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교육적 관점에서의 Zero Waste 패션 디자인 프로세스 가이드라인 개발

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Development of Zero Waste Fashion Design Process Guideline from an Educational Perspective

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ABSTRACT

As a solution to the wasteful consumption of resources in fashion design, this research aims to develop a process guideline for ZWF Design Methods from an educational perspective. After selecting the Jigsaw Puzzle, Subtraction Cutting, and Layer Methods as representative ZWF Methods, an application experiment was designed to deduct each Method's process, characteristics, needs, and improvement points. Its results were analyzed through action protocol analysis, expert evaluation, and qualitative analysis. Based on the analysis, this research proposed a ZWF guideline and a step-by-step guide suitable to the students' needs. By following the guideline, students can use the chosen ZWF Method to create a planned or an accidental design. In addition, they can practice ZWF effectively step by step in the order of Layer, Jigsaw Puzzle, and Subtraction Cutting. Thus, this research can provide the basis for ZWF education, which can lead to expanded application of ZWF in the future and reduce textile waste.

Key words: design process(디자인 프로세스), zero waste fashion(제로 웨이스트 패션)

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Ⅰ. Introduction

Today's fashion design has been criticized for its excessive and wasteful consumption of fiber resources, which led to a rapid increase in textile waste. World Apparel Fiber Consumption Survey shows that the world textile fiber consumption reached its peak of 69.7 million tons in 2010(Food and Agriculture Organization of the United Nations & International Cotton Advisory Committee, 2013).

To reduce textile consumption, and ultimately, environmental pollution, the concept of sustainable fashion emerged. However, sustainable fashion's main methods, including recycling and using organic materials, reached their limitations. The main problem is reprocessing the wastes, since their fiber types and colors are mixed. Not to mention the difficulty of producing the astronomic number of different kinds of fabric with new sustainable materials.

Recently, as a solution, fashion designers are making attempts at Zero Waste Fashion(ZWF). ZWF is an abbreviation frequently used in numerous papers(Niinimäki, 2013), which eliminates waste generation at design and production stages(McQuillan, 2011). If waste can be prevented, it can solve both waste disposal and resource waste problems at the same time.

The effects and possibilities of ZWF have already been proven by some preceding studies. First, pioneering researches focused on new possibilities of ZWF. Rissanen(2013) opened a new research field of ZWF Methods by showing the capabilities of Jigsaw Puzzle Method to be integrated in conventional fashion design. Carrico & Kim (2014) suggested a Method called 'Minimal Cut'. Niinimäki(2013) integrated textile design with Jigsaw Puzzle Method. Second, researchers expanded their views to find the essential elements of ZWF. Townsend & Mils(2013) emphasized the 'mastery' of ZWF and Park(2012) deducted the future direction of ZWF through case study.

Nevertheless, these previous studies show several limitations. First, nearly all researches limited their scope to Jigsaw Puzzle Method, even though there are diverse Methods to achieve zero waste in fashion design. Second, many ZWF practices were done individually. Therefore, a clear classification of ZWF Methods was not established. Third, ZWF Methods are considered to be overly complicated, which led designers to avoid using them. Thus, to fully understand ZWF, its different Methods should be examined. Furthermore, an in-depth analysis of each Method's process is indispensable.

Reflecting on the needs stated above, the goal of this research is as follows. First, establishing the differences among the characteristics of three chosen representative ZWF Design Methods by defining and comparatively analyzing their detailed design processes. Second, deducting how students apply and accept ZWF Design Methods through prototype output evaluation and qualitative analysis of their subjective opinions. Third, finding out the students' needs concerning ZWF Design processes. Fourth, suggesting a revised ZWF Design process guide for each of the three Methods according to the students' needs to develop the educative possibility of ZWF.

To achieve these goals, this research first reviewed the preceding literatures on ZWF Design and its Methods. Through this step, supporting grounds for this research were obtained and ZWF Methods were classified into five Method groups. Based on this classification, three representative ZWF Methods were chosen: Jigsaw Puzzle, Subtraction Cutting, and Layer. Secondly, an experiment of applying ZWF Design Methods was designed and conducted. The analysis frame of the experiment was structured based on previous researches about protocol analysis and design evaluation criteria.

This research limited its scope to the narrow definition of zero waste: eliminating pre-consumer textile waste(Caulfield, 2009). Furthermore, it was limited to the process improvement plan(Deif, 2011) and only ZWF Methods that solved the textile waste problem through design process and maintained the existing technologies, materials, and energies were targeted. Also, it handled the Methods' individual application and not the industrial application.

Ⅱ. Theoretical Background

1. Zero Waste Fashion Design Methods

Zero waste is a shift from waste 'management' to waste 'elimination'(Zero Waste International Alliance, 2009). Instead of dealing with generated waste, it aims to prevent its production(Schnitzer & Ulgiati, 2007) as prevention is better than cure(Gertsakis & Lewis, 2003). Thus, rethinking the way of design which appreciates materials is needed(Niinimäki & Hassi, 2011).

In the conventional fashion design process, 15-20% of fabric is lost(Abernathy, Dunlop, Hammond, & Weil, 1999; Cooklin, 1997). Up to 50% is wasted in small-scale production(Niinimäki, 2013). These wastes result in loss of profit and in environmental pollution(McQuillan, 2009). They also represent losing the expense, time, and labor put into producing the fiber and fabric(Rissanen, 2013). Therefore, ZWF Design is a design method that uses 100% of its fabric to prevent waste and to minimize the amount of textile consumed. The existing five ZWF Methods are as follows:

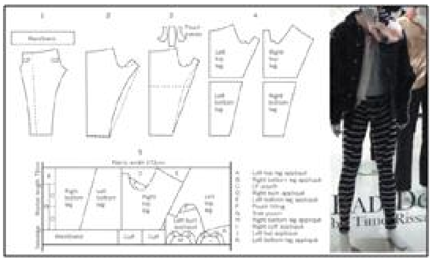
1) Knitting Method is one of the most common ZWF Design Methods(Rissanen, 2013). It is subdivided into two Methods: Pattern Piece Knitting and Seamless Knitting. The former is knitting individual garment pieces and sewing them together(Black, 2002). This Method does not involve any cutting; therefore, does not generate any waste. The latter is knitting a whole garment and does not require any sewing(Black, 2002).

2) This research named the ZWF Design approach that uses line-shaped patterns as 'Layer Method' after the terminology of 3D printer principle. Even though Layer Method is widely used by designers, there is no existing research yet on this Method. Fabric is cut into thin strips (‖‖‖=layers) and by attaching these layers together, a surface is formed (▥). When these surfaces come together, a figure is made as shown in 〈Fig. 1〉. By adding layers, nothing is subtracted and no waste is generated. Layer Method can work in the same way as the conventional fashion design process, in the context of making after choosing the final design.

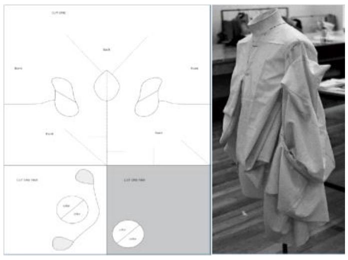
3) Minimal Cutting Method designs garments through draping and minimizes the number of cuttings(Carrico & Kim, 2014). It consists of two Methods: No Cut and Minimal Cut. No Cut Method designs without any cutting as in traditional costumes, similar to the Indian sari. Minimal Cut realizes a design through designing a single piece of pattern with cuts (slits).

4) Unlike the conventional fashion design, Jigsaw Puzzle Method designs patterns to interlock perfectly on the fabric as in 〈Fig. 2〉, and leaves no waste(McQuillan, 2009; Niinimäki, 2013; Rissanen, 2013; Townsend & Mills, 2013). Patterns do not have to be shaped as they usually are. It can be shaped to fit the margins of the puzzle. As this Method designs through alternations, the design cannot be finalized at the initial part of the process.

〈Fig. 1〉 Zero Waste by Carlos Villamil (Villamil, 2012)



〈Fig. 2〉 Pants by Timo Rissanen (Rissanen, 2013, p. 95)



〈Fig. 3〉 Collaboration Shirt by The Cutting Circle (McQuillan et al., 2013, pp. 43-44)

5) According to Roberts(2013), Subtraction Cutting Method designs a garment's negative space, not its outer silhouette. It repeatedly alters its design with the negative space in mind. As it suggests a creative approach to fashion design, The Cutting Circle, an international research initiative (McQuillan, Rissanen, & Roberts, 2013), used it to accomplish ZWF as in 〈Fig. 3〉. ZWF is obtained by adding additional space with cut-out pieces.

These five ZWF Methods were categorized into two according to their design process frames based on Rissanen(2013): conventional fashion design process and reversed fashion design process. 'Reversed fashion design process' was renamed in this paper to cover all ZWF Methods' processes.

The conventional process starts with sketching or draping and makes a decision on the final design, and then moves on to pattern making. Reversed process begins with an abstract idea or draping and finalizes its design through pattern designing. It does not start with a fixed design. Knitting and Layer were positioned under the former category and Minimal cutting, Jigsaw Puzzle, and Subtraction Cutting were placed under the latter.

In this research, Jigsaw Puzzle, Subtraction Cutting, and Layer Methods were selected as representative ZWF Methods and their design processes were analyzed to deduct their effective educational application method.

2. Protocol Analysis and Coding Scheme

To build a foundation for the analytical method of this research's experiment, preceding studies on protocol analysis and coding scheme were reviewed. Protocol analysis was chosen since it has been widely used to investigate designers' behaviors (Cross, Chrisiaans, & Dorst, 1996). It has been used in numerous areas, including software engineering, architecture, and mechanical engineering, to clarify their detailed design processes and designers' actions(Dorst & Dijkhuis, 1995; Jin, 2008).

Protocol method can be divided into concurrent verbalization protocol and retrospective verbal reports protocol(Ericsson & Simon, 1984). The former protocol analysis focuses on the process itself and the latter concentrates on the cognitive contents of the process(Gero & Tang, 2001). As this study aims to further understand the design process of ZWF Design Methods, the former method was chosen among the two.

For the coding scheme, Suwa, Purcell, & Gero (1998) divided actions of designers into four: physical, perceptual, functional, and conceptual. Bilda & Demirkan(2003) and Kavakli, Suwa, Gero,

& Purcell(1999) formed their coding schemes based on Suwa et al.(1998). By referring to Bilda & Demirkan(2003), Jin(2008) constructed a coding system of three groups: thinking, skill, and management.

3. Design Evaluation Criteria

Lastly, previous researches on design evaluation criteria were considered to prepare for this research's experiment output analysis: preliminary experiment evaluation and prototype output evaluation.

Yoo(2006) defined the evaluation criteria of a design project by two main categories: creativity and design integration. Creativity was classified into three: creation ability, idea visualization, and sense of aesthetics. Design integration was divided into three: topic comprehension/planning, analytic thinking, and consideration of users. Every sub-standard was scored on a 5-point scale. Chung(2002) synthesized various evaluation standards of good design awards into eight: aesthetical, economically feasible, manufacturable, usable, satisfiable, suitable, purposeful, and sustainable.

Ⅲ. Methods

Experimental research method was chosen to observe the actual application of ZWF Methods, while controlling other variables. Through experimentation, the design process of each Method can be deducted. Additionally, the assessment of design output is possible. The experiment was constituted as follows: preliminary experiment, main experiment of ZWF Method application, open-ended questionnaires, and semi-structured interview. It was carried out separately from the existing curriculum.

The number of participants was chosen based on the reviewed studies of design process protocol analysis. Participants of this experiment were limited to fashion major undergraduates to focus on the educative side of ZWF Method application, and none had prior experience in ZWF. Participants were selected through maximum variation sampling and were from different year level (year 2 to 4). Four participants were assigned to each of the three Methods, 12 participants in total.

Based on Guba(1981), credibility was obtained through member checking, peer examination, and triangulation of data (interview, observation, video recording, and survey). For transferability, maximum variation sampling method was used. Through audit trail, confirmability and dependability were supported. Every process of the experiment was observed and recorded.

1. Preliminary Experiment

Preliminary experiment was conducted to ensure the design capabilities of participants to make sure that suitable participants were recruited. 'Sustainable fashion' was given as a broad design topic and the topic was not limited to ZWF, as the preliminary experiment's main purpose was to evaluate the participants' design abilities beforehand. Every participant had 20 minutes to ideate and turn their ideas into a final design sketch.

The results were assessed by the criteria in 〈Table 1〉, which focused on evaluating the participant's ability to understand, plan, ideate, and visualize a given topic. They were structured based on Chung(2002) and Yoo(2006). Each standard was scored on a 5-point scale, 5 being the highest.

The evaluation was done by four professionals with more than five years of expertise in fashion design. Results were gathered to calculate each participant's individual average score. Average by Method was also calculated to confirm that the

〈Table 1〉 Preliminary experiment evaluation criteria

Evaluation Category		Detailed Contents	Evaluation Category		Detailed Contents
Creativity	Creation ability	Diversity of ideas	Design Integration	Compre-hension	Topic understanding
		Originality			Grasping the process
	Idea visualization	Flexible show of ideas		Analytic thinking	Direction setting
		Creative visualization			Solution exploration
	Sense of aesthetics	Design visualization		User consideration	User consideration
		Use of design elements			Design practicality

difference of participants' design abilities between the Methods was minimized.

2. Main Experiment

Before the design process, The concept of ZWF and the three Methods' principles were explained. Then, a Method was assigned to each participant to design and make a prototype of a woman's dress. Design topic was the same as the preliminary experiment. The allotted time of applying the ZWF Method was 150 minutes, but additional time was given to those who could not finish on time. Because ZWF also has to fulfill the elements of fashion design, the experiment did not limit its design possibility. Therefore, textile use was not limited. However, participants were told to use the minimum amount of textile possible. Muslin was used to make the prototypes.

To define the process of ZWF Methods, action protocol analysis method was used to analyze the results. Observations and video recordings were coded according to time based on the coding scheme developed in 〈Table 2〉. Then, these records were clustered to deduct the key design actions performed by the majority of participants (75-100%). This led to constructing the Methods' design processes. The average time of the key actions, their order, and proportions were comparatively analyzed among the Methods.

The coding scheme was developed based on Bilda & Demirkan(2003), Jin(2008), Kavakli et al.

〈Table 2〉 Coding scheme of the main ZWF Method application experiment

Category	Code	Definition	Category	Code	Definition
Under-standing -Action (U-Action)	U-df	difficulty in understanding	Making -Action (M-Action)	M-jst	judging suitability
	U-rs	reference data study		M-mk	marking location
	U-pt	small-scale practice		M-lo	layout of pieces
	U-qu	question		M-tc	tracing
Thinking -Action (T-Action)	T-dc	design and conception		M-tmk	textile marking of design
	T-idc	improvised design and conception		M-tct	textile cutting
	T-pctw	consideration of textile waste prior to making		M-dp	draping
	T-ctw	consideration of textile waste during making		M-hrt	simple handling of residual textile
	T-cs	attempt at creative solution		M-dc	making decorations
	T-es	problem soving with lessons from prior experience		M-bp	basting with pins
	T-em	exploration of materials, tools		M-ft	fixing textile with sewing or adhesive
	T-sr	search for a part or an object in need	Evaluation & Revision -Action (ER-Action)	ER-as	assessment
	T-rf	reference of sketch or prior work		ER-sm	exploration of problems through simulation
	T-ch	check on mannequin		ER-re	revision after assessment or simulation
				ER-fa	failure of overcoming a problem

(1999), and Suwa et al.(1998). Then codes on textile waste and garment making were added. Final coding scheme was made of four groups: Understanding-Action(U-Action), Thinking-Action (T-Action), Making-Action(M-Action), and Evaluation & Revision-Action(ER-Action). Detailed codes are in 〈Table 2〉.

3. Prototype Output

Participants' prototypes were evaluated by three professionals who have evaluated the preliminary experiment. Their evaluation criteria were formed based on Chung(2002) and Yoo(2006). As shown in 〈Table 3〉, these criteria concentrated on evaluating the overall design, but 'Sustainable' criterion focused on ZWF. Each standard was scored on a 5-point scale.

4. Interview and Questionnaire

The questionnaires were open-ended and the interview was semi-structured to grasp the details of subjective opinions. Questionnaires inquired about the needs and difficulties during the process. The interview asked about improvement suggestions and the problems that they have faced.

The key words and key relationships of the data were deducted through qualitative analysis. This was done by NVIVO 10 word frequency query.

〈Table 3〉 Prototype output evaluation criteria

Evaluation Category		Detailed Contents
Aesthetical	Aesthetical	effective visualization of design elements
		suitable use of design elements
	Fit	visualization of intended fit
	Creative	diversity of ideas
		originality
Economically feasible	Economically feasible	conservation of fabric
		labor-saving
Manufacturable	Effective	effective making
Suitable	Trendy	aesthetically suitable in certain time and place
	Marketable	marketable
Purposeful	Usable	consideration of user's convenience
	Functionable	fulfillment of fundamental use
Sustainable	Changeable	modifiable, transformable, substitutable
	Durable	physically durable
	Recyclable/Reusable	recyclable, reusable
	ZWF Method utilization	clear understanding of ZWF Method
		appropriate direction setting with ZWF Method
		effective application of ZWF Method
		diverse exploration of applying ZWF Method
	Zero waste	no remaining textile waste
		creative, effective elimination of textile waste
		ease of grading without making textile waste

Based on this insight, the scripts were coded and were used to perform a within-case analysis and then a cross-case analysis. Through this, participants' needs, difficulties, and improvement requirements were found.

Ⅳ. Results

1. Preliminary Experiment Evaluation Analysis

The evaluation of the four professionals were collected and individual average scores were calculated. All participants scored 3.0 or more, which implied that they had appropriate abilities to take part in the experiment. Average score by Method was calculated as in 〈Table 4〉 to verify that the difference of design abilities between the three Methods was minimized.

2. Main Experiment Analysis

Protocol Recordings of Participants' Actions

Participants' action protocols of the main experiment were recorded according to time. Each design action's specific amount of time is listed in 〈Table 5〉. The recordings were also converted into percentage. Then they were clustered by Method to deduct the key design actions in 〈Fig. 4〉.

Comparative Analysis of Action Categories

According to 〈Table 5〉 and 〈Fig. 4〉, M-Action occupied the biggest percentage in all three Methods; however, the differences of action proportions and their appearances between the Methods were significant.

T-Action and ER-Action took up the biggest proportion in Jigsaw Puzzle, 32.8% and 9.75% respectively. U-Action and M-Action occupied the smallest proportion, 0.35% and 57.1%. For Subtraction Cutting, U-Action accounted for 10.3%. T-Action took up only 23.5%, the smallest proportion among the three Methods. Layer gave the most weight to M-Action (62.9%) and the least weight to ER-Action (4%) among the Methods.

1) U-Action: U-Action appeared mostly at the beginning and Subtraction Cutting differed with the other two Methods. All participants of Subtraction Cutting found it difficult to understand (U-df) its concept and method.

2) T-Action: Differences between the Methods' T-Action in frequency, weight, contents, and point in time during the processes were as follows. Design and conception preceding the making action (T-dc) appeared at the beginning of the process in

〈Table 4〉 Average preliminary experiment evaluation score by Method

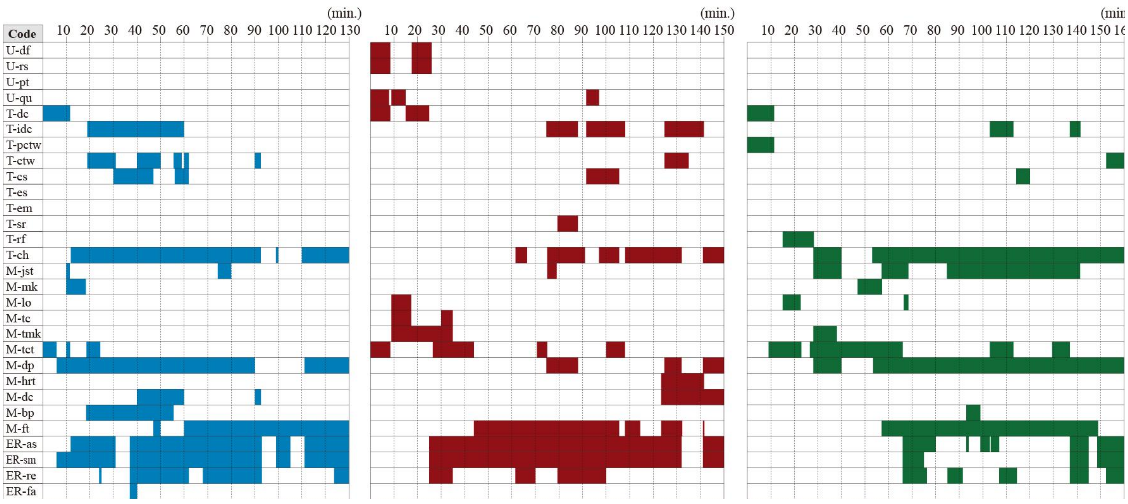
Evaluation Category		Jigsaw Puzzle				Subtraction Cutting				Layer			
Creativity	Creation ability	3.6 / 3.0	3.3	3.3	3.3	3.2 / 3.0	3.1	3.2	3.2	3.1 / 2.9	3.0	3.2	3.2
	Idea visualization	3.6 / 3.1	3.3			3.4 / 3.2	3.3			3.5 / 3.3	3.4		
	Sense of aesthetics	3.1 / 3.3	3.2			3.2 / 3.1	3.1			3.1 / 3.1	3.1		
Design Integration	Comprehension	3.8 / 3.7	3.7	3.4		3.6 / 2.9	3.2	3.1		3.3 / 3.1	3.2	3.2	
	Analytic thinking	3.3 / 3.5	3.4			3.1 / 3.1	3.1			3.3 / 3.1	3.2		
	User consideration	2.8 / 3.4	3.1			2.9 / 3.3	3.1			3.0 / 3.3	3.1		

〈Table 5〉 Average work time (sec(%)) by Method

Code	J1	J2	J3	J4	S1	S2	S3	S4	L1	L2	L3	L4
U-df	0 (0)	0 (0)	0 (0)	0 (0)	215 (2.1)	500 (5.1)	110 (1.1)	805 (14.4)	680 (10.1)	0 (0)	0 (0)	0 (0)
U-rs	0 (0)	0 (0)	0 (0)	0 (0)	140 (1.3)	275 (2.8)	90 (0.9)	280 (5)	250 (3.7)	0 (0)	60 (0.8)	0 (0)
U-pt	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	200 (3.6)	0 (0)	0 (0)	0 (0)	0 (0)
U-qu	35 (0.6)	0 (0)	50 (0.7)	20 (0.1)	145 (1.4)	100 (1)	100 (1)	85 (1.5)	145 (2.2)	60 (0.6)	140 (1.7)	75 (0.6)
total	35 (0.6)	0 (0)	50 (0.7)	20 (0.1)	500 (4.8)	875 (9)	300 (3)	1370 (24.5)	1075 (16)	60 (0.6)	200 (2.5)	75 (0.6)
avg.	26.25(0.35)				761.25(10.3)				352.5(4.9)			
T-dc	290 (4.6)	350 (8.9)	400 (5.5)	0 (0)	410 (3.9)	260 (2.7)	220 (2.2)	150 (2.7)	0 (0)	1050 (10.6)	205 (2.5)	700 (5.6)
T-idc	415 (6.6)	160 (6.1)	595 (8.1)	1830 (14.5)	350 (3.4)	655 (6.7)	440 (4.3)	485 (8.7)	1315 (19.6)	490 (5)	10 (0.1)	60 (0.5)
T-pctw	0 (0)	0 (0)	200 (2.7)	0 (0)	45 (0.4)	0 (0)	10 (0.1)	0 (0)	25 (0.4)	250 (2.5)	255 (3.2)	360 (2.9)
T-ctw	305 (4.8)	180 (4.6)	215 (2.9)	455 (3.6)	280 (2.7)	210 (2.1)	65 (0.6)	195 (3.5)	40 (0.6)	210 (2.1)	180 (2.2)	35 (0.3)
T-cs	100 (1.6)	125 (3.2)	285 (3.9)	145 (1.2)	120 (1.2)	125 (1.3)	155 (1.5)	185 (3.3)	90 (1.3)	780 (7.9)	90 (1.1)	250 (2)
T-es	0 (0)	0 (0)	150 (2.1)	0 (0)	0 (0)	30 (0.3)	0 (0)	40 (0.7)	225 (3.3)	35 (0.3)	0 (0)	0 (0)
T-em	180 (2.8)	5 (0.1)	10 (0.1)	0 (0)	10 (0.1)	120 (1.2)	0 (0)	0 (0)	25 (0.4)	0 (0)	0 (0)	425 (3.4)
T-sr	0 (0)	0 (0)	0 (0)	0 (0)	1110 (10.6)	375 (3.8)	330 (3.3)	110 (2)	0 (0)	0 (0)	0 (0)	0 (0)
T-rf	0 (0)	0 (0)	160 (2.2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	140 (1.4)	220 (2.7)	1095 (8.8)
T-ch	440 (7)	655 (16.6)	600 (8.2)	1415 (11.3)	680 (6.5)	445 (4.6)	540 (5.3)	240 (4.3)	420 (6.2)	650 (6.6)	5 (0.1)	1120 (9)
total	1730 (27.4)	1475 (37.5)	2615 (35.7)	3845 (30.6)	3005 (28.8)	2220 (22.7)	1760 (17.3)	1405 (25.2)	2140 (31.8)	3605 (36.4)	965 (11.9)	4045 (32.5)
avg.	2416.25(32.8)				2097.5(23.5)				2688.75(28.2)			

Code	J1	J2	J3	J4	S1	S2	S3	S4	L1	L2	L3	L4
M-jst	65 (1)	15 (0.4)	105 (1.4)	75 (0.6)	150 (1.4)	65 (0.7)	10 (0.1)	5 (0.1)	165 (2.5)	155 (1.6)	160 (2)	1100 (8.8)
M-mk	0 (0)	5 (0.1)	230 (3.2)	695 (5.5)	45 (0.4)	25 (0.3)	15 (0.2)	30 (0.5)	70 (1.1)	170 (1.7)	205 (2.5)	5 (0.1)
M-lo	0 (0)	0 (0)	30 (0.4)	5 (0.1)	35 (0.3)	50 (0.5)	35 (0.3)	5 (0.1)	110 (1.6)	0 (0)	200 (2.5)	65 (0.5)
M-tc	0 (0)	0 (0)	20 (0.3)	385 (3.1)	415 (4)	310 (3.1)	390 (3.9)	95 (1.7)	470 (7)	0 (0)	555 (6.9)	0 (0)
M-tmk	0 (0)	0 (0)	365 (5)	945 (7.5)	515 (4.9)	515 (5.3)	900 (8.9)	95 (1.7)	55 (0.8)	25 (0.3)	810 (10)	0 (0)
M-tct	20 (0.3)	35 (0.9)	650 (8.9)	455 (3.6)	1145 (11)	725 (7.4)	560 (5.5)	615 (11)	270 (4)	1905 (19.2)	1740 (21.5)	735 (5.9)
M-dp	1105 (17.6)	565 (14.3)	585 (8)	1630 (12.9)	185 (1.8)	875 (8.9)	425 (4.2)	430 (7.7)	685 (10.2)	1545 (15.6)	0 (0)	2080 (16.7)
M-hrt	65 (1)	0 (0)	0 (0)	150 (1.2)	105 (1)	260 (2.7)	1675 (16.5)	160 (2.9)	0 (0)	0 (0)	50 (0.6)	0 (0)
M-dc	555 (8.8)	295 (7.5)	1065 (14.5)	560 (4.4)	205 (2)	255 (2.6)	1675 (16.5)	215 (3.9)	0 (0)	0 (0)	10 (0.1)	0 (0)
M-bp	170 (2.7)	75 (1.9)	10 (0.1)	665 (5.3)	0 (0)	120 (1.2)	225 (2.2)	0 (0)	20 (0.3)	50 (0.5)	60 (0.8)	220 (1.8)
M-ft	2045 (32.5)	1160 (29.5)	895 (12.2)	1480 (11.7)	2830 (27.1)	2720 (27.8)	1615 (15.9)	665 (11.9)	1420 (21.1)	1855 (18.7)	2955 (36.5)	3530 (28.3)
total	4025 (63.9)	2150 (54.6)	3955 (54)	7045 (55.9)	5630 (53.9)	5920 (60.5)	7525 (74.2)	2315 (41.5)	3265 (48.6)	5705 (57.6)	6745 (83.4)	7735 (62.1)
avg.	4293.75(57.1)				5347.5(57.5)				5862.5(62.9)			
E-as	160 (2.5)	60 (1.5)	280 (3.8)	860 (6.8)	380 (3.7)	275 (2.8)	185 (1.8)	165 (3)	40 (0.6)	100 (1)	95 (1.2)	160 (1.3)
E-sm	150 (2.4)	115 (3)	225 (3.1)	415 (3.3)	335 (3.2)	290 (3)	190 (1.9)	160 (2.9)	40 (0.6)	85 (0.9)	55 (0.7)	150 (1.2)
E-re	175 (2.8)	135 (3.4)	180 (2.5)	400 (3.2)	450 (4.3)	200 (2)	180 (1.8)	140 (2.5)	140 (2.1)	345 (3.5)	30 (0.3)	285 (2.3)
E-fa	25 (0.4)	0 (0)	15 (0.2)	15 (0.1)	140 (1.3)	0 (0)	0 (0)	25 (0.4)	20 (0.3)	0 (0)	0 (0)	0 (0)
total	510 (8.1)	310 (7.9)	700 (9.6)	1690 (13.4)	1305 (12.5)	765 (7.8)	555 (5.5)	490 (8.8)	240 (3.6)	530 (5.4)	180 (2.2)	595 (4.8)
avg.	802.5(9.75)				778.75(8.7)				386.25(4)			
total	6300 (100)	3935 (100)	7320 (100)	12600 (100)	10440 (100)	9780 (100)	10140 (100)	5580 (100)	6720 (100)	9900 (100)	8090 (100)	12450 (100)
avg.	7539(100)				8985(100)				9290(100)			

all three Methods. However, only the participants of Layer Method showed this action through detailed sketches and the ideas were maintained throughout the process. Furthermore, when performing T-dc, participants of Jigsaw Puzzle stayed at abstract ideation level. For Subtraction Cutting,



〈Fig. 4〉 Key design action protocol records of Jigsaw Puzzle, Subtraction Cutting, Layer participants focused on mapping out the flat pattern of the prototype's inner space structure and not its exterior. Unable to predict what the outcome will be, they relied on the accidental effect and were not able to plan the garment's details. 'Accidental effect' in this research refers to the unanticipated result in the course of one's work.

T-idc appeared in the early and middle stages of Jigsaw Puzzle process. Participants added flesh (T-idc) to their vague idea (T-dc) during the process. For Subtraction Cutting, T-idc was done in the middle and last stages when intentional design of garment's exterior was possible. For Layer, T-idc appeared near the last stage as it did T-dc through detailed sketches unlike the other two Methods. T-rf was only shown in Layer Method.

T-pctw only appeared in Layer Method. T-ctw occurred in all Methods. However, in Jigsaw Puzzle process, T-ctw appeared frequently and repeatedly throughout the procedure as a part of T-idc. In Subtraction Cutting, participants only took the matter of textile waste into account at the last stage of the process. Layer Method also performed T-ctw near the end.

3) M-Action: As participants of Jigsaw and Layer approached through draping, M-dp appeared throughout their process. In Subtraction Cutting, M-dp appeared only after constructing the garment's inner space. It is when participants moved on to designing the garment's exterior through draping.

M-dc appeared in the Jigsaw Puzzle and Subtraction Cutting processes, but not in Layer. In Jigsaw Puzzle, M-dc was found in the middle stage as participants tried to achieve zero waste through sublimating surplus textiles into decorations while realizing their design. As a proof, M-dc was found with T-ctw. Similarly, M-dc and T-ctw had a close relationship in Subtraction Cutting. For Layer, even though it also performed T-ctw near the end, it included the remaining textiles into the original design component.

4) ER-Action: Every participant of Jigsaw Puzzle started with an abstract idea. The idea was specified as participants proceeded on, accompanied with ER-as and ER-sm. Then problems or drawbacks were revised (ER-re). In Subtraction Cutting, because of its lowest design predictability, ER-as and ER-sm were done frequently and continuously. For Layer, as participants began with a detailed design sketch, the least weight was given to ER-Action among the three Methods.

Comparative Analysis of Zero Waste Fashion Design Methods' Processes

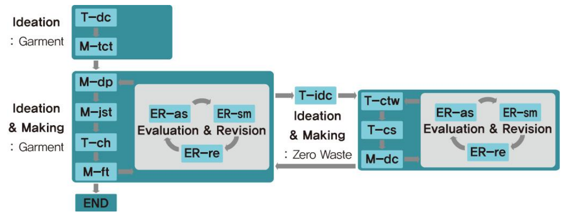
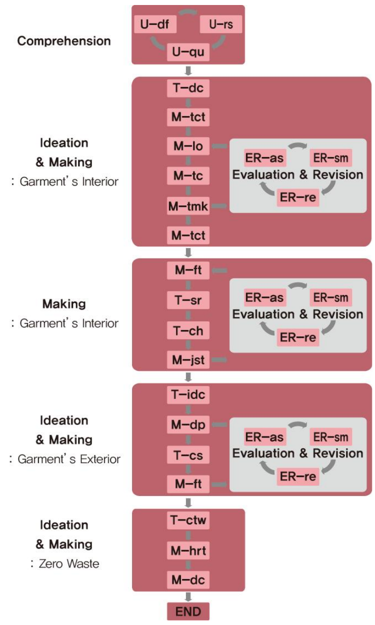
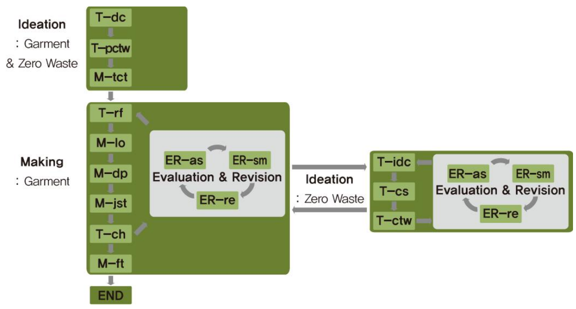
The recorded protocols were reorganized in a chronological order, which provided the groundwork for constructing the flow of each ZWF Method as in 〈Table 6〉. The comparative analysis of the three ZWF Methods' processes showed a great difference from the conventional design process.

Thus, the following five design stages can be stated as the key ZWF Design stages: Comprehension, Ideation, Making, Zero waste, and Evaluation & Revision. Zero waste, which is a part of Ideation and Making stages, was set aside as an independent stage as it is the core element of this research. Evaluation & Revision stage was included as it appeared simultaneously with almost every stage. Jigsaw Puzzle and Subtraction Cutting took on the frame of reversed fashion design process. Layer progressed with a chosen design, similar to the conventional process.

3. Prototype Output Evaluation Analysis

The goal of the evaluation was to discover the strengths and weaknesses of each Method. The

〈Table 6〉 Deducted design process of each ZWF Design Method

<table>
<tr><th></th><th>ZWF Design Process</th><th>Diagram of ZWF Design Process</th></tr>
<tr><td>Jigsaw Puzzle Method</td><td>Jigsaw's process was composed of four stages accompanied with Evaluation & Revision stage: Ideating garment, Ideating & Making garment, Ideating & Making zero waste, and Ideating & Making garment.
Three Jigsaw Puzzle participants began with an abstract idea and gave body to the idea as the process went on. Thus, ideation occurred throughout the process.</td><td>
</td></tr>
<tr><td>Subtraction Cutting Method</td><td>The design process of Subtraction Cutting Method was made up of five main stages alongside Evaluation & Revision stage: Comprehension, Ideating & Making garment's interior, Making garment's interior, Ideating & Making garment's exterior, and Ideating & Making zero waste.
All four Subtraction Cutting participants relied on accidental effects to progress their design process. Therefore, its process relied on chance. It also showed short, repetitive ideation throughout the process as the design was not fixed, but specified during the process based on accidental effects.</td><td>
</td></tr>
<tr><td>Layer Method</td><td>The design process of Layer Method was constituted of four main stages accompanied with Evaluation & Revision stage: Ideating garment & zero waste, Making garment, Ideating zero waste, and Making garment.
Three out of four participants made preconceptualized designs (sketches) that led to the deduction of a planned process.</td><td>
</td></tr>
</table>

evaluation was restricted to the main experiment's outputs, not its design processes. The participants' prototypes are listed in 〈Fig. 5〉.

According to 〈Table 7〉, Layer scored the highest point of 3.6 and Jigsaw Puzzle scored the lowest of 3.2. Subtraction Cutting was 3.3. The individual scores were located between 3.1 and 3.7, which signifies that ZWF Methods can meet the

<Fig. 5> 12 Participants' Prototypes
(Photograph by researcher, 2014.09.01.)

basic design criteria. In addition, considering the similarity of participants' design abilities, Layer participants made the most of their ability in all six categories, followed by Subtraction Cutting and then Jigsaw Puzzle. This indicates that Layer can result in a better outcome, even on the first try.

As the evaluation was not an assessment of a finished product from a planned production, the prototypes were relatively devalued. Also, because this research focused on ZWF Methods, zero waste related subcategories were considered to be more important than others. Thus, other aspects should be more considered in the future studies.

4. Interview and Questionnaire Analysis

Questionnaires and interviews were organized into two: improvement suggestions of design stages & actions and needs of ZWF Method users.

<Table 7> Average prototype output evaluation score by Method

Evaluation Category		Method											
		Jigsaw Puzzle				Subtraction Cutting				Layer			
Aesthetical	Aesthetical	3.6	3.5	3.4	3.2	3.9	3.9	3.6	3.3	4.0	4.0	3.8	3.6
		3.5				3.8				3.9			
	Fit	3.5	3.5			3.2	3.2			4.0	4.0		
	Creative	3.3	3.2			3.4	3.4			3.5	3.6		
		3.2				3.4				3.7			
Economically feasible	Economically feasible	3.4	3.1	3.1		2.9	2.9	2.9		3.7	3.3	3.3	
		2.8				2.9				2.8			
Manufacturable	Effective	2.7	2.7	2.7		2.3	2.3	2.3		2.9	2.9	2.9	
Suitable	Trendy	3.3	3.3	3.0		2.9	2.9	2.8		3.4	3.4	3.3	
	Marketable	2.8	2.8			2.7	2.7			3.3	3.3		
Purposeful	Usable	2.7	2.7	2.8		2.6	2.6	2.7		2.8	2.8	3.0	
	Functionable	2.8	2.8			2.8	2.8			3.2	3.2		
Sustainable	Changeable	2.9	3.0	3.4		3.0	3.0	3.6		3.1	3.2	3.7	
	Durable	3.1				3.0				3.4			
	Recyclable/Reusable	3.0				3.1				3.1			
	ZWF method utilization	3.5	3.2			3.8	3.8			4.0	3.9		
		3.2				3.8				4.0			
		3.0				3.7				3.8			
		3.2				3.8				3.8			
	Zero waste	5.0	4.0			5.0	4.0			5.0	4.0		
		3.3				3.4				3.7			
		3.6				3.5				3.3			

1) Suggestions for improvement of the design process stages & actions:

In Comprehension stage, being dauntless and undeterred by the conventional pattern design frame were essential. In Ideation stage, 'sketch as a rough draft' and 'accidental design' were the key words. In Making stage, draping was chosen as a simple way to approach ZWF. In Zero waste stage, using simplified pattern pieces was considered helpful. In Evaluation & Revision stage, altering patterns to prevent waste and rectifying the planned design during the design process were the keys.

2) Needs of ZWF Method users:

The needs of students set the direction on how the design processes should be revised to form a guideline. The needs were categorized into three: making an accidental design, making a planned design, and approaching ZWF step by step according to the Methods' levels of difficulty.

(1) Making an accidental design: Considering zero waste simultaneously in the ideation stage was difficult and it required more time and effort. Hence, participants felt that making an unpredictable, accidental design was easier and it also lifted the burden that was weighing them down. Moreover, unpredictable design can lead to more creative outcomes and design variables can be supplemented and altered. Therefore, it can make the attempts at ZWF easier and may lead to creative outcomes.

> "Thinking and ideating while considering zero waste were too difficult. Therefore, I just made shapes and started developing." (J2, J4, S2, S3) "Creative design was possible with relatively small effort and short time" (J1, S2, S3, S4) "It was easy because of its unpredictable, accidental design. It does not need much effort as it is made freely and creatively without detailed planning." (S1, S2, S3)

(2) Making a planned design: As shown above, students sometimes relied on accidental design and chose a reversed process. This led to the appearance of an opposite need: making a pre-conceptualized garment. Planned design can help secure the output's qualities and it lets users set an appropriate direction throughout the process. However, it should be based on a flexible plan that can be easily altered. Thus, the users of ZWF Design Methods need a way to create an output based on a flexible plan.

> "Planned design can help set an appropriate direction. It will be more efficient." (S2, L4) "A garment design can lack aesthetical qualities without selecting a design in advance." (S3) "After ideation and sketching, the making procedure had some conflicts with the ideated design. I modified the conflicting elements." (J1, L2, L3, L4)

(3) Approaching ZWF step by step according to the Methods' levels of difficulty: All participants complained of difficulty in understanding and applying the ZWF Methods. Therefore, starting ZWF step by step was needed as it can help ease the students' acquisition of ZWF Design.

> "ZWF Design Methods' levels of difficulty are different. Development of Methods according to the user's ability is needed." (L3) "Layer Method is the easiest. It can be the basis of ZWF Design Methods." (S3, S4, L2, L3, L4)

As a proof, the Methods' difficulty levels were found to be different. They were measured upon comprehension, application, and accessibility. These standards were judged based on the protocol records, prototype evaluation, and the quotations in 〈Table 8〉 of interviews and questionnaires.

〈Table 8〉 Difference in accessibility levels among the three ZWF Methods

Method	Quotations
Jigsaw Puzzle	"Jigsaw Puzzle is a concept that we learn in elementary school." (J2, J3) "I was afraid to make an attempt. I got scared when the process started." (J1, J2) "Creating a puzzle pattern seems difficult." (J1, J4, S4, L3)
Subtraction Cutting	"Structural design of Subtraction Cutting seems hard." (J1, S4, L3) "Subtraction Cutting includes an unfamiliar concept. Thus, it is not easy to approach and access Subtraction Cutting Method." (S3, S4, L3)
Layer	"Layer is the most accessible, because of its simple principle and easiness of making and revising the intended design." (J1, J3, J4, S2, S4, L1, L2, L3 L4) "Layer Method is the most accessible, because it is easy to comprehend." (S1)

Ⅴ. Zero Waste Fashion Design Guideline from an Educational Perspective

By integrating the results of ZWF Method application experiment, interviews, and questionnaires, a basic design process guide for each Method was developed. The final guideline was based on the characteristics and processes of the three Methods deducted from the experiment. Advantages and improvement points mentioned in the interviews and questionnaires were emphasized. Students' needs, difficulties, and disadvantages mentioned were used to revise and improve the guideline.

The main directions of the guideline are as follows: First, students required a design process which fulfills their need for making a planned design and an accidental design. Second, students also sought for a guide with which they can effectively approach ZWF Design Methods step by step, from a relatively easy Method to a difficult Method. By taking these directions into consideration, ZWF Design processes of Jigsaw Puzzle, Subtraction Cutting, and Layer Methods were revised and improved.

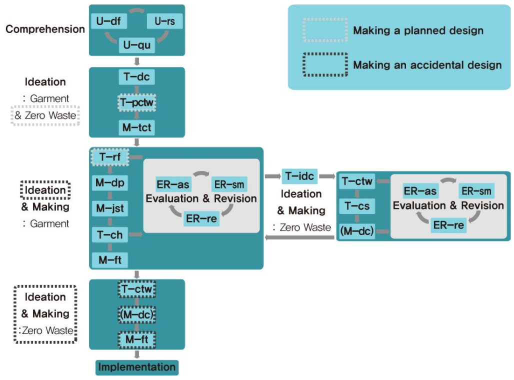
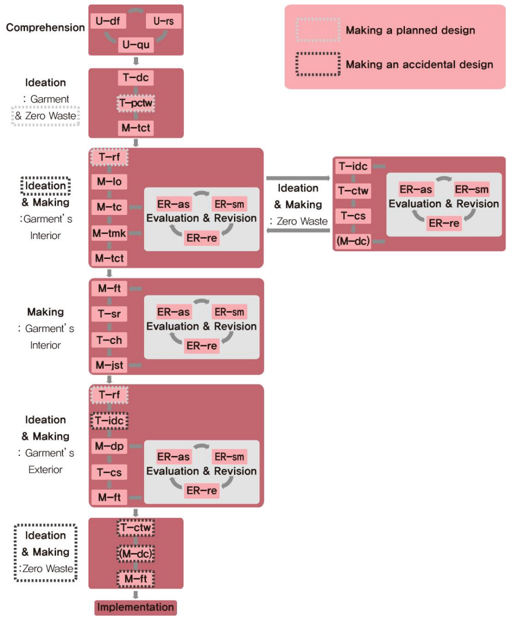
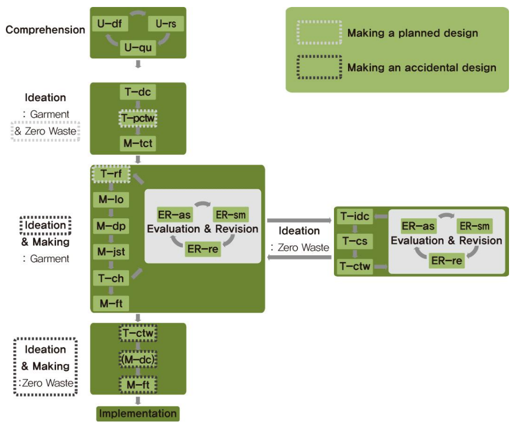
1. Revised Zero Waste Fashion Design Process Guideline Overview

When making a planned design, a design was chosen at the beginning like the conventional design process, but it was open to revision throughout the progress. Making an accidental design took on the frame of a reversed fashion design process and added the element of surprise.

To make planned/accidental designs possible, the structure of each Method's process was revised as follows. The stage of considering zero waste, which appeared in the middle of Jigsaw Puzzle and Layer processes, was added to the Subtraction Cutting process. Ideation considering zero waste at the initial stage of Layer process was added to Jigsaw Puzzle and Subtraction Cutting. Furthermore, the stage of relying on coincidence was added to the Layer's process. Evaluation & Revision stage accompanied each process stage of the three Methods. This is shown further in 〈Table 9〉.

After revising the ZWF Design processes, it was found that some design stages and actions were shared between the process of making a planned design and that of making an accidental design. However, it was also discovered that the proportion of each action and stage, their contents, and to what extent the action must be carried out were

〈Table 9〉 Revised fashion design process guideline of each Method

	ZWF Design Process	Diagram of ZWF Design Process
Jigsaw Puzzle Method	Planned design: Comprehension 》 Ideating: garment & zero waste 》 Making: garment 》 Ideating & Making: zero waste 》 Making: garment 》 Implementation Accidental design: Comprehension 》 Ideating: garment 》 Ideating & Making: garment 》 Ideating & Making: zero waste 》 Ideating & Making: garment 》 Ideating & Making: zero waste 》 Implementation	
Subtraction Cutting Method	Planned design: Comprehension 》 Ideating: garment & zero waste 》 Making: garment' s interior 》 Ideating & Making: zero waste 》 Making: garment's interior 》 Ideating & Making: garment's exterior 》 Implementation Accidental design: Comprehension 》 Ideating: garment 》 Ideating & Making: garment's interior 》 Ideating & Making: zero waste 》 Ideating & Making: garment's interior 》 Making: garment's interior 》 Ideating & Making: garment's exterior 》 Ideating & Making: zero waste 》 Implementation	
Layer Method	Planned design: Comprehension 》 Ideating: garment & zero waste 》 Making: garment 》 Ideating: zero waste 》 Making: garment 》 Implementation Accidental design: Comprehension 》 Ideating: garment 》 Ideating & Making: garment 》 Ideating: zero waste 》 Ideating & Making: garment 》 Ideating & Making: zero waste 》 Implementation	

different. The process of making a planned or an accidental design first depends upon the weight of T-dc and the presence of T-pctw. Whether the user decides to plan the design in detail and puts effort on T-dc and T-pctw or decides to do an accidental design by starting only with a vague idea and passes through T-dc without T-pctw determines the characteristic of the process.

Accordingly, a guide for making a planned design and one for making an accidental design were organized together in a diagram to help users learn their differences and similarities and to increase the guides' usability. The user can choose the design actions and stages among the options of planned and accidental design according to one's preference. Actions or stages that are only limited to making a planned design or an accidental design are marked in a light gray or a dark gray dotted line. Following the light gray dotted steps without the dark gray dotted ones leads to making a planned design. And following the dark gray dotted steps and disregarding the light gray dotted ones lead to an accidental design. Therefore, this revised process can be suitable for users with different design aims.

2. Zero Waste Fashion Design Step by Step Guideline

The difficulty levels of Jigsaw Puzzle, Subtraction Cutting, and Layer Methods were measured upon comprehension, application, and accessibility. The easiest Method gained 3 points, moderate 2 points, and the hardest gained 1 point. Considering U-Action in 〈Table 5〉, 'comprehension' was rated in the following order (from easy to difficult): Jigsaw Puzzle, Layer, and Subtraction Cutting. For the difficulty level of 'application', Layer was judged to be the most applicable, followed by Subtraction Cutting and then Jigsaw Puzzle. This resulted from taking the preliminary experiment and prototype output evaluations into account. For 'accessibility', Layer was placed at the easy level based on 〈Table 8〉. Jigsaw Puzzle was ranked at the moderate level, and Subtraction Cutting was ranked as the hardest.

The average of the difficulty level scores above were Layer 2.7, Jigsaw Puzzle 2.0, and Subtraction Cutting 1.3. Thus, Students should start with Layer Method, which is relatively easy to understand, the easiest to apply, and has the lowest barrier among the three Methods. Then, Jigsaw Puzzle Method should be used as it effectively shows the concept of zero waste and is fairly accessible. The last Method to try out is Subtraction Cutting. It is difficult to comprehend and not easily accessible. However, after comprehension and overcoming one's fear, it is relatively easy to apply to an actual design.

Ⅵ. Conclusion and Discussion

The final objective of this study was to develop a ZWF Design process guideline for educational purposes. By establishing a guide based on students' needs, the experience of applying ZWF Methods can be ameliorated. Moreover, the barrier of ZWF Methods can be lowered, ultimately increasing their usage. This has been considered crucial by numerous existing studies(Carrico & Kim, 2014; Niinimäki, 2013). The guideline may also be used as a stepping stone for students interested in ZWF to easily acquire the different characteristics of ZWF Methods and make an attempt at its application.

Thus, this research may serve as a preliminary data for ZWF Design Methods education, which can lead to their expanded usage and diversification. Furthermore, it may also contribute to the application of ZWF Design Methods on the conventional fashion design process, raising the possibility of their role on eliminating textile waste and on promoting awareness of the current textile waste situation.

However, this research has two limitations. First, this research limited its scope to individual practices and did not cover the industrial viewpoint of ZWF Design Methods. Second, the main experiment dealt with prototyping and not the finished product. Therefore, industrial point of view and design aspects other than zero waste should also be taken into account in the future to further utilize ZWF Methods and to realize their full potential.

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