 3.5 and gives the related findings.

- An overlap was observed in the two projects voted as the least successful (Group 8 and Group 2) by the guest jury members and peer reviewers. Except for these two projects, only the work of Group 1 was the lowest-rated project by the jury members (once). On the other hand, all the projects except that of Group 5 were rated as the lowest at least once by the peer reviewers.
- Both the guest jury members (5 times) and the students (8 times) rated the Group 5 project as the best. A conflict was observed regarding the project of Group 1,

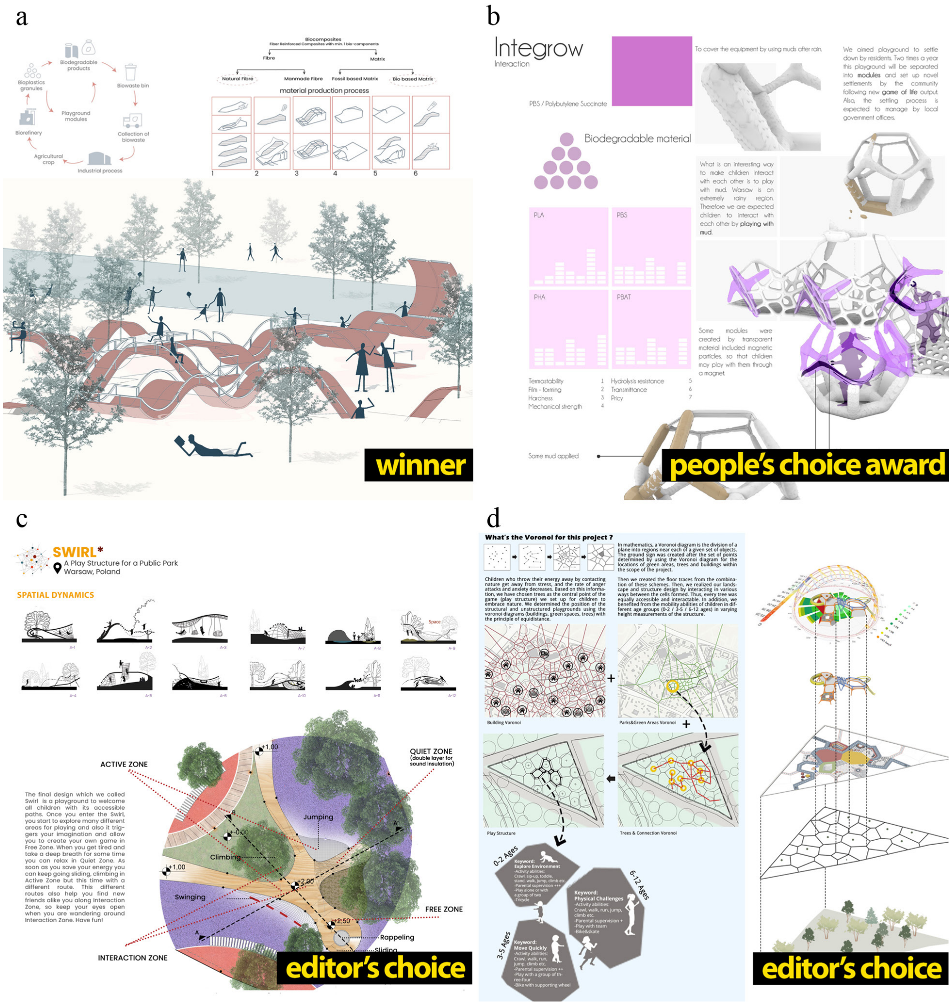

Figure 6. *Prize winning projects developed in DDM course. (a) Winner; (b) People's choice; (c) Editor's Choice; (d) Editor's Choice.*

which was rated as the best 7 times by the peer reviewers but was not rated as the best by the guest jury members.

- With regard to the project evaluations made by the guest jury members, the D, F, and M phases were rated as the worst phase at least once. While 6 of the 9 jury members evaluated the F phase as the worst, the D and M phases were rated worst 2 times. On the other hand, the students rated D (15 times), F (7 times), M (6 times), and A (3 times) as the worst.
- Phase F, which the jury members rated as the most unsuccessful, and phase D, which the students rated as the most unsuccessful, do not overlap. However, the F phase was rated as the most unsuccessful by the students 7 times. While the jury members never voted for phase A to be the most unsuccessful, the participants noted it 3 times.
- When considering the evaluation of the criteria instead of phases, according to the jury members the fabrication material selection (F1) and the ability to use digital fabrication tools (F2) should be developed. Due to the competition's final submission date, the fabrication phase was limited to the weeks following the second jury. Students' opportunities to experiment with materials (F1) and experience digital fabrication tools (F2) were also limited in a completely online course. However, while generative modeling tools (M2) were used in some phases of the projects, they were not dominant throughout the entire workflow. Since the generative modeling tool was only used in a single phase, its role in the final project was found to be insufficient.
- When the evaluation done by the

students was examined in detail, the sustainability of the design solutions (D3) was criticized more compared to the appropriateness of the design solutions for children (D2), and the development of innovative/computational approaches.

- When the evaluations of the peer reviewers and jury members (Table 3) were compared to those of the competition jury, there were clear differences in opinion. Group 5 was evaluated to have the best project by the peer reviewers and jury members during the semester, but they were unable to participate in the competition.
- The projects that received awards from the competition jury did not match the final evaluations. A reason for this mismatching was the difference between the evaluation criteria defined by the tutors and those of the competition jury. The 12 criteria listed in Table 1 were defined by the tutors, but the competition jury focused on their own subjective evaluation criteria that considered the conceptual, spatial, construction, and material aspects of the projects.

5. Discussion and conclusion

This study presents a competition-based framework and tests it through a digital design studio experience. The quantitative evaluations by both the guest jury members and the peer students, as well as the qualitative evaluation by the competition jury, allowed the tutors to assess the effectiveness of the proposed framework and improve the course. As these qualitative and quantitative evaluations were based solely on the course's final products, the tutors also considered the project development phases throughout the semester. According to the tutors' observations, students had no difficulty developing a project that considers the real site, user, and architectural program described in the competition brief while employing computational design approaches, methodologies, and tools throughout the process. It is possible to develop and represent a competition project with the traditional use of CAAD software. However, there were no misconceptions about the methodology used among the students, and CAAD tools were not used in the traditional manner. On the other hand, the fact that students were awarded in an international design competition demonstrates that projects of a certain level of quality can be produced using the proposed framework.

The evaluations of the guest jury members (partially supported by peer reviewers) showed that the most evident shortcoming in the assignment occurred in the materialization phase. Within this context, the authors raised the question of what kind of strategies should be developed to produce a more successful materialization phase. When the project processes were examined, it was observed that the initial studies of materialization presented to the first jury were abandoned in the later process. The fact that physical models were not requested in the competition was the most important factor for the submission of the competition projects as this followed a design and modeling path that was already familiar to the students. On the other hand, being completely online, working on computers instead of in an atelier, and having limited access to digital fabrication equipment are other factors that affected the materialization stage negatively. The time period between weeks 12 and 15 was determined as the fabrication phase, and the students faced all of the material selection, structural issues, and detail problems of the physical models during these weeks.

The authors suggest the following strategies to achieve more successful results in the fabrication phase:

- Fabrication at every phase of the semester without the requirement for a fully developed design,
- Conducting seminars and tutorials on the use of digital fabrication tools at the beginning of the semester instead of during week 12.
- Short-term integration of consultants from related disciplines within the university to resolve structural and detail problems.

Another strategy for increasing the efficiency of the materialization phase is to continue fabrication work in the graduate program's fabrication-oriented courses the following semester. Award-winning projects of some competitions are built by the institution that launched the competition. In the case that the competition project becomes a construction, a collaborative study with industry actors can be conducted to improve the project's quality in detail production, material selection, and structural issues.

In contrast to the guest jury members, the students regarded phase D as the most unsuccessful. Since the beginning of the semester, students have evolved their designs based on a variety of criteria such as child behaviors, types of play, security, and the scale of the structure in relation to the size of the children. Furthermore, the materials to be used in the design's construction, the material's sustainability, and the life cycle assessment of the playground have been explored since the conceptual design stage. According to the evaluations, the students have gained a more critical perspective for phase D, where they had the opportunity to think deeply, as a result of these discussions.

Similar to the project-based CAAD pedagogies discussed in Section 2.1, the framework presented in this study is project-based and includes both individual and group works. Current project-based digital design pedagogies are not limited to digital productions; rather, through the use of digital fabrication, their processes result in physical products at 1:1 scale (Stavric et al., 2019; Wallisser et al., 2019). However, since the organization did not request the fabrication of the competition projects, the projects were not rationalized/ simplified for 1:1 scale fabrication.Instead, using digital design and modeling tools and methods, conceptual designs that focused on the site and the user were developed. In the presented teaching experiment, the site served as more of a context and environmental data input to the project. The physical characteristics of the site (e.g., level, paving) are not considered in the design process, yet is likely to arise during a 1:1 scale fabrication of the design on site. In other project-based digital design pedagogies, designs are generally developed for a generic user (Sousa & Xavier, 2015; Agirbas, 2020; Lanzara, 2021). This teaching experiment differs from other digital design pedagogies in that it includes an in-depth analysis of children's behavior and physical play, as well as the development of customized designs for children as users.

In previous years, distance education was not the communication type of course. It was preferred for the experiment and semester presented in this paper, and it offered some advantages. The group work of the students created a synergy in this online course, and the collaborative environment provided by the online meeting platforms positively affected the design process with task definition, completed tasks, and transparent data flow. Participation in the competition gave the students the opportunity to compete with other designers from all around the world instead of the other students enrolled in the course. Being involved in a design competition also lead to the students' exploration of novel design solutions. In addition, having a strict submission date and the opportunity to win awards provided extra motivation.

The proposed framework could be used in other digital design studios. While the framework's components remain constant, their contents can change depending on the new term project or competition brief. According to the brief, the user profile, location, and architectural program may vary. Furthermore, the modeling approach and software (e.g., solid, parametric, generative), fabrication tool and technique, and scale of the prototypes may differ depending on the expected digital and physical outcomes.

Acknowledgment

The content of this paper was developed in the MBL 513E Digital Architectural Design and Modelling (DADM) course during the 2021-2022 Fall Term in the Architectural Design Computing Graduate Program at ITU. We would like to thank to our dear mentor Prof. Dr. Sinan Mert Şener, and our students for their hard work; Group 1-Triplay (Sena Ayça Metin Akşahin (S1), Bahar Okuyucu (S2), Fatih Erdil (S3), Merve Taşdelen(S4)), Group 2-Cocoon (Baver Bekiroğlu

(S5), Doğan Kalak (S6), Mehmet Salih Özalp (S7)), Group 3-Swirl (Ahsen Zeynep Doğan (S8), Hanım Gülsüm Karahan (S9), Baha Tekin (S10), Hatice Kübra Saraoğlu (S11)), Group 4-Integrow (Ahmet Keleş (S12), Alim Battal (S13), Betül Şen (S14), Osman Zinnur Melikoğlu (S15)), Group 5-FuzzyScape (Şeyma Bengü Özmutlu (S16), Zeynep Erkoç (S17)), Group 6-Plug'n Play (Kaan Büyükmıhçı (S18), Semin Erden (S19), Can Müezzinoğlu (S20), Ceylin Ceyda Hündal (S21)), Group 7- Challenge Playground (M. Münir Keleşoğlu (S22), Habibe Şenkal (S23)), Group 8- Batwing Minimal Surface (Ali Reza Gogani). We also would like to thank our jury members, for their valuable critics and support throughout the semester; Sinan Mert Şener (J1), Ayşegül Akçay Kavakoğlu (J2), Asena Kumsal Şen Bayram (J3), Altan Atik (J4), Salih Küçüktuna (J5), Çağda Özbaki (J6), Sabri Gökmen, Orkan Güzelci (J7), Derya Güleç Özer (J8), and İnanç Şencan (J9).

References

Acar, H. (2015). From module to space: Playground design. *Global Journal on Humanities & Social Sciences*, *1*, 301–313.

Achten, H. (1996). Teaching advanced architectural issues through principles of CAAD. *Proceedings of the 14th eCAADe Conference* (pp. 7–16). Lund, Sweden.

Achten, H. (2003). New design methods for computer aided architectural design methodology teaching. *International Journal of Architectural Computing, 1*(1), 72–91.

Agirbas, A. (2020). A teaching methodology for parametric design: a case study with parametric bench. *Proceedings of SIGraDi 2020: The 24th Conference of the Iberoamerican Society of Digital Graphics* (pp. 720–725). online conference.

Akçay Kavakoğlu, A., Güleç Özer, D., Domingo-Callabuig, D., & Bilen, Ö. (2021). Architectural design communication (ADC) in online education during COVID-19 pandemic: A comparison of Turkish and Spanish universities. *Open House International. 47*(2), 361–384.

Akin, Ö. (1990). Computational design instruction: toward a pedagogy. *Proceedings of the CAAD Futures '89 Conference* (pp. 302–316). Cambridge, MA.

Alnusairat, S., Al Maani, D., & Al-Jokhadar, A. (2021). Architecture students' satisfaction with and perceptions of online design studios during COVID-19 lockdown: the case of Jordan universities. *Archnet-IJAR, 15*(1), 219–236.

Andia, A. (2002). Reconstructing the effects of computers on practice and education during the past three decades. *Journal of Architectural Education, 56*(2), 7–13.

Asanowicz, A. (1989). Four Easy Questions. *Proceedings of the 1989 eCAADe Conference* (pp. 9.18.1–9.18.4). Aarhus, Denmark.

Asanowicz, A. (1998). Approach to computer implementation in architectural curriculum. *Proceedings of the 1998 eCAADe Conference* (pp. 4–8). Paris, France.

Barbour, A. C. (1999). The impact of playground design on the play behaviors of children with differing levels of physical competence. *Early Childhood Research Quarterly, 14*(1), 75–98.

Benabdallah, G., Bourgault, S., Peek, N., & Jacobs, J. (2021). Remote Learners, Home Makers: How Digital Fabrication Was Taught Online During a Pandemic. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (pp. 1-14).

Ceylan, S., Şahin, P., Seçmen, S., Somer, M. E., & Süher, K. H. (2021). An evaluation of online architectural design studios during COVID-19 outbreak. *Archnet-IJAR, 15*(1), 203–218.

Chiu, M. L., Liao, C. J., Wu, R. L., Peng, J. C., & Huang, C. C. (2003). Educating digital designers: a process-oriented approach. *Proceedings of the 21st eCAADe Conference* (pp. 583–586). Graz, Austria.

Covill, D., Katz, T., & Morris, R. (2008). Teaching and assessing CAD using online demonstrations. *Proceedings of E&PDE 2008: the 10th International Conference on Engineering and Product Design Education* - Vol 2 (pp. 681–686). Barcelona, Spain.

Duarte, J. (2007). Inserting new technologies in undergraduate architectural curricula. *Proceedings of the 25th eCAADe Conference* (pp. 423–430). Frankfurt am Main, Germany.

Flemming, U., & Schmitt, G. (1986). The Computer in the Design Studio. Ideas and Exercises that Go Beyond Automated Drafting. *Proceedings of the ACADIA Workshop '86* (pp. 55–78). Houston, TX.

Gelmez, K., & Arkan, S. (2022). Revisiting a CAD course in the midst of the global pandemic with an activity-centered framework : Reflections from design students. *FormAkademisk*, *15*(1), 1–20.

Goepel, G., & Crolla, K. (2021). Secret Whispers & Transmogrifications: a case study in online teaching of Augmented Reality technology for collaborative design production. *Proceedings of the 26th CAADRIA Conference - Vol 2* (pp. 21–30). Hong Kong.

Gross, M., & Do, E. (1999). Integrating digital media in design studio: Six paradigms. *Proceedings of the American College Schools of Architecture Conference* (pp. 144–148). Minneapolis, MN.

Güzelci, O. Z., Sousa, J. P., & Xavier, J. P. (2022). Integrated Structural and Environmental Form-Finding: A Teaching Experiment. *Nexus Network Journal, 24*(1), 247–264.

Hemsath, T. L. (2010). Searching for innovation through teaching digital fabrication. *Proceedings of the 28th eCAADe Conference* (pp. 21–30). Zurich, Switzerland.

IPEMA (2022). International Play Equipment Manufacturers Association. Retrieved from https://ipema.org/ (accessed 10 January 2023).

Kokosalakis, J., Brown, G., & Moorhouse, J. (1997). Incremental reflective learning and innovative practice in Electronic Design Media. *Proceedings of the 15th eCAADe Conference*. Vienna, Austria.

Koutamanis, A. (1996). CAAD teaching in the electronic era. *Proceedings of the 14th eCAADe Conference* (pp. 239–242). Lund, Sweden.

Koutamanis, A. (1999). Approaches to the integration of CAAD education in the electronic era: two value systems. *Proceedings of the 1999 eCAADe Conference* (pp. 238–243). Liverpool, UK.

Lanzara, E. (2021). Generative Design Strategies for Customizable Prototypes: Academic Research and Entrepreneurial Education. In E. Garip, S. B. Garip (Eds.), *Handbook of Research on Methodologies for Design and Production Practices in Interior Architecture* (pp. 68–93). Hershey, PA: IGI Global.

Little, H., & Eager, D. (2010). Risk, challenge and safety: implications for play quality and playground design. *European Early Childhood Education Research Journal, 18*(4), 497–513.

Mark, E., Martens, B., & Oxman, R. (2001). The ideal computer curriculum. *Proceedings of the 19th eCAADe Conference* (pp. 168–175). Helsinki, Finland.

Mark, E., Martens, B., & Oxman, R. (2003). Preliminary stages of CAAD education. *Automation in Construction, 12*(6), 661–670.

Moore, R. C., Goltsman, S. M., & Iacofano, D. S. (1992). *Play for All Guidelines: Planning, Designing and Management of Outdoor Play Settings for All Children (2nd Edition)*. Berkeley: Mig Communications.

Naboni, R. (2016). Form-finding to fabrication of super-thin anisotropic gridshell. *Proceedings of SIGraDi 2016: The XXth Conference of the Iberoamerican Society of Digital Graphics* (pp. 418–425). Buenos Aires, Argentina.

Ostrowska-Wawryniuk, K., Strzała, M., & Słyk, J. (2022). Form Follows Parameter: Algorithmic-Thinking-Oriented Course for Early-stage Architectural Education. *Nexus Network Journal, 24*(2), 503–522.

Pektaş, Ş. T. (2007). A structured analysis of CAAD education. *Open House International. 32*(2), 46–54.

Pittioni, G. (1992). Concepts of CAAD-Instruction. *Proceedings of the eCAADe'92 Conference* (pp. 363–376). Barcelona, Spain.

Roberts, A., & Forster, W. (1998). From CAAD Lab to Studio: Integration of CAAD with studio in a 'linear'based scheme of study. *Proceedings of the EAAE/eCAADe International Workshop* (pp. 131–138). Leuven, Belgium.

Silva, N. F. (2000). Computer-Aided Architectural Design Teaching: a design oriented post-grad experience. *Proceedings of the 4th SIGraDi Conference* (pp. 370–373). Rio de Janeiro, Brazil.

Siu, K. W. M., Wong, Y. L., & Lam, M. S. (2017). Inclusive Play in Urban Cities: A Pilot Study of the Inclusive Playgrounds in Hong Kong. *Procedia Engineering, 198*, 169–175.

Sliwinski, J. (1996). CAAD-To Teach, or not to Teach?. *Proceedings of the 14th eCAADe Conference* (pp. 403–406). Lund, Sweden.

Sousa, J. P., & Xavier, J. P. (2015). Symmetry-based generative design and fabrication: A teaching experiment. *Automation in Construction, 51*, 113–123.

Stavric, M., Wiltsche, A., Bartaky, M., & Hess, E. (2019). Geometrically Controlled Digital Workflow from Scratch to Fabrication. In L. Cocchiarella (Ed.), *ICGG 2018 - Proceedings of the 18th International Conference on Geometry and Graphics (*pp. 1050–1061). Cham: Springer.

Susa, A. M., & Benedict, J. O. (1994). The Effects Of Playground Design On Pretend Play And Divergent Thinking. *Environment and Behavior, 26*(4), 560–579.

UNI.xyz (2021). Child Play - A Play Structure for a Public Park. Retrieved from https://uni.xyz/competitions/child-play/info/about (accessed 10 January 2023).

Voice of Play (2020). 2020 Survey on the Importance of Play and the Mental Impacts of Social Injustice in the U.S.. Retrieved from https://voiceofplay.org/2020-survey/ (accessed 10 January 2023).

Wallisser, T., Henriques, G. C., Riberio, A., & Menna, R. L. (2019). Weaving physical-digital networks: Brazil-Germany integration experience. *Proceedings of 37th eCAADe and 23rd SIGraDi Conference - Vol 1* (pp. 315–324). Porto, Portugal.

WBDG Whole Building Design Guide (2017). Playground Design Guide. Retrieved from https://www.wbdg.org/resources/playground-design-and-equipment (accessed 10 January 2023).

Weissenböck, R. (2021). Augmented Quarantine-An experiment in online teaching using augmented reality for customized design interventions. *Proceedings of the 39th eCAADe Conference - Vol 2* (pp. 94–104). Novi Sad, Serbia.

Yorgancıoğlu, D. (2020). Critical reflections on the surface, pedagogical and epistemological features of the design studio under the “new normal” conditions. *Journal of Design Studio, 2*(1), 25–36.