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# A Cross-Disciplinary Workshop on 3D Modelling: Students' Design Concepts in the Bottle form Design Task

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## Abstract

*3D modelling and rapid prototyping skills have become an essential technique in design education and cross-disciplinary educational settings provide opportunities for students to develop design expertise on 3D modelling. In the present study, we focused on 3D modelling in a product design context, and we analysed what kind of design concepts emerge in students' work when they are taught 3D modelling in a cross-disciplinary setting. This study aims to provide design educators with new insights into novices' design practices in cross-discipline design education. The research employed a qualitative case-study approach to analyse textual and visual representations (i.e., concept maps, sketches, 3D models, and reflective reports) to explore the students' design concepts. The cross-disciplinary setting consisted of graphic design, interior design, and product design students who were given a product form design task. All students succeeded in creating description-based concepts that met the problem requirements. However, principle-based concepts emerged only in product design students' processes. We argue that these kinds of principle-based concepts are related to the product's structure and functionality, when engaged students can apply product design domain-specific knowledge. In conclusion, this kind of design task has benefits for individual learning and developing usable and aesthetically appealing products. However, there is a clear need for studies that develop workshops and tasks where students can participate in collaborative multi-disciplinary projects.*

## Keywords

*Design Concept, Design Education, Design Principle, Design Representation, Product Design.*

# Introduction

In recent years, the boundaries of the different design fields that have been earlier recognized as discrete design disciplines (such as product, textile, graphic, interior, etc.) have become more blurred and dissolved (Rodgers & Bremner, 2019). Rodgers and Bremner (2019) argued that the work in the design industry has moved toward project work and more often collaborative multidisciplinary projects. Thus, the design work is characterized as project-based, fluid and enhanced by practices with increasing use of new digital design tools and production technologies across various disciplines. Further, this cross-disciplinary shift is started to be emphasized and encouraged also in design education so that the students can purposely borrow and utilize design methods, practices and digital tools from other design fields (Nae, 2017). There is a clear need for studies that develop workshops and tasks across a diverse range of creative design disciplines. The cross-discipline educational setting could provide new learning experiences for various design students, and thus, the present study analyses the differences of design concepts regarding domain knowledge between graphic, interior, and product design students while all working on a product form design task.

The research on expertise has highlighted the differences between domain-general and domain-specific knowledge and skills in design (Goel & Pirolli, 1992; Cross, 2006). However, the traditional division between domain-general and domain-specific knowledge has become blurred. The domain-specific knowledge represents subject specialist of the single discipline whereas domain-general knowledge represents more transversal competencies for example knowledge of design processes, creativity and communication skills. According to Cross (2006) design practice, methods, techniques, and approaches can be seen as designerly ways of thinking. IDEO advocated design methods and practises as the way of design thinking (Brown, 2008) that represents a transferable disciplinary skill. Norman and Klemmer (2014) describe design thinking skills as the key aspect for creative designers. According to Nae (2017), there are various cross-disciplinary educational models that support the concept of T-shaped designers. The first model is the foundation curriculum with a broadness of subjects (e.g., Bailey & Spencer, 2019). The second model allows students to selectively expand the vertical depth of a secondary subject by completing courses. This model creates opportunities for knowledge cross-over which can assist in the making of the expert-generalist. The third model responds to additional T-shaped horizontal skill development and to industry demand for team-orientated collaboration.

This study aims to provide design educators with new insights into novices' design practices in cross-discipline design education. A design teaching experiment called Rapid Modelling Techniques (RMT) was organised to provide the relevant product form design course. The student participants came from three different design disciplines to learn 3D modelling software application techniques and we analysed four kinds of design representations — concept maps, sketches, 3D models, and reflective reports— produced by design students from three distinctive design disciplines while addressing product design tasks. The research question was: What are the main differences in design concepts among students of the three design disciplines (graphic, interior, and product)?

## Theoretical Background

In previous research, external design representations have been seen as sources of design knowledge and how a design will look and function without the need to construct the actual object (Visser, 2011). Several dimensions of aesthetic preference have influence on the product design choices (Hung & Chen, 2012). The novel products should be both aesthetically stimulating and practically understandable i.e., the physical form of the products express how it will be used. Sketching is an acknowledged thinking tool for designing, but it is also a tool for evaluating and testing design ideas — the explorative cycles of sketching, reinterpretation, and evaluation are central to the creation of design ideas— (Menezes & Lawson, 2006). Furthermore, Akoury (2020) has emphasised that there is a relationship between drawing and conceptual articulation and that drawing is an iterative act of ideation and observations.

Along with the sketching, mind mapping has been presented as a preferred thinking tool in the initial stages of creative design conception, helping designers design novel and advanced products that meet people's needs and handling *Who, What, Where, When, Why, and How* design issues (Dong et al., 2021; Kokotovich, 2008). Dong et al. (2021) stated that when novice design students use mind maps for divergent thinking and engage in deeper and more detailed analyses of design topics, they can produce a more appropriate final output. Further, drawing detailed sketches when making mind maps can help novice design students integrate design elements more appropriately into the final design solution.

The present study focuses on visual representations of product design concepts and reflective reports that elicit participants' intended design concepts and their explanations. To translate abstract intentions into plans for the product's visual form, designers use several types of representations, such as thumbnail sketches, idea sketches, information sketches, and various 3D-models (Evans & Al-Doy, 2011; Pei et al., 2011). These representations support the generation and evolution of design ideas through the conceptual design process towards the constrained and detailed specification of a given design task. It comprises the designer's attempts to explore and communicate the intentions of their design concepts (Visser, 2011). Chamorro-Koc et al. (2015) employed the visual representation of design concepts as a research method to elicit experiential and contextual (e.g., product use and context of use) aspects of design ideas. There are previous studies in which images produced during design were studied as representations of reality (Kokotovich, 2008), as well as studies in which visuals were recognized as representations of experience (Oxman, 2002). Reflective reports, on the other hand, allow participants to describe and explain their design concepts and to point out any other aspect that could not be conveyed in the drawings, enabling the drawing to be understood through the participant's eyes.

In product design education, the importance of integrating user perspective into design learning has been well established (e.g., Dahiya & Kumar, 2021; Frascara, 2017) and applied user-centered design (e.g., Altay, 2014; Imbesi & Scataglini, 2021). The creative process conveys a designer's intentions about form development (Hsieh et al., 2021). Related to design intentions and product experience, Crilly (2011) has emphasised some intended determinants for product form such as drawing attention to the product, generating attraction for the product, and supporting the comprehension of the product function. Further, da Silva et al. (2015) maintains that the aspect of product experience involving aesthetics and usability can be shaped by persuasive intentions in design practice. These intentions can be inferred from the product concepts and these inferences may also shape users' experiences. While sketching, designers can discover the object forms that they believe will best satisfy user needs. However, our previous study (Yang et al., 2022) showed differences between three design disciplines (product design, graphic design, interior design) when the students collaboratively solved the same form-giving task. Only the product design students utilized the viewpoints of end users during the design process.

During conceptual design, designers leverage their own memories, experiences, and knowledge, they may also contrast their experiences and existing knowledge with available user data and thereby create new concepts. For example, usability has been defined as the interaction between the user and the product, *mainly focused on how people use the product* (Kahmann & Henze, 2002). Designers' experiences and intentions alone do not determine product form, which is affected by a variety of other factors, such as a brand, manufacturing constraints, techniques of visual representation, and inspiration sources, which need to be considered (Jagtap, 2018). Furthermore, it is also beneficial to consider ergonomic aspects early in the design process (Harvey & Stanton, 2013). With a variety of influencing factors, designers' tasks can be viewed as the planning of products that appropriately reconcile many competing and conflicting constraints, further resolving these factors by constructing visual representations that describe the planned form of the product.

# Methods

## Study Context

The present study aims to explore design concepts embedded in students' design representations. We analysed how students from three design disciplines approached re-designing a novel product form. For our case study, a design teaching experiment with cross-disciplines design students called Rapid Modelling Techniques (RMT) was organised in the summer of 2020 at the School of Communication & Design Art at Yunnan University of Finance and Economics, China. This optional course was offered to early four-year undergraduate students in graphic design, interior design, and product design. The course consisted of 21 hours of workshop training across seven weeks consisting of seven sessions and practical assignments (Table 1). The lectures mostly focused on computer-aided design and the introduction of design-thinking processes related to the product's appearance aspects but did not involve any user-centered design method. The goal of the workshop was to fulfil the research requirements that each participating student has some experience with rapid digital prototyping.

**Table 1:** *The course schedule with the main topics.*

| | | |
|---|---|---|
| **Session 1: Introduction** | ▪ Design Intent<br>▪ File References<br>▪ The SolidWorks User Interface<br>▪ Using the Command Manager | Assignment:<br>Become familiar with the user interface |
| **Session 2: Sketching with SolidWorks** | ▪ 2D Sketching<br>▪ What are We Going to Sketch?<br>▪ Sketching Sketch Entities<br>▪ Basic Sketching | Assignment:<br>Cases practice of sketching Entities |
| **Session 3: Sketching with SolidWorks** | ▪ Rules That Govern Sketches<br>▪ Design Intent<br>▪ Sketch Relations<br>▪ Sketching on a Planar<br>▪ Dimensions Extrude | Assignment:<br>Cases practice of bowl and chopsticks |
| **Session 4: Basic Modelling I** | ▪ Choosing the Best Profile<br>▪ Choosing the Sketch Plane<br>▪ Details of the Part<br>▪ Boss Features<br>▪ Revolved | Assignment: Cases practice of writing box |
| **Session 5: Basic Modelling II** | ▪ Cut Feature<br>▪ Filleting<br>▪ Editing Tools<br>▪ Linear and Circular Pattern<br>▪ Hole wizard | Assignment: Cases practice of flower vase |
| **Session 6: Basic Modelling III** | ▪ Symmetry<br>▪ Sketching the Model<br>▪ Using Model Edges in a Sketch<br>▪ Creating Trimmed Sketch Geometry | Assignment: Cases practice of scent bottle |
| **Session 7: Design Thinking Introduction** | ▪ Theory Background<br>▪ Method & Processes<br>▪ Design Principles<br>▪ Commodity Products Appearance Design | Assignment:<br>Become familiar with design representations |
| **Bottle Form -Design Task** | ▪ Define the Essential Design Context<br>▪ Ideate Visual Features<br>▪ Make a 3D Model<br>▪ Write a Reflective Report | |

We focused on 17 students who individually engaged in the well-structured Bottle Form design task. The topic of the design brief was to develop the form of a detergent bottle (product) to meet the requirements of the client. The constraints included;

**1.** Expanding 30% of the capacity of the original bottle
**2.** Adding some novel features for details of the appearance
**3.** Fulfilling the design requirements so that the 3D model should be at least 50% similar to the original form of the bottle.

The following four design outcomes were required from the students: concept map, sketching, 3D modelling, and reflective essay. Each student's design process included paper-based documentation during the problem-solving process and OBS STUDIO software with screen recording during the 3D-modelling phase. The duration of the design task was limited to three hours. Students were required to perform their design task according to the sequence, as follows:

**1.** Define the essential design context e.g., intended users and the context of product use by using the concept maps.
**2.** Ideate visual features through sketching on the paper.
**3.** Make a 3D model using SolidWorks.
**4.** Write a reflective report to answer three supporting prompts: How do you think the result of the 3D model meets the task's requirements? Explain your design concepts and how you developed them through sketch and 3D models.

The research data was collected at the end of the design task including the visual data from sketches and 3D models, and the textual data from concept maps and reflective reports. This research is based on the premise that previous experience is necessary to successfully solve the design problem in question. Therefore, the students' designs were affected by four aspects concerning their previous experience:

**1.** 3D Modelling Skills: The product design students were most experienced using SolidWorks, the interior design students had some previous experience using other 3D modelling software (3D Max), and the graphic design students did not have any previous experience using 3D software before the workshop.
**2.** Product Usability: Aspects of this were emphasised in the product design students' domain-specific studies.
**3.** Individual Experience: Each participant's behaviours, feelings, thoughts, and understandings are derived from their previous experiences of daily activities with everyday objects.
**4.** Design Ability: The participants were senior design students with all having previous experience of studies and their domain-specific practise.

## Research Method and Data Analysis

The research employed visual and textual representations (i.e., concept maps, sketches, 3D models, and reflective reports) to explore the participants' design concepts and their explanations. The students' visuals and textual data were analysed with ATLAS.ti, qualitative analysis software that assisted us with the process of coding the data and creating memos. We employed theory-driven data analysis, and the categories were adapted from Chamorro-Koc et al.'s (2015) study.

The categories of design concepts and their definitions are presented in Table 2 ATLAS.ti was used to identify from the concept maps and reflective reports to whom (user), what, where, when, why, (situation, intended use) and what kind (aesthetic) and how (functionality, usability) aspects. In addition, excerpts of coding visual data with ATLAS.ti are presented in Table 2.

**Table 2:** *Coding Schemes of Design Concepts.*

| Categories | Subcategories | Codes | Definition | Excerpts |
|---|---|---|---|---|
| *Use Context* | Situation | ST | A particular situation in which situated issues emerge and lead users to intentional actions with products. | Mind Maps: Both washing and protecting. |
| | Intended Use | IU | Indications about the purpose of use of a product or part of the product, which aims at considering effective use in a context. | Sketches: Designed the pump head on the top for pushing down actions. |
| *Knowledge* | Description-Based Concept | DBC | Indications about aesthetic aspects such as describing placement, shape, pattern and decoration of a product and its features. | Sketches and 3D models |
| | Principle-Based Concept | PBC | Indications about the relationships between the product's structure and its functionality, usually connected to usability and ergonomics. | 3D models and reflective reports: Used a concave structure to create the bottle's bottom with the ark shape, which has a better structure against the effects. |
| *Experience* | Episodic Data | ED | Reflections of memories of product use that a person has experienced in the past. | Reflective Reports: At that moment I achieved a long-distance running, it was required for washing clothes with sweat. |

# Results

Each student generated design outcomes according to the requirements of the brief and nobody exceeded the 180-minute time limit. The intended user was considered in the three user segments as woman, young people, or family members. The product design students tended to emphasise *family member* as the defined users' segment, whereas the other two types of design students both applied the users' segments as *woman* and *young people*. The duration taken on the 3D modelling varied, the interior design students used less time and fewer operations in 3D modelling, whereas graphic design students used the most time (82 minutes on average). The design concepts emerged from the data and conveyed various views of the use of context, knowledge, and experience. The students began their design process with a range of concept generation. While they understood the detergent product or its user's needs as their starting point, they also generated some specific concepts related to product experience, the context of use, and functions. The students drew thumbnail sketches for making decisions and one sketch was usually selected for 3D modelling. In the following, we present examples of students' design solutions related to the classification categories. The qualitative content analyses of the students' design outcomes (concept maps, sketches, 3D models, and reflective reports) demonstrated aspects of students' design concepts related to either description-based concepts or principle-based concepts.

## Thinking About Situation (ST) through Concept Maps and Reflective Reports

In concept maps, the ideas within the connections allow the designer to describe important interrelationships among the design issues (Dong et al., 2021; Kokotovich, 2008). In our data, considerations about the situation (ST) were mainly revealed from the concept maps and reflective reports. Figure 1 shows the digital version of the concept map (originally constructed in Chinese) drawn by Interior Design Student A. The concept map clearly demonstrated the analysis and association process of the design context.

For example, the central theme was the idea of *Liquid detergent*. Accordingly, the use of the arrow illustrates that the majority of women users need a detergent product to wash clothing (*Wash clothing daily* [ST]), and the washing process will arouse a need to protect the clothes (*Both washing and protecting* [ST]). This situation for the use of the detergent suggests an association with environmental protection (issue *Ingredients*) and values for sustainability (safety, environmentally friendly [ST]). Thus, this concept map groups topics together into themes and subthemes that further enhance the design students' understanding and analysis of the problem and its concomitant issues (cf. Kokotovich, 2008).

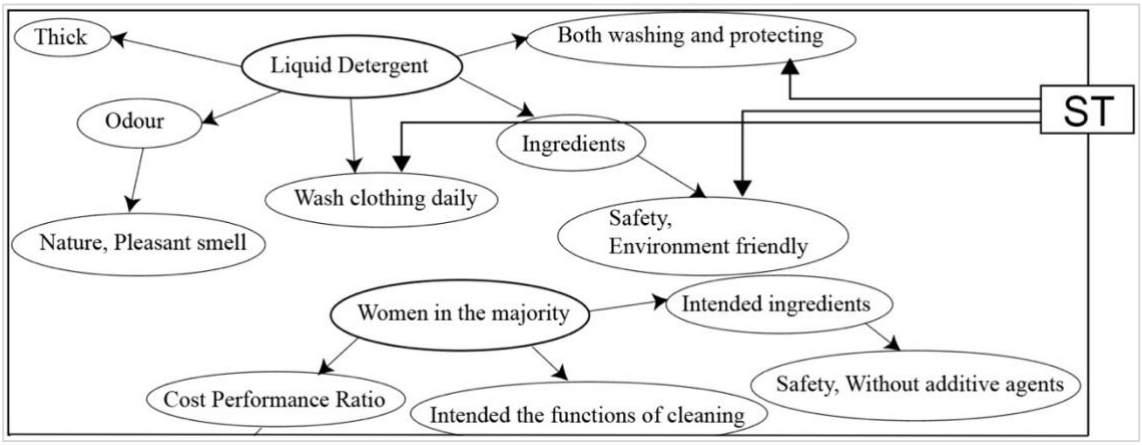


**Figure 1:** Concept map of Interior Design Student A.

Furthermore, the students' reports provided some explanations regarding the selected solution and its relationship with ST. For example, Interior Design Student A set the users' needs as the canter to create design ideas:

- Interior Design Student A: *I considered the creative development of the form of the bottle to break down the traditional style of such bottles in the markets. Thus, I illustrated the design of the bottle shape more as a female feature. The merits of this design were the innovative thoughts that were unlimited in the detergent product itself, and further consideration of the specific needs of the women users.*

Another student's description of how context-of-use is related to the users' segment of young people included the following:

- Graphic Design Student A: *The task started with problem-solving. I listed the problem statements required for reference use to look for solutions, such as adding details on the body, adding vertical lines to the cap, and used double handles setting to make the visual of the form more special. I thought this is a semicircle form for shaping the handles on the two sides of the body, it should create a special feeling of aesthetic, therefore, young people would well prefer such a design.*

## Sketching Intended Use (IU)

Intended use (IU) indicates the purpose of a product or part of a product, which aims to consider effective uses based on users' needs. These solution-oriented ideas regarding the situated issues were related to user–product interactions (e.g., intensity of use) or usability aspects (e.g., ease of use), which were characterised within a given type of user. Two examples that indicated the intended uses of a product's parts are presented in Figure 2. The left sketch solution shows a belt device on the body of the bottle indicating the product's relationship within the environment, where the bottle with a belt feature can be used as a hung on a wall. The right sketch shows a pump head design on the top for pushing down actions. These kinds of sketches usually contained partial designs of the product with annotations to indicate usage.

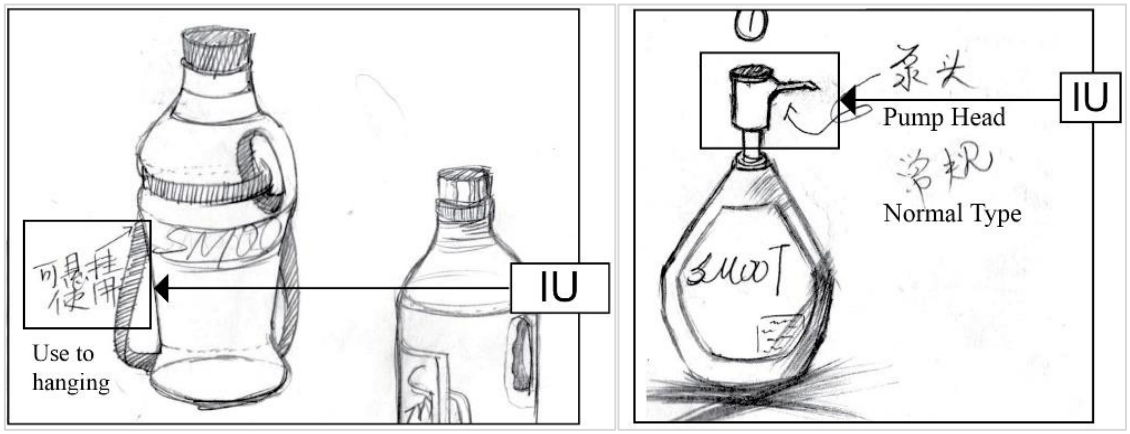


**Figure 2:** Sketches from Product Design Student C (Left) and Student A (Right).

## Illustrating Description-Based Concepts (DBC) Through Sketches and 3D Models

The category of knowledge is divided between description-based concepts (DBC) and principle-based concepts (PBC). DBC are used to facilitate the illustration of product features concerning aspects of aesthetics such as describing the placement, shape, patterns and functions of a product. Figure 3 shows Interior Design Student B's design perspectives of the outlooks of the bottle using a variety of shapes and making a final 3D model. The work was consistent with the idea of setting women as the users' segment in the transition process from the beginning by developing the bottle shape in a visual manner. The 3D model gives the impression of being a skirt or dress with female features. The shape does not vary within the three last sketches.

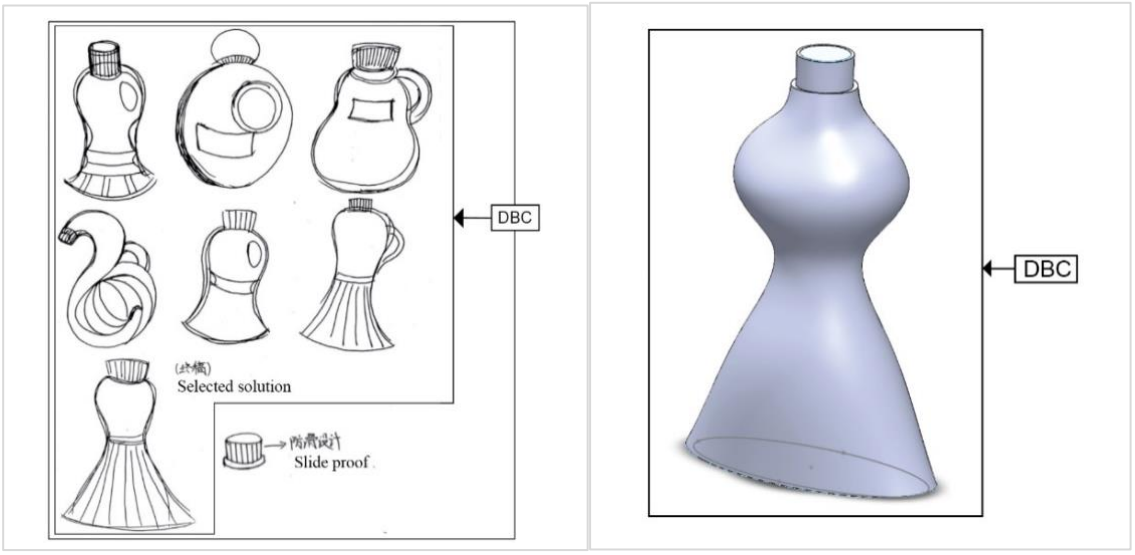


**Figure 3:** Sketches and 3D Model of Interior Design Student B.

Similar way, sketches of Interior Design Student C and the 3D model show the development of the shape and form of the bottle with a variety of circle elements on the bottle surface (Figure 4). The initial idea of the *Air Bubble* came from the author's mind map and it was conceptualized further by using circle patterns in the sketches and onto the surface of the final 3D model.

There were innovative developments in the created forms from a series of consistent design representations, which were unique and distinguished from traditional detergent bottle shapes. In these both cases, determinants for product form can be seen as related to drawing attention to the product, generating attraction and stimulating emotion (cf. Crilly et al., 2011), thus demonstrating aesthetical aspects embedded in their design representations.

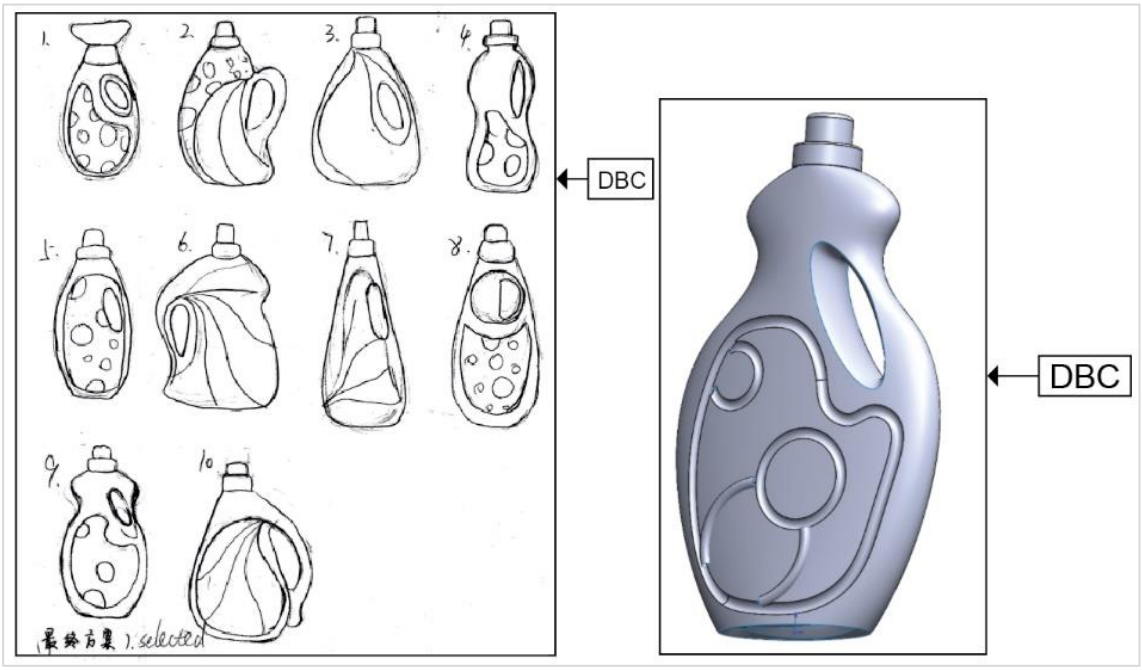


**Figure 4:** Sketches and 3D Model of Interior Design Student C.

## Describing Principle-Based Concepts (PBC) Through 3D Models and Reflective Reports

PBC indicate a designer's knowledge of the relationships between a product's structure and its functionality, which is usually connected to the ergonomic or user experience of a product. For example, handle design ergonomics can provide higher comfort and increased performance within the user–product system. In Cupar et al.'s (2021) study, many designers tried to optimise the size and shape of the handles to prevent physical discomforts, such as muscle soreness or blisters. In this sense, the designer aims to reduce discomfort and thus optimise the human–product interaction. Figure 5 shows the 3D model from Product Design Student A and the ways in which PBC were used. PBC are strongly related to design usability, and some design students intended to explore the interactions and relationships between people and objects.

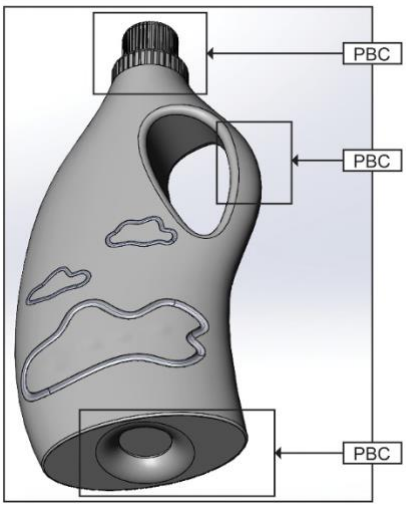


**Figure 5:** Generated 3D Model of Product Design Student A.

The codes of PBC revealed the functional relationships to describe the features of the product parts and their roles. For example, Figure 5 shows the vertical lines structuring the cap to increase friction force, the handle with a smooth curve structure for comfortable holding in the hand, and the concave structuring of the bottom for stable standing on the ground. Intentions towards ergonomic factors not only offer the appropriate functionality, but the product must be designed to allow suitable access, operation and maintenance. These aspects of PBC were embedded in the illustration of the parts of the 3D model, and corresponding aspects were also found in the student's report:

- Product Design Student A: *Designing a two-layers structure for the mouth of the cap to prevent liquid stack up and flow backwards. Particularly the inside layer of the cap was created higher than the outside layer, which design can facilitate the liquid flowing backwards through the inside layer. While the outside layer should not be touched by the liquid. [...] Used a concave structure to create the bottle's bottom with the ark shape, which has a better structure against the effects from the external force, by which it has the capability to be filled with the liquid, at the same time it can stably stand on the ground.*

## Reflecting Episodic Data (ED)

Experience is reflected in episodic data (ED) based on memories of what a person has experienced in the past. In a design, ED refers to a particular situation in which a product is used — occasion, event, or environment of use—. It is linked to a person's sensorial (smells and visual-tactile clues) or emotional experiences (feelings). In the present study, the category of ED includes various conceptualizations regarding shaping a detergent bottle for users, where the ideas are relative to personal memories and past experiences. The following kinds of relationships were mentioned in the reflective reports:

- Interior Design Student B: *These sketches came out with daily products in my life, like perfume bottles, body wash products and flower vases. Considering environment protecting issues, it could be retrieved by us for reuse again. It could be drawn like a vase to put some flowers in.*
- Interior Design Student C: *These various waterdrop shapes [in the student's sketches] presented a lot of dirt, like sweat stains and oil stains. I considered the function of the detergent was to remove these stains. At that moment I achieved a long-distance running, which was required for washing clothes with sweat.*

## Summary of the Main Differences in the Students' Representations

The results indicated that all students succeeded in creating a new 3D form of a detergent bottle that met the problem requirements despite the differences in the domain knowledge. As an overview, IU and DBC had main roles in all students' design representations, whereas PBC and ED were found in a few students' works. Half of the interior design students (A, B, and C) considered issues related to ED and sensorial experiences (e.g., memories of a flower vase and skirt or dress). Chamorro-Koc et al. (2015) argued that designers' episodic experiences tend to visually emphasise a product's features. Almost all participants utilised ST, except Product Design Student D and Graphic Design Student E who further preferred to adopt a straightforward way to engage — i.e., from the beginning they created some problem statements in response to the requirements of the brief—. Table 4 presents the summary of subcategories in the students' design representations and reports. The 3D models are presented in Table 3.

It should be noted that PBC as a source of domain knowledge only emerged in product design students' processes. One could argue that these kinds of specific product concepts are related to their structure and functionality, engaged when applying domain knowledge in product design. This type of student's process revealed various skills involving aspects of product experience and ergonomics, such as considering problems of liquid stack-up and shaping the handle to better fit human palms. For example, Product Design Student A presented a two-layered structure for the cap to solve the problem of liquid stacking (Figure 5).

**Table 3:** *The 3D models.*

| Interior Design | | Product Design | | Graphic Design | |
|---|---|---|---|---|---|
| **Students** | **3D Models** | **Students** | **3D Models** | **Students** | **3D Models** |
| Student A | | Student A | | Student A | |
| Student B | | Student B | | Student B | |
| Student C | | Student C | | Student C | |
| Student D | | Student D | | Student D | |
| Student E | | Student E | | Student E | |
| Student F | | Student F | | | |

To clarify the distinction between description-based and principle-based design concepts, we used two illustrative examples. Figures 6 and 7 present samples wherein PBC were used or not used by student designers. Two graphic design students considered the shape of the bottle without any kind of physical interaction. They created the bottle form taken on analogy study through online searching or specific experiences in daily life (Figure 6). Product Design Student B relied on PBC in the generated 3D model in handle design (Figure 7). In this instance, the student's intention was to reduce discomfort through the optimisation of the user–product interaction by structuring the contact area where it comprises that a hole structure is indented to the position to fit the thumb, then the palm can band to grasp action on the handle so that one hand could fit well to the gripping surfaces. The student tried to optimise the size and shape of the handles to provide uniform contact pressure on a user's hand. The top cap was also designed for easy opening by considering an increase in the friction force.

**Table 4:** *Participants' Design Concepts.*

| | Situation | Intended Use | Description-Based | Principle-Based | Episodic Data |
|---|---|---|---|---|---|
| ***Interior Design*** | | | | | |
| Student A | ST | IU | DBC | | ED |
| Student B | ST | IU | DBC | | ED |
| Student C | ST | IU | DBC | | ED |
| Student D | ST | IU | DBC | | |
| Student E | ST | IU | DBC | | |
| Student F | ST | IU | DBC | | |
| ***Product Design*** | | | | | |
| Student A | ST | IU | DBC | PBC | |
| Student B | ST | IU | DBC | PBC | |
| Student C | ST | IU | DBC | PBC | |
| Student D | | IU | DBC | PBC | |
| Student E | ST | IU | DBC | | |
| Student F | ST | IU | DBC | | |
| ***Graphic Design*** | | | | | |
| Student A | ST | IU | DBC | | |
| Student B | ST | IU | DBC | | |
| Student C | ST | IU | DBC | | |
| Student D | ST | IU | DBC | | |
| Student E | | IU | DBC | | |

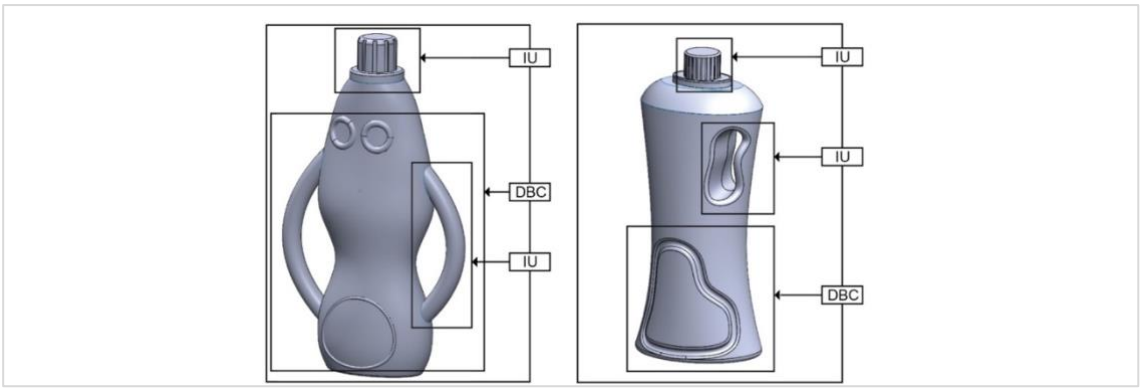


**Figure 6:** 3D Model Solution of Graphic Design Student D (Left) and Graphic Design Student C (Right).

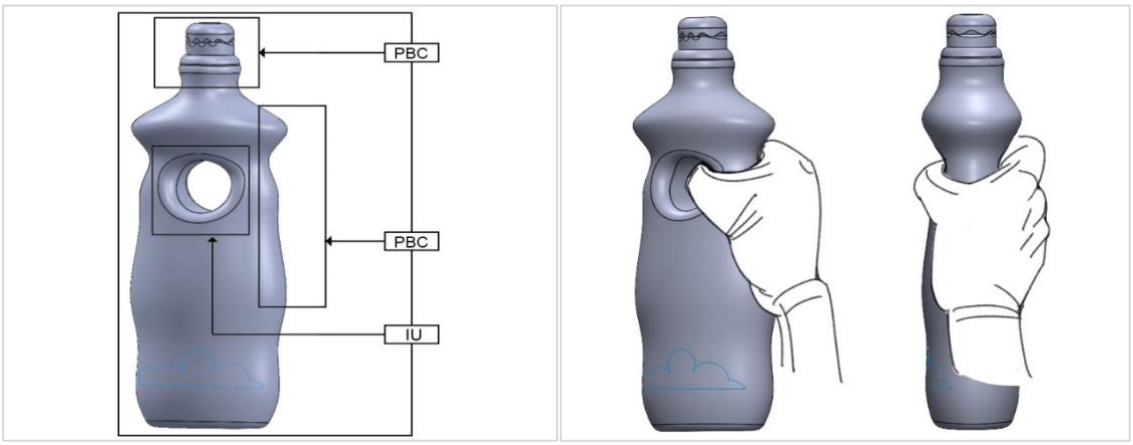


**Figure 7:** 3D Model of Product Design Student B and the Handle with Grasping Action on the Contact Area.

In the essay, the product design student B wrote: *I wish that the curve of the handle to the sides of the body cannot be entirely smooth, there should be a lot of ups and downs, so it could better fit our palms through an interface when someone takes it up with a hand. […] Due to the reason of no information about the material application [in this task], I cannot think more deeply that how to deal with the relationship [shape and size] between the grasping action and the contact interface.*

The use of PBC is clearly based on the designer's inference activity from the reference of the interaction relationship between hand use and the design concepts. Furthermore, these kinds of considerations are largely done to increase the functionality of the product with its parts, as well as to improve the physical interaction between the object and the context of use. Physical interaction can be improved through the size and shape of the gripping surfaces, as well as the materials used. It has been shown that there is a correlation between the mechanical properties of the materials used and the subjective psycho-physical response of the user (Wongsriruksa et al., 2012). The use of PBC indicates that the design task is likely a routine activity for some product design students but not for other design students.

# Discussion

This study highlights design concepts in 3D form development embedded in the student designers' design representations. It is important to study the students' different design concepts and intentions by examining the differences in approaches taken within different design disciplines. Aside from an analysis of the design representations, it is beneficial to explore the participants' own interpretations and understandings of the design concepts. We focused on students' design concepts that involved a design product's form influenced by the sources of personal experience and domain knowledge. Our findings suggest that there were both similarities and differences in how the domain knowledge was used in the context of the product form design task. The students considered various design concepts that emerged from the representations — e.g., situation, intended use, episodic experience, and description-based concepts, as well as more domain-specific knowledge of PBC generated during the design process— (cf. Chamorro-Koc et al., 2015). Each of these categories was connected to approaching product experience with users' perspectives, mainly focusing on how people use the product. However, the students' product design concepts also demonstrated aesthetical values embedded in design representations, not just functional and usability aspects. Obviously, participants from the product design discipline reflected skills related to design expertise in the form of PBC. During the relatively short time and well-structured design task (i.e., new form for the detergent bottle), all design students were able to deal with a variety of product experience aspects and provide applicable solutions for design problems.

The authentic events in the students' memories represented their own individual experiences that were then used to create special scenarios indicating the use of products — e.g., washing underclothes, long-distance running, and growing flowers in daily life. Another type of experience was based on expert domain knowledge that guided the usability aspects of product design—. In our previous study (Yang et al., 2022), such domain knowledge supporting product design practice was also revealed: less experienced students tended to consider the visual aspects of the form more than user-related aspects, such as the usability of the product. According to Chamorro-Koc et al. (2008), a lack of user-centered design may be compensated for by familiarity with comparable products, but initially, hypothetical concepts of the product's use and features can be incorrect, still consecutively relevant considerations on conceptualizing product concepts to fulfil the design requirements aspects. While aesthetic appeal and pleasurable experience of the product are equally important aspects of product concept design and should not be underestimated.

The participant students were able to develop relevant design concepts that required student designers to emphasise appropriate 3D forms at the center of their designs. The design results revealed that all students succeeded in creating a new 3D form of a detergent bottle and fulfilled the problem requirements. However, product design students considered principles of use and product usability more than the students from the other disciplines did.

The validity of the findings relies on the careful data collection process and iterative interpretation of the data analysis. As a qualitative case study, we acknowledge that the sample size of participants and the type of product design task might have limited the findings. Since the study involved intensive investigation of a small number of participants, the data do not support the drawing of decisive conclusions. We do not know about the representativeness of this sample of participants, and our provisional conclusions need to be refined with other samples and other settings. Our study revealed that the combination of design representations and retrospective reports is a valuable source for gaining a holistic understanding of designers' experience and knowledge of product design. Thus, this methodological approach can be suggested for other studies that require the exploration of aspects of personal design experience while addressing design tasks.

# Conclusion

Design education facilitates the transformation from a novice to a professional designer, and design educators need to understand expert's domain knowledge, as well as novice performance. This study highlighted design concepts in 3D form development embedded in the student designers' design representations. It was important to study the students' different design concepts by examining the differences in approaches taken within different design disciplines. For example, routine design situations consist of well-defined and familiar aspects of the design field (Love, 2021). This means that a typical product design task can be understood as a routine activity for product design students but not for design students in other fields. This kind of cross-disciplinary educational setting should be utilised more in design teaching since it can provide opportunities to recognise different possibilities when students approach their design issue. It would be beneficial if the students also could explain their intentions thoroughly in collaborative sessions. This will elicit a richness of design approaches going forward and make visible various solution attempts.

The study was based on the well-structured Bottle Form, design task approaching to re-design a novel product form in a cross-disciplinary setting. Our experimental setting was limited, involving user consideration with a relatively simple product (i.e., a detergent bottle) with which the participants were quite familiar. Further, the study setting was limited to three hours and did not include any user-centered research, for example, the ethnographic research to study how the conceptual product is used by different customer segments. Thus, some of the students' user conceptualizations can be considered stereotypical and seen as a single user group.

However, we argue that it is important to reveal unformed user conceptualization to better educate towards user-centered and empathic aspects of design thinking. By revealing these design concepts, a critical educator can interrogate and challenge students' initial assumptions. It also helps educators to design briefs or subtasks that scaffold and encourage students into a deeper exploration of how various kinds of people approach the products.

To conclude, to educate creative designers design thinking approach can be utilized across various design domains. Students not only need to develop deep design skills with various design methods, digital tools and techniques but also engage in project-oriented work, learn to lead design projects and collaborate with designers and non-designers. Furthermore, there is a need for further development of various cross-disciplinary educational models that support the concept of T-shaped designers and the making of the expert-generalist. Students need a challenge to explore multidisciplinary collaboration and possibilities of the latest technologies, new materials, and innovative design solutions.

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