STRATEGIES FOR TEACHING DESIGN PROTOTYPING IN VIRTUAL MODE

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ABSTRACT

Prototyping is an ever-evolving medium that enables designers to bring their ideas to life. It plays an integral role in the design thinking process as well as in design education. However, in virtual or remote learning environments, teaching and learning a predominantly in-person hands-on course has not been investigated much. But due to the pandemic induced lockdown, this need became more evident which has motivated present work. This work presents a set of pedagogical strategies for teaching prototyping to undergraduate design and engineering students and a preliminary evaluation of the said strategies in a qualitative survey taken by the students of "Prototyping Interactive Systems" being offered at Indraprastha Institute of Information Technology Delhi (IIIT Delhi), India. The results demonstrate the potential of such strategies to effectively engage and teach prototyping methods and related processes in virtual mode.

Keywords: Design Prototyping, Design education, Virtual learning, hands-on activities, Teaching strategies, Online learning, Product Design

1 INTRODUCTION

Design thinking is an incremental process and to create a useful innovative product, it is crucial to understand the real needs of the end users. After design thinkers have gathered assumptions about the end users, it is imperative to validate what was captured and the subsequent design ideas. Producing tangible prototypes has proven to be an essential tool for establishing a common understanding of the concept acceptance with and among end users particularly in case of tangible product design. Tangible prototypes support the design thinkers' need to gather feedback from end users to validate the underlying concepts they embody. In typical design thinking projects these prototypes facilitate the validation of concepts quite early, inexpensively, and quickly. This allows design thinkers to fail early and fail often [1]. By using prototypes to elicit or provoke feedback about assumptions gathered beforehand or manifestations of design ideas it becomes possible to validate the assumptions and the resulting design choices.

Being an integral aspect of the design process itself, prototyping constitutes a major theme of design education as well [2]. Physical prototypes and the model building process, in particular, have proven to boost students' creativity, resourcefulness and assist in the better evaluation of concepts [3]. Hands-on teaching/learning methods are popularly used with students boost interest, motivation, creativity, freedom of choice, communication and mutual adaptation. A design educators role includes learning, proposing objectives, planning, creating student responsibility, teaching decision making, listening, orienting and assessing in collaboration with the students [4]. An effective design pedagogy has relied largely on hands-on activities and experiential learning methods.

However, owing to the world-wide shift of higher education to virtual modes, learning and teaching experiential topics such as prototyping became very challenging. While, interactive prototyping, for designing digital applications and spaces saw a smoother transition during the shift towards online modes, the difficulties in teaching/learning prototyping were far more evident in specific disciplines such as the ones closer to physical product design, tangible interaction design and design outcomes that require 3D forms and visualizations. This work explores several strategies for facilitating effective online teaching of prototyping method and exposure to related technologies and equipment. It also presents an implementation and preliminary evaluation of the proposed strategies in a core design course on prototyping for undergraduate level students.

2 RELATED WORKS

Though there is much literature on facilitating higher education in virtual mode and the field has seen a sudden rise in the number of publications in the recent past, there is little work that explores teaching design topics particularly which would otherwise be a more experiential learning (i.e., learning by doing). Despite this rise, work addressing design education in virtual mode is limited. Some of them have been discussed in this section. The literature also sheds light on the importance of prototyping in design curriculum which has acted as the primary motivation of this work. Researchers have argued that design practicum is the backbone of design education and prototyping being one of the core elements of design practicum has been deemed essential [5].

2.1 Prototyping in Design Curriculum

There are numerous ways in which to capture the essence of the design process each having its own advantages and disadvantages. Some of the reasons to prototype include: better understanding of the customer needs, seeing if the component will achieve its function, exploring interface issues, reducing costly iterations in the design process, public relations aspects, possibility for use in design of experiments, assembly issues, manufacturing issues, brainstorming potential and communication especially to a nontechnical audience [6]. Apart from these, prototyping methods also enables creative exploration through a multitude of media in early stages of design as well [7]. An integrative approach with both tangible and digital media has also been explored for teaching design ideation techniques [8].

2.2 Design Education in Virtual Mode

Though with increased use of internet and online communication platforms, e-learning had been an interesting research and development domain in the recent past. However, during pandemic induced lockdown across the world, this medium saw a sudden jump in interest from all stakeholders including educators, institutions, students, developers as well as researchers [9]. Several recent works have evaluated the efficacy of e-meeting platforms (i.e. ZOOM, Google meet etc.) for e-learning [10] and have found such technology to be an effective medium for lecture based communication, verbal discussions, etc. Other works have explored the use of new media such as augmented reality, virtual reality, etc. and examined how these technologies can support student engagement and retention in higher education [11], [12].

As design education is being augmented by new technological applications such as CAD modelling software, the transition from classical hands-on methods have been an area of interest for design education researchers and strategies for managing this transition have also been suggested [13] one approach has been to use and evaluate the use of soft prototyping tools (such as CAD modeling applications) to facilitate remote design education [14].

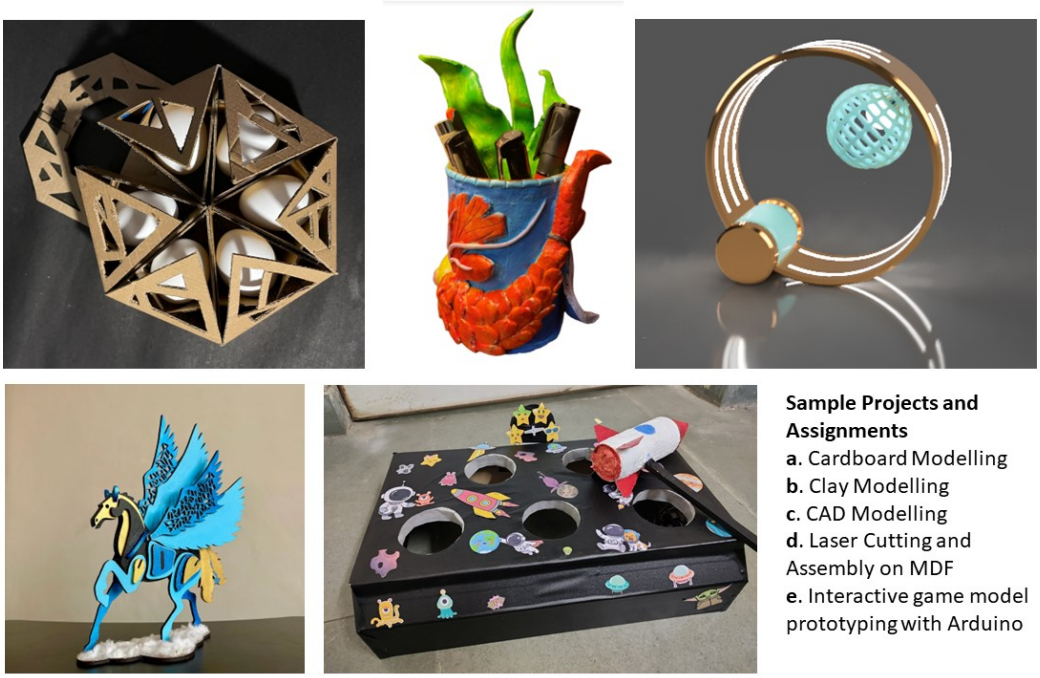

Figure 1: Sample models created by students as part of course assignments and projects

Despite these efforts, a gap in research exists which needs to explore pedagogical strategies for teaching prototyping methods to design or engineering students in remote learning environments and investigate the efficacy of the proposed strategies in facilitating learning and student engagement.

3 PROPOSED STRATEGIES

Due to the worldwide shift of education to online modes, teaching/learning saw a dramatic change in strategies. While this transition was smoother and easier for topics/subjects which largely rely on software applications and lecture-based learnings, it was particularly difficult for lab-oriented subjects and topics such as product design prototyping techniques, which relied on hands-on activities as effective teaching/learning strategy.

In a novel attempt to offer and effectively teach a course on prototyping for undergraduate students in virtual mode, some new strategies for teaching are proposed which were

implemented in a course on prototyping techniques. See Figure 1 for some sample models made by the students:

1. Designing hands-on activities around materials that can be commonly found at home, e.g., incorporating a lo-fi modelling activity using packaging cartons, bubble wrap, plastic bag, newspapers etc. – *Activity given as assignment "to make an egg packaging using repurposed corrugated sheets from delivery boxes and submit images of your model and video showing the usage".*
2. Using affordable modelling material which can be easily procured such as modelling clay, building blocks, wires, etc. – Activity given as assignment "to sculpt an object (choosing from mobile stand, necklace, pen stand, salt pepper shaker, cup saucer set) using quick drying epoxy clay which is easily available in stationery or hardware shops. Submit step by step sculpting images."
3. Utilizing CAD tools along with augmented reality tools for assignments. Platforms such as Blender, SolidWorks etc. can be used along with AR apps such as Unite for to-scale real-world product visualization and form evaluation. – *Activity given as assignment – "to create a to-scale table lamp in Fusion 360, render it with AR app on your home table and submit images and videos of the same."*
4. Organizing live video lab sessions with equipment experts and lab assistants. LIVE lab sessions were streamed using cameras in prototyping labs with the help of lab manager and teaching assistants for 3D printing machine and Laser-cutting machine.
5. Sharing videos of lab equipment usage showing a complete step by step control panel operation along with pre and post material handling if any. The same can be provided as readable handouts also. – *the LIVE lab sessions were also shared both as readable handouts and video formats.*
6. Augmenting projects/assignments with video submissions which includes clips of prototyping processes that can be used to make them. – *see points 1, 2 and 3.*

4 EVALUATING EFFICACY OF PROPOSED STRATEGIES

4.1 METHODOLOGY

The aforementioned strategies were implemented in a core design course called "Prototyping Interactive Systems (DES 206)" offered at Indraprastha Institute of Technology Delhi (IIIT Delhi), India [15]. The assignments, activities, resources and

lectures were designed with these strategies in mind. The objectives of the course were as follows:

1. Student will be able to plan, design and develop prototypes of interactive systems including its form, function, and interface.
2. Student will learn different soft and hard prototyping processes as well as operating related equipment and software.
3. Student will be able to gain an understanding of how to analyze a design and select suitable prototyping processes.
4. Student will learn the fundamentals of product design, form and aesthetics and develop design sensibility.
5. Student will learn to document and present your ideas and solutions.

An anonymous qualitative survey method was used for pre-liminary evaluation of the said strategies. Anonymity was included and communicated to the participants so as to receive a more transparent response and feedback. A Google form with 10 questions was circulated among the students registered in DES 206. Out of 10, 8 questions were Likert scale based, 2 questions were multiple choice. The survey questions are mentioned in Table 1. The form was open to filling and editing for a week and then the form was stopped from taking responses and the data was collated.

The participants of the study were in the age group 19 years – 20 years and were all registered students of B.Tech. program in 5 streams at IIIT Delhi namely Computer Science and Design, Computer Science and Engineering, Electronics and Communication Engineering and Computational Biology. The exact distribution in each stream is unknown as the survey was anonymous.

Sl. No.	Question / Statement	Response type
1	At-home hands-on activities (assignment 1 & 2) offer an effective way for learning of low-fidelity prototyping techniques such as cardboard or clay modelling as well as material manipulation	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
2	The at-home activity was effective as the material was affordable and easy to procure	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)

3	The format of submissions for at-home assignments i.e. using images and videos were easy to do and communicated the form and function of the prototype effectively	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
4	Overall, the at-home hands-on activity were interesting and fun	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
5	In class LIVE CAD tutorials were useful, easy to follow and effective in learning soft prototyping	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
6	The support material and lecture resources enabled effective online learning	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
7	LIVE Video lab sessions have been helpful in learning the use of lab equipment and be ready for future physical engagement	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
8	Overall, I feel that these strategies were effective for learning prototyping methods during pandemic lockdown	Rating on a scale of 1-5 (Strongly Disagree – Strongly Agree)
9	Which Online/remote learning strategy you found the most useful/effective for learning prototyping methods (select any 2)	Multiple Choice
10	Overall, I feel that in case the imposition of lockdown happens again, learning a workshop-oriented course in virtual mode is	Multiple Choice

Table 1: Survey questions

4.2 Results and Analyses

The questionnaire was circulated with the participants and 174 responses were received.

The responses of the participants for questions 1 to 8 which were based on a Likert scale rating between 1 and 5 have been summarized in Table 2. The responses to questions 9 and 10 have been presented as suitable data visualization charts in Figures 2 and 3.

The results show a positive response to all rating-based questions since all means are greater than the average rating of 3. Notably, all but questions 5 and 7 have received an above average response (i.e. 4 out of 5 or 5 out of 5) from more than 50% responders.

In the multiple-choice questions, the strategy of utilizing "at-home hands-on activities" was thought to be the most effective (62.1% votes). This resonates the effectiveness of experiential learning in case of such subjects. "Lecture resources", "LIVE class tutorials" and "video and image-based submission" followed in at 46%, 44.3% and 42.5% respectively. "LIVE lab sessions" were not well appreciated with only 28.7% votes.

Sl. No.	Frequency and Percentage response					Mean Rating	SD
	1	2	3	4	5	Out of 5	
1	15 (8.6%)	10 (5.7%)	44 (25.3%)	61 (35.1%)	44 (25.3%)	3.63	1.17
2	13 (7.5%)	26 (14.9%)	35 (20.1%)	53 (30.5%)	47 (27%)	3.55	1.24
3	13 (7.5%)	12 (6.9%)	33 (19%)	60 (34.5%)	56 (32.2%)	3.77	1.19
4	17 (9.8%)	12 (6.9%)	36 (20.7%)	62 (35.6%)	47 (27%)	3.64	1.22
5	13 (7.5%)	24 (13.8%)	52 (29.9%)	57 (32.8%)	8 (16.1%)	3.36	1.13
6	10 (5.7%)	6 (3.4%)	46 (26.4%)	69 (39.7%)	43 (24.7%)	3.74	1.05
7	22(12.6 %)	33 (19%)	41 (23.6%)	50 (28.7%)	28 (16.1%)	3.16	1.27
8	11 (6.3%)	13 (7.5%)	41 (23.6%)	70 (40.2%)	39 (22.4%)	3.64	1.1

Table 2: Description of responses form 174 students for question no. 1 - 8

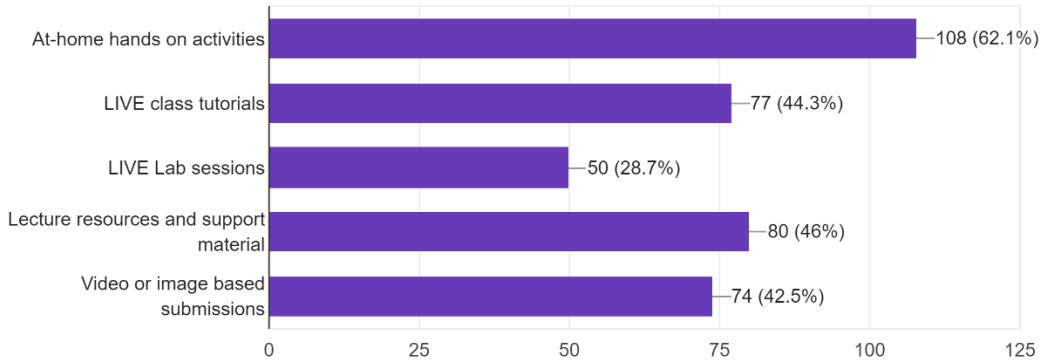

Figure 2: Frequency distribution of responses for question no. 9 – Which online/remote learning strategy you found the most useful/effective for learning prototyping methods (top 2)?

Figure 3: A pie chart showing distribution of answers for question no. 10

5 DISCUSSIONS

A set of teaching strategies for effective virtual delivery of a predominantly hands-on course on prototyping are proposed. They were also implemented in a course offering (DES206) at IIIT Delhi. The results indicate that overall, the proposed teaching strategies were found to be effective, interesting and engaging by the students who participated in the activities, lectures and assignments of DES206.

Above average ratings on the Likert scale about the various aspects of the strategies indicate potential in the utilization of these strategies in design pedagogy particularly for higher education and larger classes. There are several logistical bottlenecks which can be

accounted for some of the low ratings or preferences. Such as the low effectiveness of LIVE lab sessions may be owing to the jittery camera handling in the lab as it was done by lab assistants and teaching assistants who do not have videography expertise. Another fact that some students could not "easily" find the materials required for at-home activities may have resulted in a low rating for related questions.

Evidently, it has been challenging to teach and learn design in the virtual mode, however, the last two years forced the education to shift online and educators to come up with innovative teaching strategies. This is one such initiative in this direction. Though the implementation and evaluation of the proposed strategies are preliminary, the results are promising and show potential for further pedagogical use and long-term efficacy evaluation in the future.

The lockdown was lifted in the middle of the semester in which these strategies were implemented and long-term evaluation could not be conducted. However, question no. 10 in the survey investigated the overall thought of using such strategies in case of forced lockdown. Though, nobody could deny the quality of offline classes, physical engagement and tangible hands-on experiences, participant responses did show an overall promise of potential in using such pedagogical strategies for effective virtual access of design education particularly in case of a mandatory lockdown situation.

6 CONCLUSION AND FUTURE WORK

Prototyping is an integral aspect of design thinking and thus design education. Various teaching strategies have been proposed to facilitate an engaging and interactive learning experience for students and to effectively teach design prototyping in virtual mode which is otherwise a workshop intensive course. The strategies have been implemented in a course offering at IIIT Delhi and student evaluation is proposed. The results are promising and demonstrate the efficacy of these strategies. Such teaching strategies can be utilized in other design courses as well which usually involve hands-on activities. They can be beneficial in overcoming challenges of learning and teaching design in a virtual mode and keeping the students engaged and invested in the course.

In the future, a long-term evaluation to gauge the effectiveness of such pedagogical strategies that can fit the ever-changing needs of the world can be a valuable research direction. Other logistical limitations also need to be addressed in further studies so as to remove logistics related biases in participant response. A deeper investigation using interview or focus group discussion can also garner valuable insights and help in improving upon the proposed strategies.

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