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Understanding and Creating 3D Forms Using Familiar Objects

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Abstract

A fundamental for first-year design students is to express ideas by drawing and creating volumetric models. Traditionally, this education includes spatial geometry and generation of forms whereby students learn to appreciate intersections of volumes and projections to describe three-dimensional (3D) forms in two dimensions. However, given the aptitude of today's students to operate 3D-modelling software and the general accessibility of current technology, spatial geometry as a core subject may seem less relevant. Our goal is to re-engage students in learning required basic knowledge and skills through a complex multifaceted design process. We have designed a first-semester course of four project-based learning activities that apply learning- by-doing methodology. For each of the past three years, 65 to 75 students have participated in our 3D Expression studio course, in which they develop understanding of design process, vocabulary, and skills to create 3D models with precision, refinements, and high-level visual impact. This paper reports on the successful results of activities conducted during the 14 full days of this studio course.

Introduction

A cornerstone in design education is "basic design"—defined by many schools in reference to Bauhaus and, particularly, works of Kandinsky. Teaching centres on distinguishing basic elements from other elements, "elements without which a work cannot even come into existence" as mentioned by Lupton [1]. Understanding and mastering 2D drawings, 3D forms (volumes, interaction of shapes, etc.), composition, colour, and materials and familiarity with techniques are considered fundamental to all design expression. This understanding is reinforced in studio course activities, whereby students expand their comprehension by making connections with their learning. Traditionally, basic design includes spatial geometry and generation of 3D forms. But given the aptitude of today's students to operate 3D-modelling software and the general accessibility of current technology (e.g., 3D scanning, generating surfaces in complex modelling), teaching spatial geometry as a core subject may seem less relevant. Therefore, we have established a teaching approach to design focused on understanding and creating 3D forms along with development of visual vocabulary. The teaching is studio- based and offered to first-year university design students, who come from a variety of high-school backgrounds; many have never studied in art and lack skills in drawing and handcrafts. The course is mandatory and taken immediately following an introductory course on basic 2D drawing, where students learn about observational drawings and perspective. The course is called 3D Expression. Pedagogy is student-centred and applies the backward design model [2]. The theoretical project-based framework targets development of creativity and innovation based on constructivism ideas of Dewey [3] and Piaget [4]. As Piaget explains, [4], "Knowledge is actively constructed by the learner, not passively received from the environment." Project-based, experiential, and hands-on learning has always been a tradition in design education.

The learning curriculum consists of a set of "projects" (see Section 3). The projects are introduced in sequence to help students develop competencies in imagining harmonious 3D forms and expand skills in creating models. Understanding and applying notions of point, line, coordinate systems, axes, planes, projections, transformation, intersection, rotation, etc. are embedded in the exercises. This curriculum has been applied since 2012, involving 65 to 75 students each year. Teaching is supported by cycles of individual coaching and feedback to help students acquire understanding of the process leading to creation of innovative 3D forms—enriched by visual design vocabulary. Students also develop skills to create precise 3D mock-ups with simple materials and low-tech applications.

Experience and learning

With the goal to construct knowledge on principles of generation of 3D forms, first-year students are placed in an experimental set-up where they are asked to draw on past experiences, understand a current situation, and then create new 3D artifacts. Dewey's leading ideas of experience and learning-by-doing [3] are central: Students receive limited instructions and undergo an iterative process to build knowledge. The pragmatic aspect of experimentation is essential for designing and developing new artifacts "to foster skill development and the learning of factual information in the context of how it will be used" [5]. Dewey's project-based learning [3] is arguably the most significant contribution to design education. Among the benefits of this student-centred strategy are greater understanding of concepts within context, heightened creativity, improvement in communications, and better response to feedback. Project-based learning is considered to be a comprehensive approach that engages and motivates the learner [6]. Another key advantage of project-based learning is that students integrate knowledge and skills through a process of learning-by-doing. Learning-by-doing is significant because students develop a sense of critique and reflexive practice toward their actions and experiences [7], [8].

They engage with the learning experience to become more independent and develop critical thinking. Furthermore, project-based learning encourages active involvement of students in sharing knowledge through collaborative discussion and problem-solving [9]. Other important components of learning-by-doing are the physical conditions where learning occurs (environment and tools) and the coaching of students [6].

Backward design process

Explained by Wiggins & McTighe [2], backward design aims to provide learning experiences for better understanding of subjects and processes by setting goals before choosing instruction methods. The model has three basic stages: (1) identify desired results; (2) determine acceptable levels of evidence that results have occurred; and (3) plan activities that enable results to happen. In project-based teaching, it seems important to add an additional stage to the model: “coach” the process.

Stage 1 - Desired results: First-year students start basic design education with a concentration on observation drawings (2D expression), where they explore use of media, composition, light, and shades. This is followed by 3D expression. Each of these studio-based trainings is conducted two days a week for seven weeks. The belief is that observational understanding is key to make sense of formal, perceptual, symbolic, and technical aspects of objects. Thus, the following goals were defined as desired learning outcomes:

- Discover, analyze, and identify the visual language and patterns of an existing object through specific terminology. Interpret and apply the visual language to another object.
- Communicate intentions through drawing and 3D models with different materials.
- Put learned principles into practice in design projects.
- Develop understanding about the design process: learn to accept that new and more interesting ideas can be developed through iterative exploration.

Exploration activities in the studio allow students to develop the ability to imagine, design, and modify volumes in space. Students also experiment with creative problem-solving, which they will apply later in designing products. They work with simple mediums: mostly pencil for drawing: a variety of papers and metal wires for creating 3D shapes. They learn precision in craft techniques, composition, and visual vocabulary: harmony, contrast, balance, etc. This first introduction to project-based learning at university focuses on the design process as a hands-on experimental and iterative activity, and is based on the following theoretical concepts: spatial geometry in design; methods of representing 3D forms in 2D and vice versa; decomposition, intersection, addition, subtraction, and repetition of forms.

Stage 2 - Knowledge transfer and evidence of results: Students work on exercises and projects in the studio individually, except for the last project. A tutor who is a professional practitioner is assigned to every 12 to 15 students. The studio facilitates transfer of theoretical knowledge by allowing students to apply their learning in projects. Theoretical content is provided in the form of short lectures, conferences, and demonstrations; tutors also share case studies from their practice. All studio work requires multiple iterations during development and representation in 2D and 3D. For each exercise or project, the acceptable level of evidence that results have occurred is defined and discussed with tutors, who closely follow the development of students and help them to overcome challenges. Three levels of assessment are acceptable: Level I (lowest) is application of learned theory to a project. Level II calls for in-depth understanding of issues when theory is applied to a project. Level III includes criteria of the other levels plus familiarity with design vocabulary.

Stage 3 - Activities: Students undertake six exercises and four projects. The exercises are preparation for the projects. Each project begins with analysis of a familiar concept or artifact and leads to creation of a new abstract 3D form. At the beginning of each project, students receive a document that outlines process, timeline, desired learning results, and evaluation criteria. Students are asked to use oversized paper for sketches and advanced drawings and to assemble them for future study of their progress.

Projects, Sequence, development

3D Expression starts with a short team-building activity. A set of exercises and projects are introduced in a set order to build student knowledge and skills. Learning from each exercise has important consequences on following projects and each project has an impact on the succeeding one. In other words, projects are building blocks to desired results. The first two projects are presented below; they have proved to be effective approaches for knowledge transmission and learning.

Understanding 3D through carving: a subtractive process

The first experimental project is a ludic introduction to 3D forms. It challenges students to create a letter of the alphabet in 3D. The main steps of are the following: (1) Students select three letters of their names and imagine the letters in 3D. They explore making models of their imagined 3D letters by removing material from a mass— carving a potato. (2) Students display their “artworks” on a large table for observation and comment. Five potato letters are selected that have the most interesting 3D constructions and best proportions from all angles. These five letters serve as models for the next step. Figure 1 shows a grouping of potato letters prior to selection of the most promising ones.

Figure 1. 3D letters created by carving process

(3) In this step, the goal is to create a 3D letter in cardboard inspired by one of the five potato models. Students sketch and refine the shape of the 3D letter, make precise technical drawings, and think about strategies of construction of the letter in cardboard. The required height of the

letter is 30 cms; students define the other dimensions. The conceptual model that is the result of this activity is an individual and subjective interpretation of the selected letter.

Figure 2. Process of drawing and construction of model

The activity allows for comment on the following capacities of students: to select a letter that has an interesting complexity and structure; to generate a 3D form based on a familiar 2D form; and to carve (subtract) a form from a solid based on a cognitive model. The unusual material (potato) creates special motivation and excitement. With this simple and playful exercise, students by the second day of the studio are developing sharing and interaction skills, critical thinking, and visual understanding. Resnick and Rosenbaum [9] qualify this kind of approach as "tinkering," which is "characterized by a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities." The project workshop takes two days of the 3D Expression studio. Figure 2 shows the drawing process, developing layout strategies for construction, and testing interaction of folded cardboard volumes. Figure 3 shows selected end results.

Figure 3. Examples of 3D letters

Understanding special geometry of 3D forms

The second project helps students to acquire understanding of 3D objects and create new ones that share similar principles. The activity is based on: (1) study of spatial geometry of a familiar object by observation and analysis to find its visual vocabularies; (2) creation of a new object by considering the visual vocabularies as principle guidelines. This project takes four days over two weeks. The method consists of the followings three steps. (1) Students choose a bottle from among three types that seem to be a priori common: a shampoo bottle with an organic shape; a soft drink bottle with a rounded shape, comparable to a female body; or a mouthwash bottle with sharp edges, representing robustness. They observe the bottle carefully, measure and draw it, and study its shape by noticing axes (i.e, symmetrical, rotational), by breaking down its volume into simple geometrical shapes (i.e., parts are parallelepipeds, cylinders, cones), and by identifying interaction of volumes (i.e., addition, subtraction, merge, union). This step allows students to distinguish proportions and formal structure that makes the bottle to be in balance, stand-alone, etc. Thus, students identify the formal vocabularies revealed by the object. (2) Based on understanding of forms and visual vocabulary of the bottle, students draw variations and make mock-ups of volumes. Three proposals are selected to be further developed by drawing orthogonal and perspective views. (3) The most promising proposal is then selected as a starting point to build a model of a new object. The goal of this step is to build an abstract form inspired by the visual vocabulary of the original bottle three times larger than its actual size. The rescaling detaches the form from its original function and helps students to study the basic elements of the new form. It also adds new challenges related to proportion, visual harmony and structural balance, technical drawing of the new form, and strategies of construction of mock-up.

Through discussions with their tutor and trial-and-error, students develop a strategy for building the form with cardboard. Several test models are needed to validate the method of construction of the final model. Students are encouraged to anticipate creases and common edges between shapes and to minimize breakdowns and chunking shapes.

Figure 4 shows examples of early drawings by a student that helped to understand geometry and interaction of forms, proportions, formal and structural guiding lines, rhythm, and vocabulary of forms. The image on the right illustrates the abstract artifact—60 cm in height—created as a result of the project. The foundations and impacts of this project are discussed in detail in another paper: “De(re)construction of Geometrical Forms.” This approach reveals to students the iterative process of design. The approach also makes students realize that good planning and rigorous execution allows for considerable time-savings when creating cardboard models.

Figure 4. Example of transformation of original object into abstract form

Next two projects

The third and the fourth projects (not part of this report) reinforce learned concepts and challenge students with greater complexity and more precise constructions: an individual project on better understanding of visual design vocabulary; a collaborative project by teams of two on design of a 3D construction inspired by the human body.

Research methodology

The first author of this paper taught a theoretical course on spatial geometry for design students prior to transforming the teaching into project- and experimental-based studio content. She redesigned the pedagogical method of this particular spatial geometry course (now 3D Expression) and conducted the studio course for three consecutive years. The second author played the role of coach. He worked very closely with a number of students, encouraging them to explore, test ideas, and learn from mistakes. Both authors together observed students’ progress as well as difficulties in understanding concepts and in developing skills in representing 3D ideas with different materials and techniques. Exercises were adjusted and new ones were added to create better transitions between projects. Theoretical modules, expert demonstrations, and specific guidelines were also added and provided for students to enrich learning methods. This teaching/adjusting approach follows on Kolb’s four-stage cycle of experiential learning: concrete experiencing, reflecting on observations, generalizing, and applying (new experience) [8]. The cycle allows for exploration of processes associated with making sense of concrete experiences.

Discussion

Our students are from diverse education backgrounds, and thus they have diverse ways of thinking, learning, and overall functioning. In their learning, they have the challenge of understanding “design thinking” and acceptance of “ill-defined” problems [10], [7], which can be difficult and destabilizing. We also expect students to explore and understand the iterative process of design [11]. As design educators, our challenge in teaching spatial geometry was how to help students to develop a hands- on understanding about interaction of 3D forms without using software applications—how to help them develop skills in generating new forms. With the first project, we found that students' experiences of carving helped them to visualize and understand interaction of simple geometrical volumes. Then, the carved model was used in interpretation of the 3D concept in 2D drawings, refinement of the concept, and study of proportions; precise drawings led to construction of 3D letters. While students showed little difficulty in meeting project requirements, results related to quality of performance, precision, and cleanliness of models were mixed.

The second project imposed a greater requirement to follow constraints, beginning directly with 3D observations of a specific bottle. The question became: How can novice design students be taught to carefully "look" at 3D forms of familiar objects, analyze them, and grasp their visual characteristics to apply to creation of new objects? Through reinterpretation of a bottle and many iterations of its form, students were guided to develop ability to express creativity. By rescaling the size, students became detached from the original form of the bottle and its function. Figure 5 illustrates student evaluations through two workshops, and reflects their progression from an average grade of C+ to B.

Conclusion

Figure 5. Student evaluations through two workshops

The teachings of 3D Expression, which includes principles of geometry, can be considered as part of a liberal arts education that helps students to develop creativity and a sense of aesthetics. In Plato's words, geometrical forms are "forms of beauty". In art and architecture, geometry is traditionally a foundation subject in most design curriculum; however, while it remains a subject that contributes greatly to design, its teaching by traditional methods and tools may have lost connection to other subjects of design studies. This reflective report enabled us to validate that students are able to express new mental constructs and develop a deep sensitivity to forms that is useful in designing products. The results of proposed methods and the feedback from peers and students confirm the belief that the projects of the studio course help students to improve understanding of volumes, capacity for imagining new abstract forms, critical thinking, understanding of the iterative process of design, understanding of visual vocabulary, and development of skills in the creation of models based on deeper understanding of underlying geometry.

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