WACANA SENI
Journal of Arts Discourse

Intuitive Design Thinking Criteria of Designers in Problem Solving

Zainudin Siran[1,2]*, Rusmadiah Anwar[2], and Mohd Hafizuddin Mohd Yusof[3]
[1]Centre for Interaction and Experience Design (CIED), Multimedia University, Persiaran Multimedia, 63100 Cyberjaya, Selangor, Malaysia
[2]Institut Seni Kreatif Nusantara (INSAN), Universiti Teknologi MARA, 40450 Shah Alam, Malaysia
[3]School of Creative Media, Bahrain Polytechnic, Bahrain

*Corresponding author: zainudin.siran@mmu.edu.my

Published online: 31 December 2025

To cite this article: Zainudin Siran, Rusmadiah Anwar, and Mohd Hafizuddin Mohd Yusof. 2025. "Intuitive Design Thinking Criteria of Designers in Problem Solving." *Wacana Seni Journal of Arts Discourse* 24(Supp. 1): 51–67. https://doi.org/10.21315/ws2025.24.s1.3

To link to this article: https://doi.org/10.21315/ws2025.24.s1.3

ABSTRACT

Industries involved in research and development for new product development (NPD) typically employ experts from various disciplines and knowledge domains, including engineering design, art-based design, interface design, information technology, and more. These differences in discipline and experience influence the approaches and solutions taken when addressing problems in NPD projects, such as functionality, aesthetics, usability, manufacturing, and so on. For this reason, an in-depth study was conducted to explore intuitive design thinking behaviour across different knowledge domains. The study employed an empirical method involving the observation of experimental design and Design Protocol Analysis (DPA), conducted with the participation of 30 final-year undergraduate students who were divided into three groups: engineering design (ENG), art-based design (IDE), and interface design (ID). Besides profiling the intuitive design thinking behaviours of these three domain groups, findings also revealed distinct patterns in problem solving whereby ENG participants emphasised usability with less focus on aesthetics; IDE participants prioritised aesthetics with less emphasis on usability; and ID participants balanced both ergonomic and aesthetic considerations. Based on these findings, the researchers proposed a new model for design management within organisations that employ multidisciplinary designers. This model is intended to enhance the quality of operations in the NPD process and to shorten project durations by reducing repetitive processes caused by rejections at different stages of development.

Keywords: *intuitive design thinking behaviour, problem solving, multi-discipline organisations*

INTRODUCTION

Design is a key component of any business entity and plays a critical role in determining the future sustainability of a company. In business, design serves to meet user needs and achieve strategic objectives (Cuffaro 2006; Cuffaro and Zaksenberg 2013; Siran, Zainal Abidin, and Anwar 2020). Anything involving the transformation of an actual situation into a preferred one falls under the domain of design (Schön 2017; La Velle et al. 2020), including aspects such as conceptual development, cultural evolution, user needs, technical specifications, and more.

However, design issues often require input from multiple disciplines to ensure a balanced analysis of potential solutions from different perspectives. At times, poorly considered design decisions can lead to outcomes worse than the original problem (Schön 2017; La Velle et al. 2020).

In this context, scholars such as Pugh (1991), Yuri (1999), and Li et al. (2023) advocated for a multidisciplinary approach to the design process, as it tends to yield strategies better suited to addressing core challenges. Multidisciplinary organisations composed of individuals from diverse fields inevitably feature varied behavioural tendencies and ways of thinking. For instance, art-based designers (AD) often focus on the external appearance of a product rather than specific user problems. Their approach, which emphasises visual elements and compositional structure, differs markedly from the engineering design process (Akner-Koler 2000; Siran and Anwar 2020).

Engineering designers, by contrast, prioritise product functionality and the procedural aspects of design (Pahl et al. 1996; Liu et al. 2021). Similarly, Verma (2001) and Santos et al. (2020) emphasised solution-neutral design approaches that focus on conceptual development over geometry, cantering instead on function. Preece (2011, 17–19) and Stonewall et al. (2019) further highlighted challenges often faced by interdisciplinary design teams, including large team sizes, high costs, communication barriers due to differing professional languages, and slow progress.

Given these complexities, a detailed study is required to define the behavioural characteristics of intuitive design thinking across various knowledge domains. The goal is to establish clearer roles and responsibilities within multidisciplinary teams, thereby enhancing the new product development (NPD) process. Furthermore, this approach supports the refinement of design methodologies through the application of appropriate protocols aimed at understanding designers' thought processes (Zainal Abidin et al. 2009; Hu et al. 2024).

Research Questions and Objectives

Research Questions:

1. What are the key issues related to the criteria of intuitive design thinking among designers in problem solving?
2. What are the behavioural patterns of intuitive design thinking exhibited by designers from different knowledge domains during problem solving?
3. What are the characteristics of intuitive design thinking in designers when engaged in problem solving?

Research Objectives:

1. To understand the key issues related to the criteria of intuitive design thinking among designers in problem solving.
2. To analyse the behavioural patterns of intuitive design thinking exhibited by designers from different knowledge domains during problem solving.
3. To profile the characteristics of intuitive design thinking in designers when engaged in problem solving.

LITERATURE REVIEW

Three main factors influence different design thinking behaviours, namely the design thinking context, the NPD process in design management, and the knowledge domain. Each warrants detailed explanation.

The Context of Design Thinking

Personal justification is integral to developing solutions for specific design problems. Schön (2017) and La Velle (2020) emphasised design thinking as a design language for analysing student and teacher discussions on proposed solutions. Similarly, other scholars defined it as the way designers approach research and education (Rowe 1987; Dorst 2011; Hall 2020). A personal-based approach may lead to decisions that are justified, unstable, or unbalanced, and design solutions to public issues may sometimes produce consequences worse than the problems they address (Schön 2017; La Velle 2020). The design thinking context also involves cognitive analysis (Simon 1992; Siran and Anwar 2020), requiring in-depth exploration of specific issues. Design thinking research demands understanding users, forming assumptions, and refining problems to develop effective solution strategies (Georgiev 2012; Wangsa et al. 2022). Thus, an observational methodological approach is necessary to examine this complex and diverse context, reinforcing the need to address Research Question 1.

Design Process in NPD Management

Current NPD practices typically follow a structured, step-by-step process. The outcomes of NPD are critical to organisational direction and decision-making, often involving multiple design options (Warell 2008; Siran and Anwar 2020). Earlier product development processes, however, relied heavily on personal experience and perspective, leading to varied interpretations of design problems. As Goldschmidt (1997) noted, novice designers often produce outcomes marked by uncertainty within the problem space. Design management often faced challenges such as interdepartmental coordination, bureaucratic delays, and issues related to human factors, environment, time, and project goals (Ulrich and Eppinger 1995; Verganti et al. 2020). These factors affect user interaction, a core element of user experience (Jantan et al. 2020). A co-creation framework could enhance collaboration and guide effective design strategies. Yet, weaknesses in communication, leadership, and decision-making persisted (Zambrano and Cruz 2010). Consequently, design management in NPD integrates diverse design thinking approaches, aligning with Research Question 1.

Knowledge Domain

Within design teams, diverse knowledge domains shape how specific issues are approached and solved. For instance, engineering- based design emphasises specialised technical expertise, aligning with the concept of “Domain Position” (Pahl et al. 1996; Liu et al. 2021). In such contexts, individuals with extensive experience and higher organisational positions often influenced final decisions on problem-solving strategies. Conversely, multidisciplinary management may encounter challenges due to limited experience in product development, leading to increased time and cost consumption (Ulrich and Eppinger 1995; Verganti et al. 2020). In contrast, approaches from the art and design domains focused on integrating objects, forms, and images to create future- oriented figural compositions (Taura et al. 2009; Matsumae et al. 2020). These methods primarily enhance the visual and structural qualities of design outcomes. Therefore, variations across knowledge domains significantly influence the direction and results of design thinking processes.

METHODOLOGY

This research aims to explore and explain intuitive design thinking patterns in problem solving across different disciplinary groups. The study was conducted at the conceptual design level using qualitative methods, including observations and interviews. The research methodology comprises three main phases designed to address the research questions and objectives: (1) a survey and literature review, (2) observation and interview, and (3) data analysis.

Survey and Literature Review

In the first phase, the survey was conducted to identify some of the problems from users regarding the highest usability issues and related product types. Meanwhile, the literature review helped clarify the research gaps from theoretical studies related to intuitive design thinking and the design process in NPD.

Observation and Interview

In Phase Two, the observation method was applied using the Design Protocol Analysis (DPA) technique across three categories of respondents with different disciplinary backgrounds. Final-year project (FYP) students were selected as respondents to validate research data in the field of creativity, as they represent design thinking behaviour patterns comparable to those of experienced professionals within the same knowledge domain (Yuan et al. 2014; Othman et al. 2022). According to Roscoe et al. (1975) and Biswas et al. (2022), a sample of 30 respondents is adequate for generating constructive analysis in this research context. The sample comprised 10 students each from engineering (ENG), interface design (ID), and industrial design (IDE) programmes (Table 1). The ID group was from the Faculty of Multimedia, Multimedia University (MMU), Cyberjaya; the ENG group from the Faculty of Engineering, MMU; and the IDE group from the Faculty of Art and Design, Universiti Teknologi MARA (UiTM), Shah Alam. These groups represented the technical, user experience, and artistic thinking domains, respectively, reflecting the multidisciplinary nature of NPD activities. Participants were briefed on a design task and instructed to sketch a new TV remote control concept for elderly users. Subsequently, interviews were conducted to understand their rationale and design concerns.

Data collected included sketches, behavioural actions during ideation, reference materials, and timing for each activity. For DPA, three video cameras recorded participants' behaviour from different angles (see Figure 1). Six reference materials were provided to the respondents: (1) panels illustrating technological innovations, (2) past models of remote control, (3) alternative design remote control models, (4) the button functions and specifications of current models, (5) physical product samples, and (6) personal computers for online searches. The task briefing outlined the design scope, objectives, timeframe, target users, reference materials, equipment, and process guidelines. The study design considered several methodological aspects, including survey criteria, sample size, subject selection, and the use of the DPA method. The DPA technique, originally developed at the Delft Design Protocol Workshop (1994), investigates creative design processes by analysing cognitive events that occur between the task briefing and the resulting design output (Anwar 2016; Siran and Anwar 2020).

Respondents' actions and behaviours served as indicators of their cognitive design processes. Senior citizens were selected as the target users to assess respondents' intuitive design thinking and their responses to problem solving. To identify usability issues, a preliminary survey involving 75 senior citizens was conducted. The television (TV) decoder remote control was selected as the design subject because (1) all respondents were familiar with its functions, and (2) it presents diverse aspects for study, including ergonomics, multi-function button layout, and interface design. The collected data were analysed to examine problem-solving strategies, choice of reference materials, knowledge level, user understanding, and design time phases.

Table 1 The sample criteria for design protocol analysis

Group and study programme	Knowledge domain	Level	Sample size
ID: Bachelor of Multimedia (Hons) Interface Design-MMU	Screen interface design, user interaction, user experience, ergonomics, usability, product specification, concept system, etc	Year 4 (FYP)	10
IDE: Bachelor of Art and Design (Hons) Industrial Design-UiTM	Design styling, trends, aesthetic value, usability, target user, new features concept, etc	Year 4 (FYP)	10
ENG: Bachelor of Science (Hons) Mechanical Engineering-MMU	The manufacturing process with concern on cost, mechanism, material selection, tools, testing, etc	Year 4 (FYP)	10
Total			30

Observation Requirement, Strategy, and Equipment

The DPA setup consisted of three cameras positioned to capture multiple aspects of participants' behaviour. One front camera recorded eye movement toward the reference panels 1–4 to monitor visual attention, while the top and side cameras captured hand movements during sketching, handling of the remote control, or computer use (Figure 1). These recordings also documented body language and voice intonation during the interview sessions to measure behavioural responses. The collected data were analysed and compared with the corresponding sketches to identify specific patterns of intuitive design thinking behaviour among respondents from different knowledge domains.

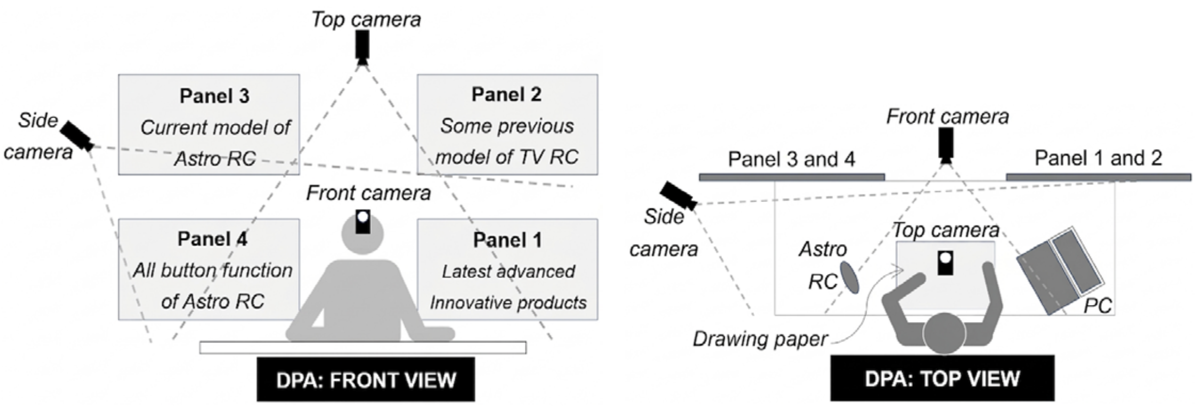

Figure 1 Layout setting of equipment and reference materials at design protocol analysis

Coding Scheme of Data Collection

Data from the design experiments were interpreted through observable behaviours during the DPA sessions. The analysis employed a coding format that included design elements, line-drawing morphing, and timestamps, which were correlated with participants' activities and behaviours (Figure 2). This coding process supported the development of a new research framework by generalising factors such as design rationale, problem-solving processes, and usability considerations for elderly users. It enabled the identification of design processes and concerns in idea construction, producing standardised and consistent design interpretations.

The approach was adapted from established design research models by Warrel (2001), Akner-Koler (2000), Zainal Abidin (2012), and Anwar et al. (2022).

1	Panel 1: New screen-based innovation technology	2	Panel 2: Current model remote control design	3	Panel 3: Latest design concept of TV remote control
4	Panel 4: All button functions	5	Astro TV Remote control sample	6	PC for online research

Figure 2 Colour coding for time stamp data

Data Analysis

In the third phase, the collected data were analysed to determine the criteria of intuitive design thinking (research findings). The analysis involved three stages: (1) comparison between timestamps and behavioural actions; (2) comparison between timestamps and reference material usage; and (3) examination of external form and button function arrangement. Timestamps were recorded every 10 seconds to capture how respondents interacted with reference materials and other design elements. Through the correlation of behavioural and visual interaction data, specific elements used by respondents—such as reference types, problem-solving factors, and design strategies—were identified. Respondents expressed design ideas through mental imagery, supported by thumbnail sketches or detailed drawings (Zainal Abidin 2012; Anwar et al. 2022). These sketches were further analysed using the morphing method of design line drawings to identify each group's unique characteristics in product form and design focus. The identified characteristics were compared against multidisciplinary design management theory in the NPD process and knowledge domain theory to determine appropriate roles within the design organisation. The analysis also examined short-term memory processes in linking design problems and solutions (Lloyd et al. 1995). The results informed the development of a new organisational model for NPD management (see Figure 5), representing a significant contribution to the body of knowledge in design thinking and NPD research.

THE RESEARCH FINDINGS

Table 2 presents the list of reference materials, their purposes, and their contributions to respondents' intuitive behaviour, while Table 3 summarises the interaction data from all groups engaging with the six reference materials. These include Panel 1 (P1): innovative products, Panel 2 (P2): current TV remote control series, Panel 3 (P3): current models of TV decoder remote controls, Panel 4 (P4): button functions, along with physical remote control samples and computers for online searches. As discussed in the methodology section, respondents' interactions with these materials reflect their intuitive design thinking patterns. Sketches produced during the idea generation process were analysed across three levels: (1) abstraction, focusing on external casing shapes; (2) semi-concrete, emphasising button function selection and arrangement; and (3) concrete, examining the integration of button layout and casing design. Analytical data included timestamps, reference interactions, behavioural actions (e.g., eye movements), and sketch outputs. All sketches from each group were analysed using the morphing method to derive overall design forms that represent distinct thinking patterns. The resulting behavioural data collectively addressed the issues outlined in Research Question 2.

Table 2 List of reference materials, purpose and how they contribute to the respondent's intuitive behaviour

Reference materials	Purpose	How it contributes to the respondent's intuitive behaviour	The relation of reference materials measurement of three abstraction levels
Panel 1 (P1): The image of the latest innovative products with advanced technology	As a reference for design features and aesthetic character	Showing the respondent's level of sensitivity to the advanced features and aesthetic aspects of the new concept	Timestamps and video data were analysed to measure how often respondents referred to specific reference materials at each design stage. For instance, extended focus on P1 during the concrete stage indicates attention to futuristic and innovative features, reflecting respondents' intuitive design thinking patterns
Panel 2 (P2): Image of previous model remote control for TV/ decoder	As a reference of product series: button function, design and aesthetic character	Showing the respondent's level of sensitivity to the main button function's basic design features for the new concept	
Panel 3 (P3): Image of current models of Astro remote control	As a reference of product series: button function, design and aesthetic character	Showing the respondent's level of sensitivity to aspects of Astro design language and identity for the new concept	
Panel 4 (P4): The image of all button functions (Astro TV decoder)	Info on all buttons functions as the study subject	Showing the respondent's level of sensitivity to aspects of functionality for the new concept: which button functions should be retained or removed?	
Physical sample of Astro remote control (same model as P4)	For physical reference; holding, actual size, and ergonomic study	Showing the respondent's level of sensitivity to aspects of ergonomics for the new concept	
Personal computer	For online search of any additional info related to the task	To study the level of concern and initiative of respondents on matters related to the product (latest trend, specification, etc.) or user (weakness, requirement, etc.)	

Timestamp Compared to Reference Materials

As shown in Table 3, the IDE group spent the longest time on drawing activities, particularly at the abstract level, with a gradual decrease at the semi-concrete and concrete stages. They frequently referred to Panel 4 but engaged less with online searches and Panel 1. In contrast, the ENG group spent considerable time on online searches but referred less to physical reference materials and devoted minimal time to drawing. The ID group showed extended engagement at the abstract stage, with reduced activity at later stages, and focused primarily on online searches for user information. Timestamp data compared with reference material interactions provided evidence of behavioural patterns addressing Research Question 2. Comparative analysis of eye interaction data using non-parametric statistics revealed $P = 0.05$ and an effect size = 2. The null hypothesis stated that there were no significant differences among conditions or time points (P1, P2, P3, P4, remote, internet, total interaction, and total drawing).

Table 3 The time spent on eye interaction with all reference materials

		P1	P2	P3	P4	Sample	Internet	Total interaction	Total drawing
IDE	Abstract	60	140	280	550	500	50	1,580	2,120
	Semi-concrete	10	50	100	740	240	30	1,170	2,510
	Concrete	50	30	50	700	250	20	670	2,370
	Total	120	220	430	1,550	990	100	3,420	7,000
	%	3.5	6.4	12.6	45.6	28.9	2.9		
ENG	Abstract	10	30	50	310	1240	20	2,080	2,130
	Semi-concrete	70	120	150	630	670	30	1,670	1,530
	Concrete	30	30	60	190	290	20	720	1,720
	Total	110	180	260	1,130	2,200	70	4,800	5,380
	%	2.3	3.8	4.6	20.8	25.6	42.9		
ID	Abstract	20	40	180	550	880	80	2,060	1,610
	Semi-concrete	50	50	100	320	300	410	1,230	2,590
	Concrete	30	30	40	370	70	80	1,030	2,500
	Total	100	120	320	830	1,250	1,570	4,320	6,900
	%	2.3	5.8	7.4	19.2	28.9	36.3		

The Morphing Analysis of Sketch Drawing

A quantitative analysis using Procrustes distance was applied to measure and clarify the similarities and differences in shapes derived from the morphing results, supported by statistical evaluation. Figures 3 and 4 illustrate the mapping patterns of body casing shapes and button layout designs. The ENG group produced consistent, simplified layouts with fewer key buttons. Timestamp data indicated that they spent a significant time understanding elderly users' needs and analysing assistive products. However, their designs showed limited aesthetic balance, suggesting that their intuitive design thinking emphasises user-centric rather than product character; centric solutions. The IDE group focused primarily on ergonomics and visual appeal, often neglecting usability issues. Their concepts displayed complex button arrangements similar to existing models, with minimal simplification. Conversely, the ID group demonstrated consistent and simplified layouts, emphasising clarity over quantity. Analysis of the average line drawings revealed distinct intuitive design criteria and problem-solving behaviours among groups. As Warrel (2001) noted, design elements convey messages derived from respondents' mental imagery. Figure 2 maps all body shell line drawings, where dotted lines represent averaged shapes within each group. The ENG group's baseline form showed 75% similarity to the current model, reflecting ergonomic and usability concerns. The IDE group's form exhibited 100% similarity, emphasising aesthetic priorities. The ID group's baseline showed 25% similarity, focusing on user interaction. Morphing data of shape and button layout designs collectively establish the behavioural patterns addressed in Research Question 2.

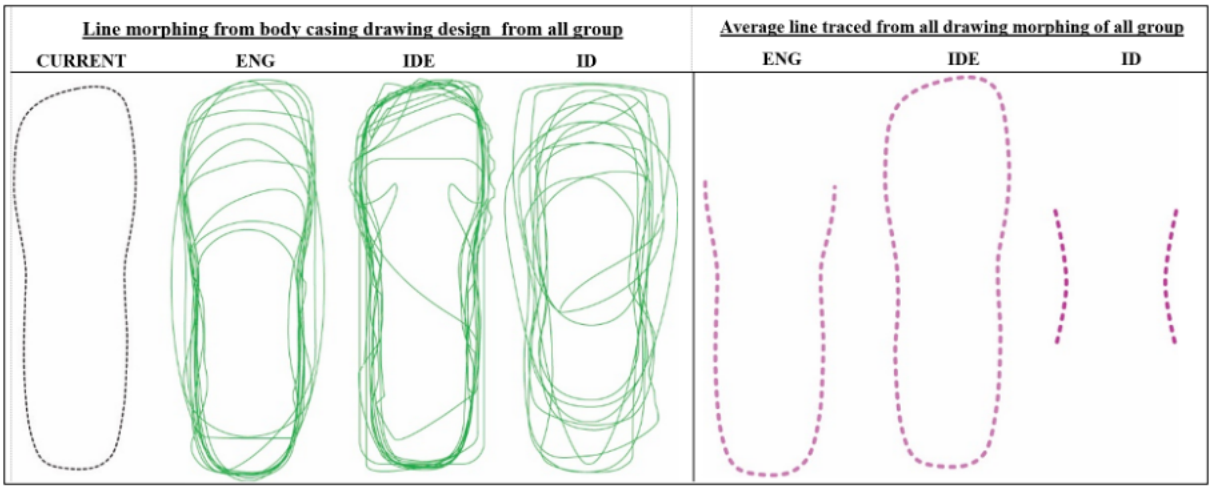

Figure 3 The morphing of line form for body casing design from all groups

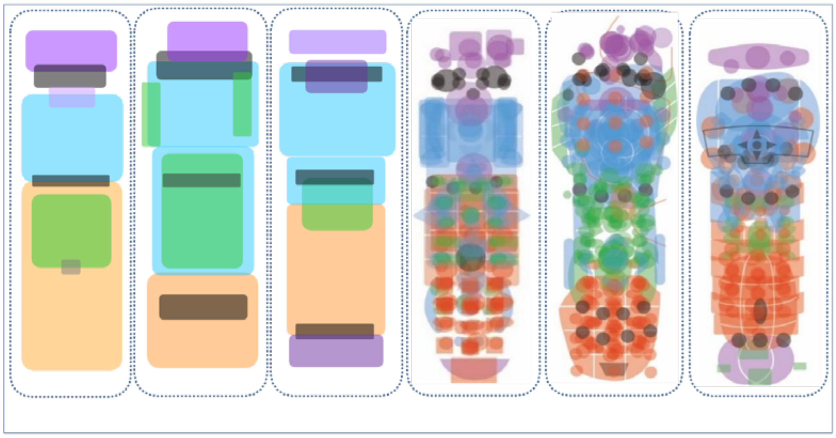

Figure 4 The morphing of layout design of button function for remote control concept

Main functions: purple and blue; support functions: brown; advanced functions: black and green

Table 4 The overall summary of drawing mopping analysis of three groups

Elements	IDE	ENG	ID
Body casing design	Similar basic form and size of all respondents, proportion similar to the current model, but different character with detailing of form	50% similar form and size, 50% different each respondent compares to the current design 75% similar to current form proportions (centre and bottom area)	Obvious differences in form and size of each respondent, mostly featured with slim size in the centre area (–25% similar to current) Looks new and different form
Interface layout button functions	Complex, many functions, different positions, all category functions (for support and advanced functions) The main function is on top and support functions at the bottom, consistent with each respondent.	Less quantity of buttons but different location for support category of function Main and advanced functions on top, consistent with each respondent	Simple, fewer, and almost consistent position of function; advanced function in a different location Main function on top and support functions at the centre, consistent with each respondent

(continued on next page)

Table 4 *(continued)*

Elements	IDE	ENG	ID
Interpretation of concern factors	Aesthetic (character with detailing)	Usability and user weakness (simple operating system and ergonomic)	Aesthetics (new style), usability and user weakness (simple operating system and ergonomic)
Overall	Different design thinking approaches and concern factors from each other		

Time Stamp Compared to Action Behaviour (Eye Interaction)

This analysis is based on respondents' activities and behaviours recorded every 10 seconds over a total duration of 2,000 seconds. The analysis of these factors revealed design solution approaches, including interactions with reference materials and design sketches. As shown in Figure 5, timestamp and eye interaction data indicate that the ENG group exhibits two main behavioural patterns. The first involves intensive research and observation of product samples and reference materials, while the second focuses on brief observations of product functions and panels. This suggests that the ENG group's intuitive design thinking emphasises usability and practicality. The ID group, meanwhile, focuses on ergonomic usability and aesthetics, beginning with online research and product testing before reviewing reference materials. In contrast, the IDE group conducts minimal observation before sketching, reflecting a stronger emphasis on aesthetic form over task understanding. The comparison of timestamps and behavioural data thus supports the criteria for the behavioural patterns addressed in Research Question 2.

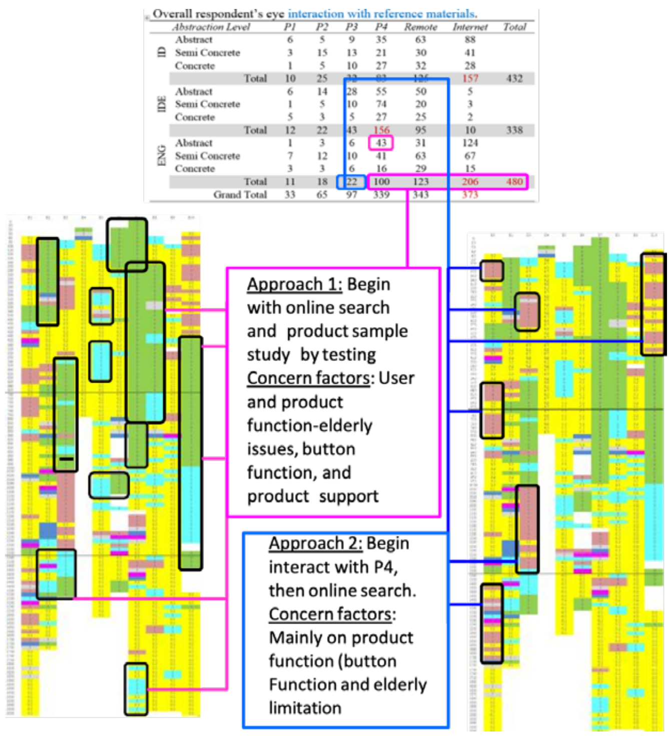

Figure 5 The comparison of data analysis of eye interaction and timestamp from the engineering group

DISCUSSIONS

The Character of Intuitive Design Thinking on Problem Solving

To determine the characteristics of intuitive design thinking and problem solving across all groups, a comparative analysis was conducted using the DPA data, Design Thinking theory, and Domain Knowledge, as visual reasoning reflects cognitive processes in design (Oxman 2002).

Tables 5 and 6 present the final findings of all groups on the characteristics of intuitive design thinking in design solutions, derived from a three-layer analysis emphasising their concerns and problem-solving approaches. The IDE group shows: (1) a strong focus on intuitive (aesthetic) elements; (2) moderate concern for product functions and ergonomics; and (3) low concern for usability due to limited research on fundamental issues. The ENG group demonstrates: (1) high concern for user usability factors; (2) moderate attention to product functions and ergonomics; and (3) low concern for intuitive and aesthetic aspects. The ID group emphasises: (1) ergonomics and product functions, particularly in handgrip form, size, and button layout; and (2) moderate concern for aesthetics and usability. These findings clarify the characteristics of intuitive design thinking and problem solving related to Research Question 3.

Table 5 Three-layer analysis summary of intuitive design thinking behaviour in problem solving

			IDE		ENG		ID	
			Approach	**Concern**	**Approach**	**Concern**	**Approach**	**Concern**
Eye interaction-research	**Research 1**		Short observing product sample by hand-held test and a little observation review of some other reference materials	A little concern on button functions	Begin with intensive online research and product sample testing	Usability: Ergonomic of hand-held posture and elderly weakness	Begin with online research, sample testing and a little review of other reference materials	Usability-elderly issues/ limitations and ergonomic of hand-held posture
	Research 2		A little and consecutive stage of study button function through Panel 4	A little concern on button functions	Begin with main component of Panel 4, then internet search	Product function (button functions) and elderly limitation	Study Panel 4 after online research and product sample testing	Product/ button function and little of elderly limitations
Drawing	**Body casing design**	**Body casing 1**	Hand-held posture with decorative form stylisation at bottom and centre	Highly concern on aesthetic and slightly on ergonomic (hand-held posture)	Shorter and smaller size dimension, narrow bottom side, rounded form	Usability: Ergonomic of practical size and hand-held posture	Body casing: Slimmer holding area and shorter total size, rounded form, new design form	Usability-ergonomic for grip, to reach few buttons by one finger, elderly limitations
		Body casing 2	Decorative parts with no reason	Highly concern on aesthetic without clear functions	Remain as current size of body casing and rounded form	A little concern on ergonomic		Aesthetic: Proportion and design balance

(continued on next page)

Table 5 *(continued)*

		IDE		ENG		ID	
		Approach	**Concern**	**Approach**	**Concern**	**Approach**	**Concern**
Drawing	**Interface of button functions**	Interface design: remain all quantity of current buttons, regroup related functions, and reposition of main functions, different shape of the main button	A little concern on usability by emphasising the form, size, and main button for easy to recognise the main functions	Interface 1: Reduce quantity buttons, regroup related functions, and reposition main function on top, and canter parts, different forms, bigger size, and wider gaps of main buttons	Deep concern on usability through simple operating system, remain basic function only and reachable button by single finger.	Interface: reduce quantity buttons, grouping similar functions, reposition different shape and wider gaps, to matching shape with body casing	Ergonomic on main function only and simple, reachable position by one finger Aesthetic: Proportion and design balance
				Interface 2: Remain almost all quantity functions, emphasise main button, reposition main function on top and canter parts	A little concern on usability-easy recognise main button		
Overall design approach of timestamp		G1) Research: Short study sample hand-held test and a little review other materials Body casing: Hand-held with decorative at bottom and centre G2) Research: A little and consecutive study button function Panel 4 Body casing: Decorative with no reasons Interface: remain all quantity buttons, regroup, reposition, different shape of the main button		G1) Research: Begin intensive online research and sample testing Body casing: Shorter and smaller size, narrow bottom, rounded form Interface: Reduce quantity buttons, regroup, reposition, reform, resize, and wider gaps G2) Research: Begin Panel 4, then online research Body casing: Remain current size and rounded form Interface: Remain all quantity, emphasise main button, reposition top and canter		G1) Research: Begin online research, sample testing and a little review others G2) Research: A little online research, Panel 4, sample testing Body casing: Slimmer holding, shorter, rounded form, new design form Interface: Reduce quantity, grouping, reposition, different shape, wider gaps, to matching to body casing	
Overall concern factors of timestamp		G1) Research: Short study sample hand-held test and a little review other materials Body casing: Remain current size, decorative and slimmer at hand-held area, bottom and centre part G2) Research: A little and repeat study of button function Panel 4 Body casing: Remain current size, decorative with unclear purpose Interface: Remain all quantity, regroup, reposition, different shape and size main button, button to matching to body casing		G1) Research: Begin intensive online research and sample testing Body casing: Shorter and smaller size, slimmer bottom, rounded form Interface: Reduce quantity buttons, regroup, reposition, reform, resize, and wider gaps G2) Research: Begin Panel 4, then internet search Body casing: Remain current size, rounded form Interface: Remain all quantity, different shape and size main button, reposition top and canter		G1) Research: Begin online research, sample testing and a little review other materials G2) Research: A little online research, Panel 4, sample testing Body casing: Slimmer holding, shorter, rounded form, new design form Interface: Reduce quantity, grouping, reposition, different shape, wider gaps, and button to matching to body casing	

Table 6 Final character of intuitive design thinking behaviour on problem solving for all groups

Patterns	IDE	ENG	ID
Behaviours/ actions	Spend long time for drawing Frequently testing product sample while drawing Less observed in Panel 4, but often repeated	Overall phase by phase process Spend long time on research, but short time on drawing Begin with intensive online research and product sample testing, then turn to drawing	Repeat the process of research and drawing Begin with moderate online research/sample study and less review on reference materials
Problem-solving character A	Tend to start design early with less time for research Highly focused on design works through, often referring to product samples, product functions, and ergonomics	Tend to clarify issues from the project task Highly focus on the research stage, then the design works stage Highly concerned with usability and ergonomics, but less intuitive	Tend to reconfirm all issues while designing in three phases repeatedly Highly focused on research and design works through three-phase processes
Interaction	Longest time spent on drawing and lowest time spent on online research	Longest time spent on research, but lowest time spent on drawing	Moderate time spent on drawing and research, repeatedly
Problem-solving character B	Focus on the product concept rather than the fundamental issue of the task	Focus on the fundamental issue of the task rather than the product concept	Focus on both fundamental issue of task and product concept
Drawing morphing: form/line	90% of all designs are similar to the sample model: basic form, size and proportion. Design: strong character and detailing, all designs are quite similar to each other	60% of all designs are similar to the sample model: basic form, size and proportion (similar in the middle and bottom area), 40% new size. Design: mostly similar to the market	80% of all designs are different from the sample model: basic form and size (slimmer in the middle area), 20% similar in size Design: new form and proportions, mostly shorter/slimmer than the sample
Problem-solving character C	Tends toward decoration detailing and character, focus on aesthetics (intuitive) and moderately ergonomic	Unclear design direction as mostly inspired by current design research, with a focus on ergonomic form	Tends toward radical design on basic form through new size and proportion with ergonomic Moderate concern with aesthetics (intuitive) and usability
Drawing morphing: button layout	Complex, many buttons and category functions Shape form is integrated into the body casing form	Simpler and fewer button functions category Button shape is not integrated into the body casing form	Simpler and fewer button functions category Button shape is integrated into the body casing form
Problem-solving character D	Unsure of the priority of the function	Understand the priority of button functions related to usability, through direct interpretations of the design form	Understand the priority of button functions related to usability

Recommendations

Proposed New Conceptual Model for Design Management Organisation

Based on the data analysis, a new conceptual model for design management in NPD is proposed, integrating three key domains: engineering (ENG), industrial design (IDE), and interface design (ID), to address differences in intuitive design thinking behaviours. These domains are essential throughout the NPD process, from concept development to production. Traditionally, each domain operates independently, focusing on distinct concerns such as usability, ergonomics, functionality, user issues, and aesthetics (Figure 6). The proposed model, however, unites these domains into a single collaborative platform, fostering multidisciplinary interaction and transparency in addressing product requirements, specifications, and procedures. For instance, the ENG group can rationalise the IDE group's aesthetic-oriented concepts, while the IDE group can consider technical, cost, and manufacturing constraints. This integrated approach minimises domain disparities and promotes a more balanced and holistic design thinking within NPD organisations.

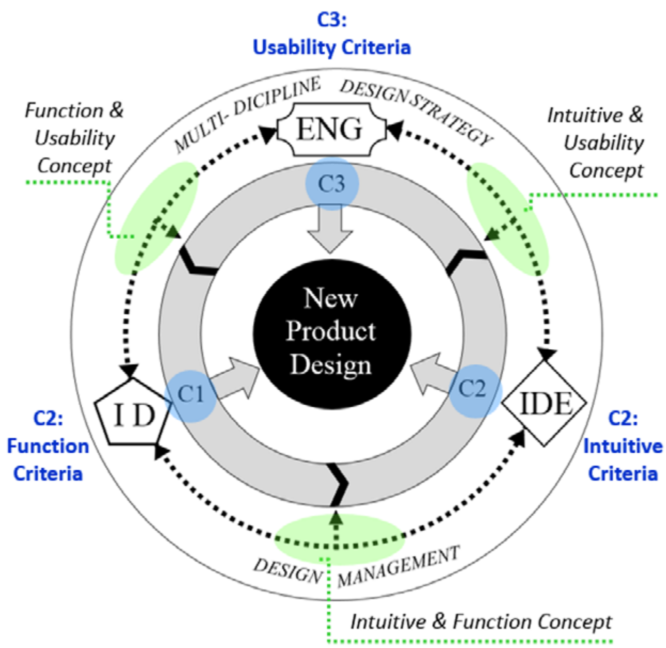

Figure 6 Proposed new conceptual model for design management organisation

Proposed Operational Changes for NPD Organisations

The research findings, mapped to the Matrix Organisation Structure model by Ulrich and Eppinger (1995) and Hayes et al. (1988), clarified the specific characteristics of design thinking behaviour across different domains. This framework helps define appropriate roles, enhance collaboration, and optimise iteration timing to align with project tasks and objectives (Table 7).

Table 7 Proposed operational changes for NPD organisations

Knowledge domain	Roles	Collaboration for new product concepts	Iteration timing
Interface Design (ID)	Mainly concerned with product function and ergonomic (as well as moderately on aesthetic and usability) Role as project manager of the product design division	IDE: Concerned with the aesthetic and function of new product concepts	IDE: Approx. 3 to 5 days
		ENG: In the context of the function and usability of new product concepts	ENG: Approx. 1 to 1.5 weeks (including product testing, etc.)
Industrial Design (IDE)	Mainly concerned with the product aesthetic (intuitive) Role as creative section manager (or art director)	ID: Concerned with the aesthetic and function of new product concepts	ID: Approx. 3 to 5 days
		ENG: Concerned with the aesthetic and usability of new product concepts, i.e., design modification for technical and cost matters To reduce the high aesthetic element for cost-effective reasons, and for rationalisation of manufacturing or technical matters	ENG: Approx. 1 to 1.5 weeks (including product testing, etc.)
Engineering (ENG)	Mainly concerned with product usability Role as general manager of the research and development division	IDE: Concerned with the aesthetic and usability of new product concepts, i.e., evaluating product quality and aesthetic ENG can rationalise the conceptual design from IDE, which consists of high aesthetic elements	Approx. 1 to 1.5 weeks (including product testing
		ID: In the context of function and usability of new product concepts	

CONCLUSION

The study of the root causes clarifies the fundamental challenges of design management in multidisciplinary organisations, emphasising the role of intuitive design thinking across different knowledge domains. The design experiments revealed specific factors influencing variations in intuitive design thinking behaviour, closely linked to problem-solving modalities. Adopting these findings enables the exploration and application of more innovative and open design processes in NPD. This aligns with Pahl et al. (1996) and Liu et al. (2021), who stated that problem solving drives creativity through diverse activities and applications. Moreover, since design organisations inherently integrate multiple knowledge domains in product development, these findings provide a foundational reference for NPD processes, highlighting the importance of understanding design thinking characteristics across disciplines.

ACKNOWLEDGEMENTS

We would like to acknowledge the appreciation of the Division of the Human Resource Development Fund, Multimedia University, for their financial support for us to conduct this research and participate in the conference.

REFERENCES

Aguilar-Zambrano, J., and M. González-Cruz. 2010. "Multidisciplinary Product Design Teams with Axiomatic Design." In *13th International Congress on Project Engineering*, Badajoz, July 2009, 411–421.

Akner-Koler, C. 2000. *Three-Dimensional Visual Analysis*. Stockholm: Reprint.

Anwar, R. 2016. "Characterizing a Syntactic Pattern of Formgiving in Design Thinking Process." PhD diss., Universiti Teknologi MARA.

Anwar, R., V. V. Vermol, and Z. Siran. 2022. "EMF: Humanoid Robots Design Scheme for Children with Autism." *Environment-Behaviour Proceedings Journal* 7(SI7): 585–591. https://doi.org/10.21834/ebpj.v7iSI7.3833

Biswas, S., G. Bandyopadhyay, and J. N. Mukhopadhyaya. 2022. "A Multi-Criteria Framework for Comparing Dividend Pay Capabilities: Evidence from Indian FMCG and Consumer Durable Sector." *Decision Making: Applications in Management and Engineering* 5(2): 140–175. https://doi.org/10.31181/dmame0306102022b

Cuffaro, D. 2006. *Process, Materials, and Measurements: All the Details Industrial Designers Need to Know But Can Never Find*. Gloucester, MA: Rockport Publishers.

Cuffaro, D., and I. Zaksenberg. 2013. *The Industrial Design Reference Specification*. Rockport: Rockport Publishers Inc.

Custódio Santos, M., A. Ferreira, C. Costa, and J. A. C. Santos. 2020. "A Model for the Development of Innovative Tourism Products: From Service to Transformation." *Sustainability* 12(11): 4362. https://doi.org/10.3390/su12114362

Dorst, K. 2011. "The Core of 'Design Thinking' and Its Application." *Design Studies* 32(6): 521–532. https://doi.org/10.1016/j.destud.2011.07.006

Georgiev, G. 2012. "Design Thinking: An Overview." *Japanese Society for the Science of Design* 20(1): 72–79.

Goldschmidt, G. 1997. "Capturing Indeterminism: Representation in the Design Problem Space." *Design Studies* 18(4): 441–455. https://doi.org/10.1016/S0142-694X(97)00011-2

Hall, A. 2020. "Design Thinking: Governing Inter-Domain Thinking for Tackling the Anthropocene." *The Design Journal* 23(1): 71–89. https://doi.org/10.1080/14606925.2019.1693211

Hayes, R. H., S. C. Wheelwright, and K. B. Clark. 1988. *Dynamic Manufacturing: Creating the Learning Organization*. New York: Free Press.

Hu, T., S. Zainal Abidin, O. H. Hassan, V. VetoVermol, and X. Zhao. 2024. "Three-Phase Sn-Based Heterostructure Nanoparticles Anchored on N-Doped Graphene as a Promising Anode for Lithium/Sodium Storage." *Journal of Electroanalytical Chemistry* 955: 118063. https://doi.org/10.1016/j.jelechem.2024.118063

Jantan, R., N. Kamaruddin, S. Zainal Abidin, T. S. Said, and H. Ramli. 2020. "Value in Exchange: The Importance of User Interaction as the Center of User Experiences." *International Journal of Innovation, Creativity and Change* 11(10): 75–83.

La Velle, L., S. Newman, C. Montgomery, and D. Hyatt. 2020. "Initial Teacher Education in England and the Covid-19 Pandemic: Challenges and Opportunities." *Journal of Education for Teaching* 46(4): 596–608. https://doi.org/10.1080/02607476.2020.1803051

Li, D., S. Chen, Y. Zhu, et al. 2023. "Application of Algorithm for Inventive Problem Solving (ARIZ) for the Heat Dissipation of Energy Storage Supply System for High-Power Locomotive." *Sustainability* 15(9): 7271. https://doi.org/10.3390/su15097271

Liu, M., S. Fang, H. Dong, and C. Xu. 2021. "Review of Digital Twin about Concepts, Technologies, and Industrial Applications." *Journal of Manufacturing Systems* 58: 346–361. https://doi.org/10.1016/j.jmsy.2020.06.017

Lloyd, P., B. Lawson, and P. Scott. 1995. "Can Concurrent Verbalisation Reveal Design Cognition?" *Design Studies* 16(2): 237–259. https://doi.org/10.1016/0142-694X(94)00011-2

Matsumae, A., S. Matsumae, and Y. Nagai. 2020. "Dynamic Relationship Design of Knowledge Co-Creating Cluster: Traditional Japanese Architectural Industry." *SN Applied Sciences* 2(3): 443. https://doi.org/10.1007/s42452-020-2209-2

Othman, M. K., L. W. Ong, and S. Aman. 2022. "Expert vs Novice Collaborative Heuristic Evaluation (CHE) of a Smartphone App for Cultural Heritage Sites." *Multimedia Tools and Applications* 81(5): 6923–6942. https://doi.org/10.1007/s11042-022-11991-4

Oxman, R. 2002. "The Thinking Eye: Visual Re-cognition in Design Emergence." *Design Studies* 23(2): 135–164. https://doi.org/10.1016/S0142-694X(01)00026-6

Pahl, G, and W. Beitz. 1996. *Engineering Design: A Systematic Approach*. Vol. 3. London: Springer. https://doi.org/10.1007/978-1-4471-3581-4

Preece, J., Y. Rogers, and H. Sharp. 2011. *Interaction Design: Beyond Human-Computer Interaction*. 3rd ed. New York: John Wiley and Sons.

Pugh, S. 1991. *Total Design: Integrated Methods for Successful Product Engineering*. Boston: Addison-Wesley.

Roscoe, A. M., D. Lang, and J. N. Sheth. 1975. "Follow-up Methods, Questionnaire Length, and Market Differences in Mail Surveys." *Journal of Marketing* 39(2): 20–27. https://doi.org/10.1177/002224297503900205

Rowe, P. G. 1987. *Design Thinking*. Cambridge, MA: MIT Press.

Schön, D. A. 2017. *The Reflective Practitioner: How Professionals Think in Action*. Routledge. https://doi.org/10.4324/9781315237473

Simon, H. A. 1992. "Alternative Representations for Cognition: Search and Reasoning." In *Cognition: Conceptual and Methodological Issues*, edited by H. L. Pick Jr., P. W. van den Broek, and D. C. Knill, 121–142. Washington, DC: American Psychological Association. https://doi.org/10.1037/10564-005

Siran, Z., and R. Anwar. 2020. "The Theoretical Framework of Design Thinking Behavior Model." In *Proceedings of the International Conference of Innovation in Media and Visual Design* (IMDES 2020), 242–247. Atlantis Press. https://doi.org/10.2991/assehr.k.201202.083

Siran, Z., S. Zainal Abidin, and R. Anwar. 2020. "The Influence of Reference Material for Sketching Strategies and Form Establishment at the Embodiment Design Level." *Environment-Behaviour Proceedings Journal* 5 (SI3): 135–140. https://doi.org/10.21834/ebpj.v5iSI3.2546

Stonewall, J., M. C. Dorneich, L. Shenk, C. C. Krejci, and U. Passe. 2019. "Inclusive Decision-Making: Applying Human Factors Methods to Capture the Needs and Voices of Marginalized Populations." In *Advancing Diversity, Inclusion, and Social Justice through Human Systems Engineering*, edited by R. D. Roscoe, E. K. Chiou, and A. R. Wooldridge, 11–29. Boca Raton: CRC Press. https://doi.org/10.1201/9780429425905-2

Taura, T., and Y. Nagai. 2009. *A Definition of Design and Its Creative Features*. 3rd ed. London: Prentice Hall.

Ulrich, K. T., and S. D. Eppinger. 1995. *Product Design and Development*. 4th ed. New York: McGraw-Hill.

Verganti, R., L. Vendraminelli, and M. Iansiti. 2020. "Innovation and Design in the Age of Artificial Intelligence." *Journal of Product Innovation Management* 37(3): 212–227. https://doi.org/10.1111/jpim.12523

Verma, R. 2001. "Service Marketing." Cornell University School of Hotel Administration. https://ecommons.cornell.edu/server/api/core/bitstreams/ab3c104a-6372-4f5f-aa36-d81f99b5c627/content (accessed 2 May 2026).

Wangsa, K., R. Chugh, S. Karim, and R. Sandu. 2022. "A Comparative Study Between Design Thinking, Agile, and Design Sprint Methodologies." *International Journal of Agile Systems and Management* 15(2): 225–242. https://doi.org/10.1504/IJASM.2022.124916

Warell, A. 2001. "Design Syntactic: A Functional Approach to Visual Product Form." PhD thesis, Chalmers University of Technology.

Warell, A. 2008. "Modelling Perceptual Product Experience—Towards a Cohesive Framework of Presentation and Representation in Design." In *Proceedings of the 6th International Conference on Design and Emotion*. Hong Kong: Hong Kong Polytechnic University.

Yuan, J. T. J, K. Y. Kong, H. A. Parveen, et al. 2014. "An Overview of Design Cognition between Experts and Novices." Paper presented at the International Conference on Applied Design Research (i-CADRE), Singapore University of Technology and Design, Singapore. https://doi.org/10.3850/978-981-09-1348-9_041

Yuri, S. 1999. TRIZ, the Right Solution at the Right Time: A Guide to Innovative Problem Solving. Insytec B.V.

Zainal Abidin, S. 2012. "Practice-Based Design Thinking for Form Development and Detailing." PhD diss., Norwegian University of Science and Technology (NTNU). https://doi.org/10.13140/2.1.3429.7921

Zainal Abidin, S., D. Christoforidou, and A. Liem. 2009. "Thinking and Re-thinking Verbal Protocol Analysis in Design Research." In DS 58-2: *Proceedings of ICED 09, the 17th International Conference on Engineering Design*, Vol. 2, edited by M Norell Bergendahl, M. Grimheden, L. Leifer, P. Skogstad, and U. Lindemann. Design Society.