INTERNATIONAL DESIGN CONFERENCE – DESIGN 2022
https://doi.org/10.1017/pds.2022.242

Overcoming Pedagogical Challenges in Product Design Education during the Pandemic

U. Thakker ✉ and S. Shrivastav

Atlas Skilltech University, ISDI School of Design and Innovation, India
✉ urvi.d.t@gmail.com

Abstract

The education sector got severely impacted by the Covid-19 pandemic. In the beginning, remote learning posed challenges to teachers and students. However, many new pedagogical experiments demonstrated the potential to continue even in the post-Covid world. This study explains the pedagogical change in product design education from a traditional studio-based model to a virtual environment, without compromising the learning outcomes. The paper also describes the learning experiences of the students and measures the effectiveness of virtual education through qualitative and quantitative studies.

Keywords: design education, product design, case study, design studio, virtual learning

1. Introduction

Design as an educational discipline blends an individual's creativity with theoretical knowledge and practical skills. All the disciplines of design - fashion design, communication design, interior design, and product design (referred to as PD) follow a studio-based approach that enables hands-on learning and peer-to-peer collaboration. The model is highly dependent on the physical environment that inspires the creation of new ideas. This traditional approach to learning and teaching design has often been beneficial in supporting interaction, active learning, and social engagement (Shreeve, 2012). The pandemic has unfortunately disconnected the students from this learning environment. Therefore, it is necessary to leverage the digital technology that can help achieve the learning outcomes (Shaqour, 2021). A digital classroom breaks the barriers of geography and time schedules. One of the most powerful advantages of the internet is the opportunity for global partnerships and learning from international teachers. Posey (2010) mentioned that by adopting digital tools, students from various parts of the world learn together, read each other's ideas, discuss common interests, and understand the differences in their attitudes. Time and place flexibility, equal opportunity for participation, and deeper reflection are dominant strengths of web-based learning (Graham, 2006). The virtual classroom allows feedback in written form for further and repeated reference (Senyapili and Karakaya, 2009).
This case study documents various approaches adopted by a design school in their undergraduate program of Product Design during the pandemic and measures its impact on the learning experience of the students. ISDI School of Design and Innovation (referred to as ISDI), Mumbai ensured minimum dilution of the academic pedagogy and attempted to provide an experiential learning environment to the students in the digital classrooms. Learning has never been immune to the societal conditions surrounding it and teachers have found suitable and unique ways of teaching and mentoring students online. New content delivery tools and methods, constructive interaction with the instructors, and collaboration with the co-learners have led to students' active engagement in the learning process. This paper describes the objectives of the study, summarizes literature on learning in a physical and virtual

design studio, pedagogical strategies implemented by ISDI, measurement of learning outcomes and learning experience, followed by discussion and conclusion.

2. Objectives of the study

Covid-19 pandemic disturbed the landscape of design education. The PD department of ISDI formulated pedagogical strategies that led to promising learning outcomes. The purpose of documenting this case study is twofold – like any other case study, it serves as a repertoire of the best practices for the design institutes to explore new ways of delivering academic content effectively in a digital classroom and secondly, it lists examples of the desired outcomes produced by the students despite the constraints caused by Covid-19. The study describes the academic initiatives of ISDI during this period in relation to the pre-pandemic period. The learning outcomes produced during both these periods are compared to serve as a measure of effectiveness of these new initiatives. The study also highlights the aspects of physical classroom that are difficult to achieve in an online classroom.

3. Design Studio

Design studios are the foundation of the product design curriculum. They have been central to design education because teachers use them to transfer design thinking knowledge and expertise to students during the development of projects (Dorta et al., 2016). Following a design process (such as double diamond) is critical to develop innovative and novel outcomes in a design studio. The emphasis of a design studio is on the presentation of design concepts and ideas, critique and communication involved in the design process, and learning of advanced design knowledge through reflection on design problems (Chen and You, 2010). PD courses - Process Drawing and Visualization, Computer Aided Industrial Design (CAID), User Research Methods, Mock-ups, Models and Prototyping enable the students to understand various concepts and acquire different skills that are utilized throughout the problem-solving process in the studio. The environment of the Physical Design Studio (PDS) includes elements such as white board, materials for experimentation, tools, workshop, and stationery materials that aid in learning. However, such an environment is irreplicable in a virtual set-up. The virtual design studio (VDS) requires critical alterations in the pedagogy and learning process compared to a PDS. The unique nature of the 'learning by doing' approach adopted in design education needs to be considered when investigating this emergency model of online learning (Alnusairat, 2020).

3.1. Physical Design Studio (PDS)

A design studio is a platform to apply the learnings from individual courses and thereby develop critical thinking skills in the students. Figure 1 shows the core elements of PDS, that include studio environment, materials, tools, design process, and the main actors - students as learners and faculties as the facilitators. PDS has a high visual and material character—it is full of material objects and design artifacts; studio walls and other less permanent vertical surfaces are covered with post-it notes, sketches, posters, and magazine clips for sharing ideas and inspiration; physical models and prototypes lying on the desks, amongst other things (Vyas et al., 2012). Senyapili and Karakaya (2009) mention that the possibility of face-to-face interaction is a key advantage of the place-based offering. The spatial aspects of design studios promote a style of learning that is based on continuous dialogue, conversation and critiquing each other's work (Vyas et al., 2012). Moreover, in PDS, much of design work is collaborative and group-oriented and physical nature of design studios can easily afford group orientation and collaborations (Vyas et al., 2012). Casakin H. (2013) suggests that the educational environment is characterized by a pedagogical approach that encourages help, interest, trust, and openness from teachers to students. Teacher support is dominant in the studio, indicating students' extensive reliance on their design instructors. Graham (2006) claims that PDS benefits from the strength of developing social presence, while at the same time suffers from limited time, lack of in-depth discussion, and the participation of all members.

https://doi.org/10.1017/pds.2022.242 Published online by Cambridge University Press

3.2. Virtual Design Studio (VDS)

Meeting all the learning objectives of a design studio in a virtual setting can be demanding. The success of a design studio is dependent on effective learnings from other courses, studio environment, studio resources, peer-to-peer interaction, and facilitation by the instructor. These factors vary in a virtual setting, some incrementally (such as faculty instructions) while some significantly (such as the studio environment). Duart & Sangrá, (2010, p. 7) mention that teaching possibilities of virtual education are innumerable and “requires a methodology that has to change the way teachers traditionally teach and students learn.” In addition to new ways of communication, online platforms support student learning, manage course content, and provide assessment tools, collaborative whiteboards, and design environments (Nespoli et al., 2021). Figure 1 shows difference in student workspaces in PDS and VDS.

Figure 1. Student workspace for PDS and VDS

VDS also has its own drawbacks and discomforts. The learning environment contributes to the success (or failure) of a virtual studio. Unlike PDS, the working environment of VDS is like any other online class. In a design studio using the design process is critical as it tests the understanding of concepts, encourages experimentation, and develops problem-solving abilities in students. But, due to lack of access to physical spaces, experiments can be hard to follow and ‘learning by doing’ is missing in a VDS. The studio classes are longer in duration than the regular classes to allow time for experimentation and prototyping. Longer duration and absence of practical activities can cause fatigue to the students in VDS. Thus, the well-being of students becomes crucial and online teaching needs to be humanized as emphasized by Raygoza et al. (2020). Instead of an in-studio faculty-student and peer-to-peer interaction, VDS does provide a new way to interact and use collaborative tools like Miro to further assist in discussions. But a study by Bernardo and Duarte (2020) pointed that the screen-mediated relationship of a teacher-student is a critical downside of VDS. A broad ramification of this is the inability to recognize or identify tell-tale signs of student needs or unrest. However, Senyapili and Karakaya (2009) point out that students can get written critiques on their designs within a predetermined time interval without waiting for the design instructor to give face-to-face oral critiques. Online learning experiences are also affected by administrative issues, social interaction, academic and technical skills, motivation, time, limited access to resources, and technical difficulties (Alnusairat, 2020). Figure 2 illustrates the elements of PDS and VDS.

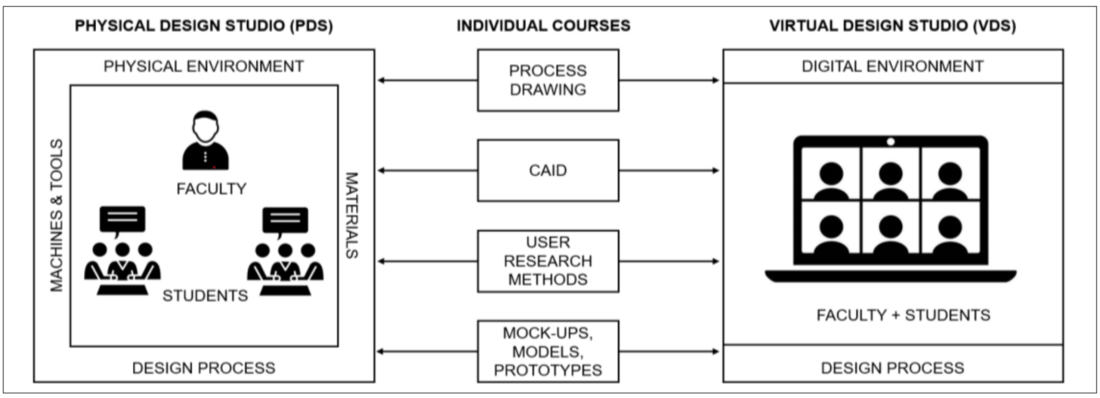

Figure 2. Elements of PDS and VDS

https://doi.org/10.1017/pds.2022.242 Published online by Cambridge University Press

3.3. Virtual Design Studio (VDS) at ISDI

Pedagogy of education defines the core principles of teaching in any institute and helps translate the learning objectives into actions. A new mode of learning implied new teaching approaches to meet the learning objectives and keep the students engaged throughout the journey. Planning at multiple levels – school, departments, and faculty, was undertaken at ISDI to successfully deliver these goals.

The average cohort size of PD students in each year (sophomores, juniors, and seniors) is fifty and students in each batch are equally spread across two sections. Each section has one lead and one support faculty driving the design studio course. This arrangement remained unchanged in the VDS. The faculty contact hours in PDS are usually five, but in VDS, these were reduced to four to cut down the screen fatigue for the students. Furthermore, a mid-semester break was planned every 5 weeks (in a 15-week semester) to help students comfortably complete their deliverables amidst personal challenges during the pandemic. This break also allowed faculties to reflect on the class performance and continuously refine their course of action.

The main objective of executing VDS in the PD department was to have minimum deviations on student learning with respect to PDS. Therefore, learning outcomes were redefined, course content was modified, new learning resources were evaluated, and evaluation metrics were recalibrated.

Design studio integrates individual learnings from various courses. Thus, alignment of learning outcomes of individual courses with the design studio was critical. For example, the lesson plans for courses involving concept development, mock-ups, and prototypes, accounted for use of materials and hand tools with easy availability for students. Project briefs were built around soft materials like paper, file card, corrugated sheets, low density styrofoam, and common household packaging waste. The missed opportunities to learn about other materials were to be fulfilled by special learning modules in the workshop, post the pandemic.

Faculties spent significant time researching and evaluating different learning tools and resources. Every lesson plan included a material list, material vendor database and software requirements which was shared with the students at the start of the semester. The use of content using audio-videos (example - TED talks, YouTube videos) was amplified for some courses. Faculties leading the skills-based courses equipped their set-ups at home to enable learning by seeing, hearing, and doing. Besides course planning and delivery, faculties were also involved in stakeholder management activities of the school. A school-level communication strategy was devised to ensure trust and build confidence in parents. As a result, faculties had to document weekly updates of their respective courses which were sent to the parents.

A Teaching Assistant (TA) was appointed for additional operational activities arising in the new learning environment. The TA (first author) worked closely with the Head of the PD Department (second author) and was responsible for planning, monitoring, and supporting the delivery of a hassle-free experience to the teachers and students. The department had four priorities - student engagement, education quality assurance, documentation of classroom practices and externalization of student work on the social media. As shown in Figure 3, ISDI ensured that the core elements of a design studio were retained in the VDS, and new elements were added (like the TA).

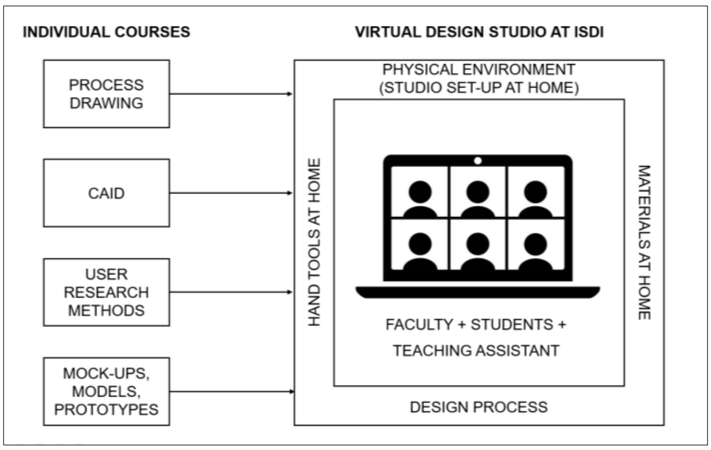

Figure 3. VDS at ISDI

https://doi.org/10.1017/pds.2022.242 Published online by Cambridge University Press

3.3.1. Discover

In the *discover* phase, understanding the problem and interpreting the issue are key (Severino et al., 2021). User research plays a crucial role to identify the problem. Unlike PDS, VDS has limitations of not being able to make contextual observations and take face-to-face interviews to build empathy with the users. This makes it difficult to see participants' context, behavior, tasks, and processes in their environment. As Zulaikha and Sari (2020) mention, some users are not accessible with the online medium, for example, workers in remote areas or little children with no access to personal digital devices. The educators at ISDI circumvented this challenge by confining briefs favorable to the situations, for example, the theme for the sophomore design studio was to design products for the elderly at home. Students reviewed the literature, observed, and interviewed their grandparents, parents, and caretakers. Online interviewing using Zoom was introduced by the faculty. It allowed students to conduct interviews with users in remote locations and external stakeholders such as doctors. To ensure in-depth primary research, students were encouraged to work in teams and analyze inputs from diverse team members present in different geographical locations. Over time, students were able to recruit more participants who also felt more comfortable sharing information online. For synthesis of the primary and secondary data, faculties introduced students to a co-creation platform called "Miro" that allowed students to visualize and analyze information in groups. As stated by Bodnenko D. (2020), use of virtual digital boards in the educational process also promotes the formation of students' ability to work independently with different sources of information, immediately see the result and evaluate their work by giving access to participants on the board.

3.3.2. Develop

For a design student, being able to generate ideas for design solutions is an important step (Zulaikha and Sari, 2020). Ideas generated are visualized through two courses– Process Drawing and Visualization and Computer Aided Industrial Design (CAID).

Process Drawing and Visualization

Sketches help to communicate and draft design ideas to other people involved in the process of designing new products (Joundi et al., 2020). In PDS, students gathered around the teacher to see a sketching demonstration. When students practiced, the teacher provided feedback and assisted students individually. To have a similar experience in VDS, a balance between synchronous and asynchronous learning was achieved. Figure 4 shows how both teachers and students faced their cameras onto the sketchbook to teach and learn respectively. It helped the teacher view multiple student sketches in real-time and provide feedback. Course outcomes suggest that students have favored this new method for learning product sketching and visualization techniques.

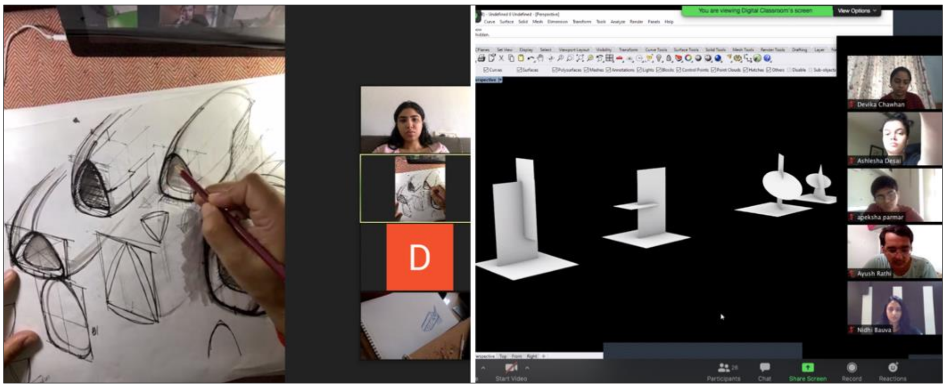

Figure 4. Drawing and CAID demonstrations by teacher

Computer Aided Industrial Design (CAID)

Today, design is inseparably associated with computer graphics, CAD, 3D scanning, and 3D printing technologies, as it has drastically transformed the way products and systems are designed (Camba, 2018). Hence, a course like CAID becomes essential for product design students. CAD tools including Rhinoceros 6.0, Autodesk Fusion 360 and Keyshot, allowed students to picture their ideas in three

https://doi.org/10.1017/pds.2022.242 Published online by Cambridge University Press

dimensions and make them intuitive to understand. Like PDS, in VDS too students looked at the teacher's work on screen, followed instructions and replicated it in their sketchbooks. Projector was replaced by the “share screen” feature of Zoom. Teachers used student’s projects to show live demonstrations of modeling or rendering to the class, as shown in Figure 4. These class videos were also recorded and shared to allow students to learn, practice and implement the teachings effectively in their home.

3.3.3. Deliver

To test, demonstrate and promote a final product, product designers create mock-ups, a scale or full-size model, which provides the most important parts of the functionality of the design (Tschimmel, 2012). Wood working, sheet metal cutting, and 3D printing are some of the processes used to develop prototypes but no access to workshops became a major limitation in the VDS. Zulaikha and Sari (2020) also mentioned that such situations should not stop the students from being creative in designing solutions with innovative materials and approaches. Teachers facilitated material exploration in class that guided students to exploit materials available at their disposal. Each student explored the possibilities of paper to create prototypes and carved fruits and vegetables to explore forms and test ergonomics of the design as shown in Figure 5. Working together enhanced class engagement as students could see and interact with each other. However, prototyping at home has limitations of getting direct assistance from teachers and workshop staff to achieve the fit and finish like that of PDS. Remote working also deprives students from acquaintance to workshop tools, machineries, and processes. These limitations were however tackled during the partial reopening of campus in Fall 2021 when students were invited for a two-day 3D printing and prototyping workshop.

Figure 5. Paper and vegetable prototypes in VDS

Creative tinkering of technology digitally

Programming is key for designers to prototype and experiment with intelligent behaviors (Alers S., 2009). “Creative Technology” is a course where students learn the fundamentals of electronic circuit design and coding using Arduino. In PDS, students used bread boards, printed circuit boards, Arduino kits, physical components such as resistors, capacitors and connecting wires to design the internals and test the functionality of the products. Virtually, students were introduced to an online tool called Autodesk TinkerCAD. TinkerCAD is an interactive and easy to use, one can generate reactions of sounds and light, and import data with different sensors (Wu et al., 2019). The codes on TinkerCAD can be embedded with Arduino, simulation environment offers more flexibility, work environment is safer and circuit performance can be easily analyzed (Mohapatra et al., 2020). In VDS, the teacher demonstrated for five minutes, and students followed the instructions for the next ten minutes. Students understood the principles of working and developed prototypes of simple electronic objects at home such as a torch, a TV remote, and a toy car. TinkerCAD can help eliminate technical errors and promote freedom to experiment without the investing in a variety of hardware. In VDS, students could not test their prototypes because it requires tangible interaction, and the students need to physically meet the target users to get their feedback (Zulaikha and Sari, 2020). However, faculties encouraged students to utilize Miro board and Zoom to perform usability testing of applications, websites, and other prototypes. When the campus reopened in Fall 2021, students had an opportunity to study physical components, convert their TinkerCAD simulations into physical prototypes and resolve their doubts as shown in Figure 6.

https://doi.org/10.1017/pds.2022.242 Published online by Cambridge University Press

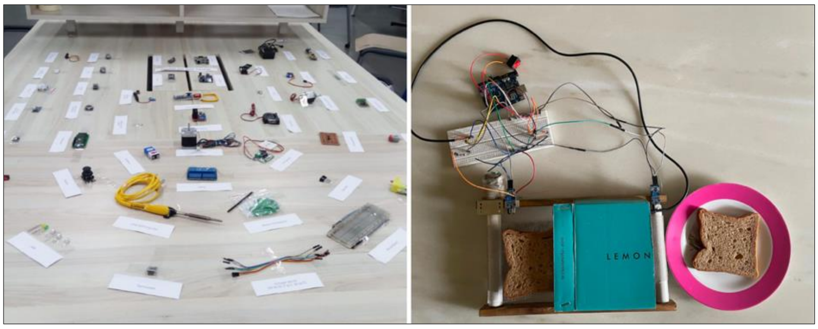

Figure 6. Physical prototypes post pandemic

4. Results

4.1. Learning Outcomes

Learning outcomes are a good indicator of student performance and the effectiveness of academic pedagogy. Evaluation of the learning outcomes done by faculties was considered as a measure for this study. Towards the end of the semester, course faculties scored the student performance for each student on 100. These scores for the four courses during the pandemic were compared with the scores for the respective courses in the pre-pandemic period. The pre-pandemic scores were drawn from the grade sheets of Fall 2019 semester, while the Fall 2020 grade sheets provided scores for the pandemic stage. Scores of all the students in a class from the two cohorts were considered for the study. The same faculties taught these courses in both the periods. Mean scores and standard deviation were then calculated for each course, as listed in Table 1.

Table 1. Comparison of student performance pre and during pandemic period

Course	Mean of marks scored by the class (μ)		Difference	Standard deviation of marks scored by the class (σ)		Difference
	Pre	During		Pre	During	
Research Methods	67.03	73.64	10%	15.56	8.49	-45%
Process Drawing	77.18	87.08	13%	7.72	7.55	-2%
CAID	89.42	88.83	-1%	4.66	5.33	14%
Mock-ups, Models	73.78	81.61	11%	14.83	9.68	-35%

4.2. Inferences

The mean scores of all the courses, except Computer-Aided Industrial Design (CAID), reflected 10% to 18% improvement in student performance in an online context. The values for standard deviation reduced significantly (upto 45%) for most courses, except for CAID. The increase in mean scores can be attributed to student performance, evaluation criteria and the grading instructions from the Dean of Academics. A new rubric for grading was used for evaluation.

Research Methods

In the online mode, the mean scores for Research Methods course improved by 10% and the standard deviation values dropped significantly, by 45%. The scores moved nearer to the mean implying the improvement in the learning outcomes produced by the students. Grading criteria includes research objectives, research planning, research execution, research synthesis and research documentation. Due to on-field primary research restrictions, the weightage for research execution was reduced and for documentation was increased. However, conducting primary research in online mode was convenient for both the students and the respondents. Time and location were not a constraint to connect with peers for analysis of the research data and tools like Miro made collaboration and information sharing easier. These findings are aligned to the study by Iranmanesh (2021) in which students' reported improvement in conducting self-dependent research to be a great asset in addressing the shortcomings. In

https://doi.org/10.1017/pds.2022.242 Published online by Cambridge University Press

another study (2021), Becerra's team was satisfied with collaboration on Miro as it conveyed an experience similar to individual groups working on different desks.

Process Drawing and Visualization

Student work in this course is graded based on their ability to represent ideas through different mediums. The quality of sketches, drawings, marker, and digital renderings produced provide a measure of their work. In a physical classroom, faculty demonstrate techniques for developing skills, review student work closely, and give instant feedback. A 13% jump in the mean scores for the Process Drawing and Visualization course was recorded, however the standard deviation scores improved marginally, by 2%. As the mean scores obtained for an online set-up point are equivalent to those scored in a physical classroom, it can be said that the outcomes were not impacted significantly despite the situation. Thus, the new method of synchronous sketching demos using two devices and giving instant feedback online was effective.

Computer-Aided Industrial Design (CAID)

CAID evaluation is decided basis students' ability to convert a 2D design into 3D form by selecting the appropriate software tools and features. No significant change in the mean scores were observed for CAID but the standard deviation values increased incrementally by 14% implying that the distribution of scores in online medium was wider than in the pre-pandemic period. The students watched the step-by-step demo shown by the faculty and then followed the same steps on their own systems. Limited attention spans and internet speed issues could be the reason for the incremental change in the distribution of scores. In a study by Alnusairat (2020), students cited the importance of improving software skills before beginning the online design class for better translation of their designs into the computer. In another study, significant improvement in the CAID skills was observed during the pandemic period (Iranmanesh, 2021).

Mock-ups and Models

In the online mode, the mean scores for Models and Mock-ups course improved by 11% and class performance significantly improved by 35%, implying the improvement in the learning outcomes produced by the students. Student are evaluated based on their thinking ability to select materials, scale and size followed by their craftsmanship to make physical models. In the absence of workshop facilities, faculties and administration believed that the course required major overhaul for its execution and evaluation of student work. However, the course witnessed many innovative approaches to model making developed by the students. Besides the regular materials such as paper and file card, students were seen using vegetables, fruits, and household waste to make their models and mock-ups. The evaluation criterion on the fit and finish of the models was excluded in the online mode.

4.3. Overall Experience of the Students

Students provided qualitative feedback and suggestions to elevate their virtual learning experience. These suggestions were focused on the interaction with teachers outside class, decreasing screen time, scheduled student presentations in class and access to digital libraries. Students quoted, "The college is making the most of their resources available as of now."; "The teachers are already making the most out of what we can do from home. I did not expect we could learn so much from home and experiment with materials at home." Suggestions were quoted as - "Only drawback is eyes pain by the end of the day. Frequent breaks can be given during the class"; "Can we have more interactions and less presentations".

5. Discussion

This case study documents various initiatives undertaken for virtual learning by the Product Design department of ISDI. It primarily compares the pre- and post-pandemic scenarios in a design studio based on the actions taken by ISDI and the outcomes produced by the students. Despite the limitations, the results demonstrate that all the courses achieved the intended learning objective to a large extent. However, importance of a physical space and infrastructure for successful delivery of learning outcomes cannot be denied. Although the online medium generated many 'firsts', such as first time use of certain tools and materials, it also lacked in some critical areas. Access to physical workshop, peer to peer interaction and socialization in campus were deeply missed by the students. It was evident from the survey that some students experienced digital fatigue due to the duration of classes. Nevertheless, success of some online academic initiatives has opened doors for the educators to continue them even in the post-Covid scenario. This study hinted at some positive developments for the faculties, such as documentation for future reference, recording classes to identify areas for improvement, and discovery of new areas for research. ISDI rightfully appointed a teaching assistant to dedicatedly work towards ensuring hassle-free learning experience. Developing new metrics for evaluation to address new circumstances demonstrates the institute's outlook and empathy at every stage of a student's journey. In the future, virtual platforms like zoom can augment the physical experience for the students to connect and discuss their projects post the college hours. Though the study is primarily focused on the students, faculties also played a significant role to strategize, plan, and execute their classes. The scope of this study can be extended to understand how the new teaching environment has treated faculties. This study can be extended to other programs in the design school to achieve an extensive understanding of design education in the pandemic times.

6. Conclusion

Design education in Product Design has been heavily dependent on the studio model that follows a learning by doing approach. The pandemic challenged the physical nature of the studio model that needed to be critically addressed at multiple levels. This case study describes how product design department at ISDI responded to the pandemic situation at the strategic, operational, and personal level. It aimed to deliver similar learning experience in virtual setting as in the physical one. Despite slow beginning, continuous improvement helped get close to the desired state. Faculties demonstrated a high degree of agility in evaluating new learning resources, reworking on their lesson plans, and addressing student queries. Innovative ways for the course delivery by the faculties and their empathy towards students was observed. Students making mock-ups using available, yet unusual resources (like vegetables) are a proof of development of their critical thinking ability. New ideas for learning that originated in a virtual classroom suggest that virtual cannot be considered temporal. The new format of learning has demonstrated good indicators of it being a mainstream or a hybrid approach post pandemic. However, pedagogical challenges like developing functional prototypes and other academic challenges, such as student fatigue and lack of in-person social interactions, are not completely addressed in the virtual mode. While the virtual experience can be further elevated, physical experience cannot be entirely eliminated.

References

Alers, S., Hu, J., 2009. AdMoVeo: A Robotic Platform for Teaching Creative Programming to Designers, in: Chang, M., Kuo, R., Kinshuk, Chen, G.-D., Hirose, M. (Eds.), Learning by Playing. Game-Based Education System Design and Development, Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 410–421. https://doi.org/10.1007/978-3-642-03364-3_49

Alnusairat, S., Al Maani, D., Al-Jokhadar, A., 2020. Architecture students 'satisfaction with and perceptions of online design studios during COVID-19 lockdown: the case of Jordan universities. ARCH 15, 219–236. https://doi.org/10.1108/ARCH-09-2020-0195

Becerra, Z.M., Fereydooni, N., Kun, A.L., McKerral, A., Riener, A., Schartmuller, C., Walker, B.N., Wintersberger, P., Kun, A.L., 2021. Interactive Workshops in a Pandemic: The Real Benefits of Virtual Spaces. IEEE Pervasive Comput. 20, 35–39. https://doi.org/10.1109/MPRV.2020.3044072

Bodnenko, D.M., Kuchakovska, H.A., Proshkin, V.V. and Lytvyn, O.S., 2020, May. Using a virtual digital board to organize student's cooperative learning. In AREdu (pp. 357-368).

Bernardo, N., Duarte, E., 2020. Design, education, and the online tech-pandemic. SDRJ 13, 577–585. https://doi.org/10.4013/sdrj.2020.133.22

Camba, J.D., Kimbrough, M., Kwon, E., 2018. Conceptual product design in digital and traditional sketching environments: a comparative exploratory study. JDR 16, 131. https://doi.org/10.1504/JDR.2018.092810

Casakin, H. and Davidovitch, N., 2013. Learning spaces and social climate in architectural education: design studio vs. traditional classroom. In DS 76: Proceedings of E&PDE 2013, the 15th International Conference on Engineering and Product Design Education, Dublin, Ireland, 05-06.09. 2013.

Chen, W., You, M., 2010. Student response to an Internet-mediated industrial design studio course. Int J Technol Des Educ 20, 151–174. https://doi.org/10.1007/s10798-008-9068-2

Dorta, T., Kinayoglu, G., Boudhraâ, S., 2016. A new representational ecosystem for design teaching in the studio. Design Studies 47, 164–186. https://doi.org/10.1016/j.destud.2016.09.003

DUART, J. and SANGRÀ, A., 2000. Aprender en la virtualidad-Gedisa.

Graham, C.R., 2006. Blended learning systems. The handbook of blended learning: Global perspectives, local designs, 1, pp.3-21.

Iranmanesh, A., Onur, Z., 2021. Mandatory Virtual Design Studio for All: Exploring the Transformations of Architectural Education amidst the Global Pandemic. Int J Art Des Educ 40, 251–267. https://doi.org/10.1111/jade.12350

Jones, D., Lotz, N., Holden, G., 2021. A longitudinal study of virtual design studio (VDS) use in STEM distance design education. Int J Technol Des Educ 31, 839–865. https://doi.org/10.1007/s10798-020-09576-z

Joundi, J., Christiaens, Y., Saldien, J., Conradie, P., De Marez, L., 2020. AN EXPLORATIVE STUDY TOWARDS USING VR SKETCHING AS A TOOL FOR IDEATION AND PROTOTYPING IN PRODUCT DESIGN. Proc. Des. Soc.: Des. Conf. 1, 225–234. https://doi.org/10.1017/dsd.2020.61

Mohapatra, B.N., Mohapatra, R.K., Jijnyasa, J. and Shruti, Z., 2020. Easy performance based learning of arduino and sensors through Tinkercad. International Journal of Open Information Technologies, 8(10).

Nespoli, O.G., Hurst, A., Gero, J.S., 2021. Exploring tutor-student interactions in a novel virtual design studio. Design Studies 75, 101019. https://doi.org/10.1016/j.destud.2021.101019

Posey, G., Burgess, T., Eason, M. and Jones, Y., 2010, March. The Advantages and Disadvantages of the Virtual Classroom and the Role of the Teacher. In Southwest Decision Sciences Institute Conference (pp. 2-6).

Raygoza, M., León, R. and Norris, A., 2020. Humanizing online teaching. Unpublished manuscript]. Kalmanovitz School of Education Faculty Works http://works. bepress. com/mary-candace-raygoza/28.

Senyapili, B., Karakaya, A.F., 2009. The Future Setting of the Design Studio. OHI 34, 104–112. https://doi.org/10.1108/OHI-01-2009-B0012

Severino, L., Petrovich, M., Mercanti-Anthony, S., Fischer, S., 2021. Using a Design Thinking Approach for an Asynchronous Learning Platform during COVID-19. ije 9, 145–162. https://doi.org/10.22492/ije.9.2.09

Shaqour, E., 2021. Benefits, Disadvantages, and Constrains of Applying Blended and Virtual Design (Case Study: Studios at Nahda University). (Dept. A). MEJ. Mansoura Engineering Journal 46, 54–62. https://doi.org/10.21608/bfemu.2021.158861

Shreeve, A., 2012. The way we were? Signature pedagogies under threat.

Tschimmel, K., 2012. Design Thinking as an effective Toolkit for Innovation. In ISPIM Conference Proceedings (p. 1). The International Society for Professional Innovation Management (ISPIM).

Vyas, D., van der Veer, G., Nijholt, A., 2013. Creative practices in the design studio culture: collaboration and communication. Cogn Tech Work 15, 415–443. https://doi.org/10.1007/s10111-012-0232-9

Wu, T.-Y., Gong, J., Seyed, T., Yang, X.-D., 2019. Proxino: Enabling Prototyping of Virtual Circuits with Physical Proxies, in: Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology. Presented at the UIST '19: The 32nd Annual ACM Symposium on User Interface Software and Technology, ACM, New Orleans LA USA, pp. 121–132. https://doi.org/10.1145/3332165.3347938

Zulaikha, E. and Sari, E., 2020. Keep online design thinking alive: A case study in Indonesia. In ICCE-Int. Conf. Comput. Educ., Proc. (pp. 503-512).