Using Modular Construction Brick-Based CAD in Online Design Education

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Abstract
The sudden change of design education into a distance education model due to the global pandemic in recent years has posed additional challenges for first-year architecture students, who have no prior design education foundation. These developments have forced instructors to tailor their tools and curricula to the changing situation. Considering the case, we propose a novel approach that will encourage students to develop architectural design ideas based on LEGO components and formal interventions that are familiar to the students. We conducted a student workshop as a design experiment using LEGO bricks in CAD, eliminating the constraints of physical space and mockup materials. In the three-day online workshop attended by thirteen first-year architecture, interior architecture, and industrial design students, the participants explored modular architectural thinking and production with LEGO bricks in a CAD environment. Participants were asked to create a user persona as their user, then design a living pod for that persona for an activity of their choice. The designers developed their architectural designs with online critiques given via CAD files and video conference presentations. They presented their final products as architectural boards and LEGO building instructions of their design. The model proposed in this workshop develops the fundamentals of some real-life architectural practice skills: the use of pre-engineered design modules such as real construction elements, or familiarizing novice students with the vocabulary of CAD tools through a construction toy they are very familiar with. This approach not only provides a valuable addition to exercises that can be used in distance architectural design education of first-year students, but also proposes an alternative tool for collaborative design in higher design education and practice. Feedback from the design workshop also provides guidelines for developing a specialized modular brick-based software tool for architectural design education.

Keywords: architectural design, design education, interaction design, distance education.

Uso de CAD Basado en bloques de construcción modular en la educación online en Diseño

Resumen
El repentino cambio de la educación en diseño a un modelo de educación a distancia debido a la pandemia global en los últimos años ha planteado desafíos adicionales para los estudiantes de arquitectura de primer año, que no tienen una base previa en educación en diseño. Estos desarrollos han obligado a los instructores a adaptar sus herramientas y planes de estudio a la situación cambiante. Teniendo en cuenta el caso, proponemos un enfoque que alentará a los estudiantes a desarrollar ideas de diseño arquitectónico basadas en componentes LEGO e intervenciones formales que sean familiares para los estudiantes. Realizamos un taller para estudiantes como un experimento de diseño utilizando ladrillos LEGO en CAD, eliminando las limitaciones de espacio físico y materiales de maquetas. En el taller en línea de tres días al que asistieron trece estudiantes de primer año de arquitectura, arquitectura de interiores y diseño industrial, los participantes exploraron el pensamiento y la produc-

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ción arquitectónica modular con ladrillos LEGO en un entorno CAD. Se pidió a los participantes que crearan una persona como su usuario y luego diseñaran una cápsula de vida para esa persona para una actividad de su elección. Los diseñadores desarrollaron sus diseños arquitectónicos con críticas en línea a través de archivos CAD y presentaciones de videoconferencia. Presentaron sus productos finales como tableros arquitectónicos e instrucciones de construcción LEGO de su diseño. El modelo propuesto en este taller desarrolla los fundamentos de algunas habilidades de práctica arquitectónica de la vida real: el uso de módulos de diseño prediseñados, como elementos de construcción reales, o familiarizar a los estudiantes novatos con el vocabulario de las herramientas CAD a través de un juguete de construcción con el que están muy familiarizados. con. Este enfoque no solo proporciona una valiosa adición a los ejercicios que se pueden utilizar en la educación de diseño arquitectónico a distancia de los estudiantes de primer año, sino que también propone una herramienta alternativa para el diseño colaborativo para la educación y la práctica del diseño superior.

Palabras clave: diseño arquitectónico, educación en diseño, diseño de interacción, educación a distancia.

Introduction

The outbreak of the COVID-19 pandemic required a rapid shift in higher design education media, tools and environments, as well as in course structure and curricula. The change from physical medium to the online studio proved to be exceptionally challenging for first-year architecture and design students, who have no prior design studio experience. The circumstances called for designing feasible, new and effective assignments to meet the course's learning outcomes. We aimed to consider creative processes that students are already familiar with, while utilizing materials they can easily find at home for design education.

LEGO bricks were a convenient choice as a base design element. Previous studies and works which utilized the LEGO system in architectural design education also remark on the advantages of using LEGO bricks as base units (Cristopher Turner, 2014). LEGO bricks are affordable and easy to acquire, as well as simple and practical to work with. They also have a great design potential with their inherent variability and modularity. These factors make building and designing with LEGO highly engaging for people. The LEGO system's component features and rules also allow high fidelity simulation and interpretation between digital and physical media. These features of LEGO bricks made us consider using LEGO brick-based CAD in online architecture and design education.

To this end, we organized the *Component-Based Living Units* workshop. We invited first-year students to explore modular architectural thinking using digital LEGO bricks. Each participant created a Minifigure persona and designed a living unit for a specific motivational activity for that persona. Then, they presented their works as digital presentation boards and building instruction manuals.

This paper presents our experiences and discusses the survey results as an overview of the workshop we propose. The aims of the workshop were: [1] designing a framework for an exercise for distant architectural design education of first-year students, [2] to propose an alternative tool for collaborative design for higher design education and practice, [3] familiarizing novice students with the vocabulary of CAD tools through a construction toy they are very familiar with, and [4] developing a specialized modular brick-based mixed reality design software for architectural design education based on the feedback from the design workshop.

Methodology

The participants of the workshop were selected from Istanbul Technical University's (ITU) Foundation Studio students. At ITU Faculty of Architecture, the design courses of the first three semesters are given by the initiative of all five departments called the "Foundation Studio" where first-year students of all departments are mixed (Gürer & Küçükersen, 2020). *Component-Based Living Units* workshop was organized as a part of the Foundation Studio workshops. The quota for the workshop was for 13 first-year (second semester) students. The workshops are announced online on ITU's learning management website with posters, short descriptions, requirements, and instructor bios with Eventbrite event links for registration. The participants were selected on a first-come, first-served basis. The participation requirements were enthusiasm on architectural design and playing with LEGO bricks, having completed the given reading list of three resources before the workshop, attending the workshop with a notebook or desktop PC with LeoCAD, Adobe Photoshop, and Adobe InDesign installed.

Participants

The participants of the workshop were 13 first-year students from the ITU Faculty of Architecture. The ages of the participants vary between 18 and 30 (age mean: 20, SD: 3.16); a majority of 8 students were 19 years old. Six students were female (46%), and seven students were male (54%). The distribution of the departments that students came from is as follows: 7 Architecture (53.8%), 3 Interior Architecture (23.1%), and 3 Industrial Design (23.1%). Eight students had used CAD tools before (61.5%), while five had no prior CAD tool experience (38.5%).

Workshop Protocol

The participants were given three pre-workshop reading assignments. *The LEGO Architect* (Alphin, 2015) and *The LEGO Architecture Idea Book* (Finch, 2018) were given as the resources for examples and inspirations on details, surface qualities, architectural tectonics, and structural forms with LEGO bricks. The chapter titled *Building Blocks of Thought* (Shores, 2017) was given as a reading about the conceptual and theoretical basis of how construction toys related with architectural design and thinking. In the lecture section of the workshop, discussion of the readings and inspiration materials took part along the introduction of the LEGO brick elements, types of LEGO pieces, and the building methods to have specific terminology in place.

In LEGO builds, the human scale is a complex issue. A brick configuration can represent a pole or a high-rise building, depending on the human scale. Therefore, we asked the participants to accept the height of a LEGO Minifigure to be equivalent to human height. This assumption gives us a scale of 42.5:1. Figure 1 shows the dimensions of a LEGO brick versus the dimensions of a LEGO brick when a Minifigure is scaled to human size.

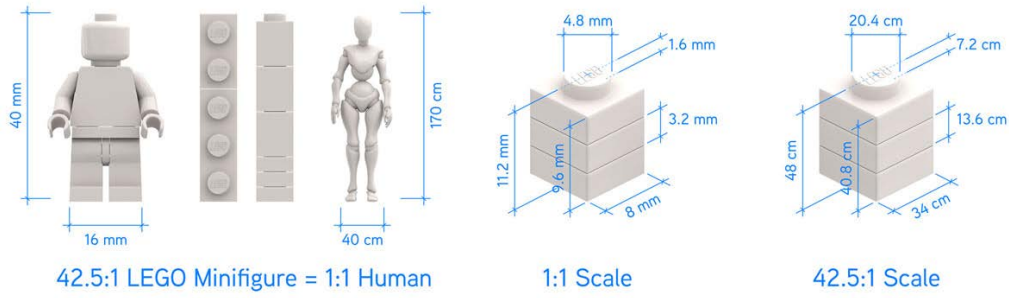

Figure 1. A LEGO Minifigure and a human figure compared in size and scaled to each other

LeoCAD is a LEGO CAD software that allows users to design with LEGO bricks, save their models, visualize it in 3D, and create building instructions. Students were asked to create their architectural designs in LeoCAD and develop them with online critiques given with the CAD files and video conference presentations.

The final assignment of the workshop was to create a persona as a custom Minifigure and to decide on a motivational activity for this persona. The participants were subsequently asked to design a single person living unit with a covered area for weather protection, accommodating sitting, sleeping, and the hobby activity they chose for the persona on a 12 by 12 by 12 unit volume with bricks, which corresponds to approximately 4 m x 4 m x 4 m.

The workshop took three days. The first day's four-hour program included introductions, lectures, discussion of reading assignments, LeoCAD training, and a warm-up exercise. Then the final assignment was announced. After a long design critique session in the second day's four-hour program, visualization in digital media and an InDesign crash course was conducted. Students had hands-on experience with the poster template using current design proposals. On the third day, all Foundation Studio workshops came together, and the works were introduced. The students presented their designs, then a general discussion of thoughts and feedback on the process took place.

Results

The students presented the final works as posters and step-by-step building instructions, similar to the instruction booklets one would expect to find in actual LEGO box sets. The final posters are being displayed online (Doma, 2021).

Post-workshop Survey Responses

At the end of the workshop, the participants took a survey to review their experiences and thoughts. The survey questions and student responses can be seen in Table 1. The results of the survey show that the participants had an overall positive experience.

Table 1.
Post-workshop evaluation survey results

	Mean Response Value (SD)	**Response Variables**
Design ideation potential with physical LEGO bricks*	4.23 (0.83)	1: Very poor 2: Poor 3: Acceptable 4: Good 5: Very Good
Design iteration potential with physical LEGO bricks‡	4.46 (0.78)	
Design ideation potential with LEGO bricks in CAD*	4.38 (0.65)	
Design iteration potential with LEGO bricks in CAD‡	4.38 (0.77)	
Advantage of physical LEGO bricks over CAD bricks	3.77 (0.93)	1: Much worse 2: Somewhat worse 3: Stayed the same 4: Somewhat better 5: Much better
Do you prefer LEGO based CAD as a design tool	0.77 (0.44) 3 No, 10 Yes	No: 0, Yes: 1

* $p>.05$, ‡ $p>.05$

The participants' responses to categorical survey questions clearly show that they see LEGO bricks as a base design element with high potential. The majority (77%) of the participants said they would use LEGO-based CAD as a design tool in their future projects.

There were also open-ended questions in the survey that asked students to briefly explain their process and give feedback on certain aspects of the procedure. The positive themes in the paragraph answers included: [1] the design process was more fun than other assignments, [2] LEGO bricks being an easily comprehensible and familiar design element, [3] ability to generate ideas faster and make iterations faster, [4] Advantage of having all the LEGO brick types and never running out of parts, and [5] ease of changing colors, and making changes to earlier steps without starting over. Negative themes were: [1] LEGO builds don't represent an architectural product accurately in detail, but good for conceptual sketches, [2] monolithic, indivisible and orthogonal nature of the LEGO pieces, [3] the loss of tactile feeling and instant feedback of physical bricks in CAD, [4] having all types of LEGO bricks brings with it some indecision and getting lost among the pieces, and [5] bugs and missing features of LeoCAD. The participants reported the most sought after features that the current tool (LeoCAD v21.03) lacked as [1] realistic connections that prevent physically impossible collided connections, [2] sharing creations and collaborating with other designers, [3] being able to organize the parts library for better search and frequently used parts, [4] structural stability check, and [5] realistic rendering in the viewport.

Discussion

In the proposed workshop framework, we examined the use of modular LEGO bricks that can be easily assembled with a simple set of rules to explore component-based design thinking and modular construction. This approach can help to teach the fundamentals of real-life architectural practice skills, such as the use of pre-engineered construction elements in architectural design.

The workshop resulted in a very open and inviting environment where the students would express their creative thinking using LEGO bricks. Students had a chance to produce building instructions with a step-by-step inductive approach, as opposed to the deductive approach in conventional architectural graphics. The participants also gave positive feedback about the advantage of learning to create product posters and architectural boards in InDesign using LEGO CAD outputs. Since the representations produced by the software were graphically correct and at a certain level of detail, the students could focus on the layout design.

The results of the survey show that the participants had a positive experience in the workshop in general. However, no statistically significant difference was found between their assessment of physical bricks versus CAD bricks ($p>0.05$). For generalizable comparisons between the CAD brick building versus physical brick building, specialized future studies with more participants are needed.

Following the workshop, students' survey responses have been further refined. Their feedback about the tool and the design process is currently being used to develop a specialized modular brick-based software tool for architectural design education as a part of our DREAMSCAPE research project.

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