DEVELOPING THE CONVERGENCE FASHION PRACTICE METHODOLOGY -FOCUSED ON THE CONVERGENCE BETWEEN ENGINEERING TECHNOLOGY AND FASHION DESIGN IN FASHION EDUCATION-

Hyunseung Lee[1]

[1]Modular Fashion Platform Research Centre, Kookmin University, Seoul City, South Korea

ABSTRACT

This study proposes a convergence design process that converges the creativity of fashion design and the technology of engineering in fashion design education considering the convergence tendency in modern industries. So, primary study that combines an engineering design process that promotes engineering thinking and a fashion design process that promotes creative thinking was developed and tested in a convergence workshop. As a result, the need refining the practice model was discovered to encourage the in-depth cooperation. Therefore, the second CFPD practice model composed of interaction design process and a fashion design method was then investigated to promote trainees' inter-connected thinking and force iterative processing. To verify the usability of the refined practice model, the second Convergence workshop using the latest model was held, here a tendency of convergence to share knowledge and techniques among designers and engineers to address problems was observed. The functionality of the developed four prototypes based on the idea of setting and solving a design issue was also embodied. It is expected that the process and results can be utilized as a basis for development of design methodologies and education programs in various design areas including fashion in this era of converged industries.

KEYWORDS

Cooperative practice, Design Process, Fashion Education, Convergence Design Education

1. INTRODUCTION

The concept of convergence is that heterogeneous things gather without distinction and become one. It draws attention in modern industries as a way of breaking out of the existing frame and creating new products and services [1]. The convergence tendency has combined various heterogeneous technologies and industries with IT that became distinguished since the middle of 2000s [2], [3]. For instance, the IoT technology embodied in the 2000s by global IT enterprises and diverse academic areas have been applied to fashion items including glasses and watches which are now called wearable devices [4], [5], [6]. These kind of IT-centred convergence trends in this Industrial 4.0 era show the new perspectives and approaches to

DOI: 10.5121/ije.2020.06103

Fashion industry as well as education areas in order to expand Fashion's new role and value in the future industries. In fact, the attempts of the convergence to adapt clothing as a media for providing digital functions to enhance human-abilities at the closest location from the human body has been proceeded from the late 20th century [7], [8], [9]. And, as mobile devices have been increasingly miniaturized, lightened, and low-priced since the 2000s [10], the potential of new roles and values in fashion have been sought by convergence [11], [12], [13]. This attempt to establish convergence Fashion presented feasible application combining Fashion and Electronics, and gradually indicated commercial potential from late 2000s [14], [15]. New sorts of fashion brands such as Electric Foxy or Cute-Circuit had emerged, which have the convergence concept in their brand identities and present remarkable fashion products providing digital functions [9], [15], [16], [17], [18], [19]. Also, historic luxury or high fashion brands also started to deal with smart fashion accessories [20].Thus, in modern industry, this convergence tendency becomes the significant topic that is not only for IT, but also for fashion industries in order to pioneer new promising values [11], [12], [15].

Consequently, the focus of this study's educational research and development (hereunder, R&D) is on functions which should be useful for customers and embodied in the form of fashion items to be closest to the users. Also, it is expected that trend changes and markets base expansion will be accelerated by the advance of Virtual reality and Augmented reality technologies [21], [22], [23], [24], [25], [26], [27].

Regarding this tendency, convergence education is essential to take the lead of industries, particularly, the area of fashion design. To this end, it is vital to develop methodologies to conduct a design process that promotes cooperation among different areas through systematic assignment division. Such methodologies need to induce convergence of knowledge, technology, and experience among different areas as well as conception of creative ideas so that professionals in different fields such as fashion and IT can derive one integrated product. Fashion items, especially garments, which are used at the closest location of their users could be a suitable medium combined with Engineering technologies to provide farther functionality and the fusion can be the keystone to expand the industrial boundary and roles of Fashion to exceed the traditional value of Fashion [9], [28], [29]. In order to achieve the substantial expansion of Fashion, in the educational areas, designers could be prepared to have flexible, alternative perspectives and practical expertise on the convergence with technologies through interactive practices with Engineering experts sharing their expertise each other. However, in general, the role of designers in R&D for the convergence tend to become remarkably passive in actual development tasks from middle of R&D processes after the initial ideation and fashion (garment) platform design were done once [9]. Due to the phenomenon, since engineers become manage overall development tasks concentrating rational and efficient completions of the digital systems and the application of them into the platforms, some of drawbacks from the Fashion's perspective are often appeared stated below: First, inner-structures of the platforms were modified to make space equipping systems disregarding the aesthetic balance of 'Construction'. Second, system devices were equipped inside of platforms dispersively without in-dept considerations on the structural interaction between wearers' bodies and platforms, which could cause negative effects on aesthetic appearance, wearability, comfortability and activeness of the platforms when they were worn on bodies. It is seemed that the above negative trends in cooperation of convergence projects were emerged by the strict role division by the majors and passive process tasking of design majors. Of course, it would be ideal to provide design majors with engineering subjects for the ultimate convergence R&D, but there is realistic limitation in the academic formation. In convergence fashion product development (hereunder, CFPD)

designers do not only play a role of exterior of product design, but they can also deal with concepts and mechanism of provided functions, and manage Fashion's aesthetics as well as range of applied technologies to promote R&D themselves in the cooperation with engineering experts.

In order to activate the fully converged-sharing expertise between the majors the institutional strategy encouraging the flexible and inter-connected ole-playing which promote trainees to cross the boundaries of their majors is needed to transcend the realistic limitation of the academic formation. It is expected that designers could be led to perform in-dept study on the exterior design of products, structural design as well as functionalities provided by their ideas with the efforts to understand mechanisms of devices what they tried to use through the inter-connected role-playing with engineers on primary investigations on the technological components of digital systems such as micro-controllers or sensors. At the same times, engineers could be also led to promote flexible thinking on the selection of components, methods of the connection among devices and making circuit boards which would be appropriate for washability of platforms and maintenance of systems in common exceeding the standard or stereotype of their majors. For the inter-connected cooperation(role-playing), instructors or lecturers' roles could be significant mediate trainees' stepwise processing and force the self-evaluation on their works' and investigation on unfamiliar expertise each other to prevent the one-sided process tasking in each processes of practices.

Therefore, in this study, the practice model of convergence fashion prototype development for the balanced and inter-connected cooperation between design majors and engineering majors was investigated to transcend the realistic difficulty to hold classes only focused on engineering subjects, Electronics, software and Mechanics. Accordingly, this study aimed to develop the effective methodology for CFPD R&D practices which could encourage trainees' inter-connected processing and verify the usability and adaptability of the methodology in Fashion design education.

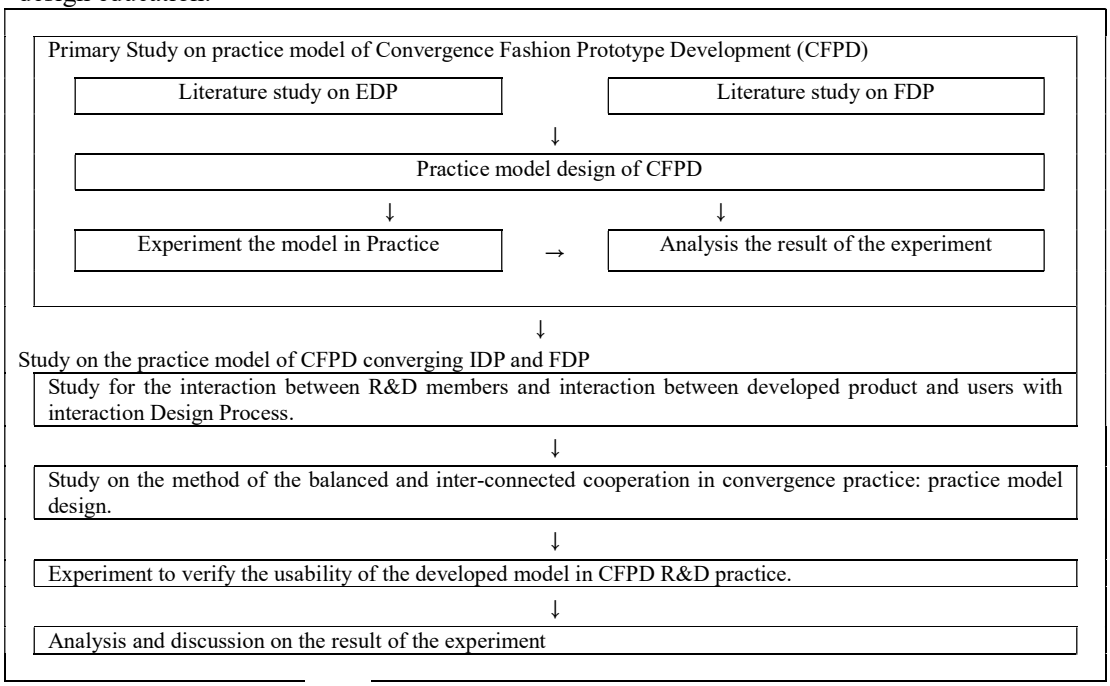

Fig. 1 The research model of this study's process

This study takes the following steps briefly:
First, a primary study on the CFDP practice model focused on the integration of the Engineering design process (hereunder, EDP) and the Fashion design process (hereunder, FDP) [13], [14].
Second, in order to promote, based on the result of above-stated practice, the thinking process thorough convergence among garment elements, and system elements and inter-connected practicing in the development of convergence fashion product design, the concept of the interaction design process and the fashion design process were combined to re-design methodology of CFPD.
Third, the second convergence workshop was conducted using the re-developed method. the basic goal was to verify the effectiveness of the convergence product development methodology in terms of interoperability and specific research model is stated in (Table 1).

2. LITERATURE REVIEW

2.1. EDP referred in this study

From the 1960s onward, Operation research (hereunder, OR) and System engineering (hereunder, SE) which was the initial concepts of EDP were spread in private sectors and utilized by companies. As the industry grew in the 1960s, product design became complicated and diversified. As a result, the necessity of scientific approaches to design methodologies was emphasized. Accordingly, systematic approaches such as the OR and the SE were required in the field of design as well although it was challenging to apply engineering problem-solving methodologies directly into design [32], [33]. In the 1960s, researchers such as J. C. Jones and C. Alexander, B. Archer facilitated researches on design methodologies, presenting the first-generation design process models of the linear hierarchy – 'analyzing problems,' 'synthesizing problems,' and 'evaluating solutions' – and going beyond the 'existing black-box models in which the relation between design work and products was vague. In the step of analysis, quantitative investigation on markets, consumers, and products was conducted. In the comprehensive stage, designs and products were developed in reflection of the findings in the previous stage. In the stage of evaluation, results of the previous stages were assessed with corrective measures developed. While the first-generation EDP of Jones, etc. preferred a scientific approach to design problems, H. Ritel viewed design problems as complicated, pluralized, and 'ill-defined' as the industrial society advanced and the social structure changed accordingly [34].

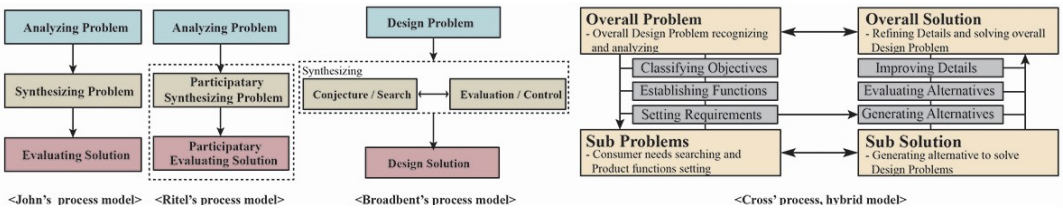

Fig. 2 (from the left side) 1st generation of Johns; 2nd generation of Ritel; 3rd generation design process of Broadbent; the hybrid model of Cross

To live up to the demands of the times, therefore, the second-generation participant process of Ritel complemented and improved the first-generation participant process of Ritel complemented and improved the first-generation linear model to some extent. The following third-generation process of inference and refutation proposed by Broadbent. In the 1990s, the hybrid model of Nigel and refutation proposed by Broadbent. In the 1990s, the hybrid model of

Nigel Cross was a asymmetric model designed to respond to the more complicated and diversified society, industrial environments, and consumers [33], [35], (Fig. 2).
Cross' hybrid model (hereunder, HM) was designed as multi-layered and circulative other than linear in order to solve design problems and present solutions to complicated problems by utilizing a combination of existing EDP theories that broke out of the existing linear structure [30]. The HM multi-stratified design problems and divided them to overall problems (hereunder, OP)' and sub problems (hereunder, SP).' Cross asserted that there is asymmetric balance and relation between Ops and overall solutions (hereunder, OS) and between SPs and sub-solution (hereunder, SS), and that there is a hierarchic correlation between each problem and its solution rather than a one-way relation [30]. Starting with the above-stated assumption, the hybrid model was designed to include 'classifying objectives' in order to start from general problems and grasp problems at the base; 'generating alternatives' in order to start from establishing functions, setting requirements, and solving problems at the base and the induce general solutions; and specific assignments of evaluating alternative and improving details [30], (Fig. 2).
With regard to specific assignments stated above, designer divided general problems to sub problems, and added sub-solutions for such sub problems in order to propose a general solution through the design work [36]. The HM specified the designer's role further by applying a diversified structure. With the concept of problem-solving system engineering (general solution, sub-solution) at the right side and with the concept of marketing at the right side as general and sub problems, design is located inside as a specific assignment and plays a role as a regulator [37], [38]. With this structure, Cross' hybrid model induces problem-solving by integrating complex perspectives in the design industry. In this perspective, the HM integrates complex concepts of engineering, marketing, and design as a mediator [37], and thus it may be viewed as a basic frame for convergence design processes. In the context of process implementation, however, aspects of engineering are emphasized basically while design work is limited only to the external features of a product. Besides, 'product concepts and storytelling, which attract consumers in this era of variety,' are neglected, and 'the buffing role' of designers is emphasized in terms of symmetry, hierarchy, and correlation of problems and solutions, Accordingly, there is a concern that designers' creativity might be diluted [39]. Now that designers' concepts and creative production of result in the area of fashion design are viewed as important as efficiency of process performance, a design process for convergence between fashion and technology needs to include a conceptual structure that can support designers' creativity, which is an issue in the context of Cross' HM. Therefore, this study seeks to examine the FDP that puts designers' 'creativity' at the centre of a process and thus to make up for the weak points of the HM.

2.2. FDP referred in this study

Fashion design processes have been studied and developed with the EDP as the basis in order to manage design, production, management, marketing, and promotion as well as product plans efficiently as the existing fashion industry was expanding in the late 20th century [40], [41], [42]. Most Fashion design Process models were indirectly based on EDP models and designed for industrial designers or senior-level students [43]. [44], [45]. The basic form of the preliminary models was derived from Wallas'(1926) model consisting of four steps; preparation, incubation, illumination and verification and Koberg and Bagnall's(1974) model consisting of seven steps; accept, analyze, define, ideate, select, implement and evaluate. Those two forms were generally adapted and adjusted to be appropriate for apparel design in FDP Studies (Watkins, Davis, Lamb & Kallal and Regun & Kincade) for industrial apparel design

[46]. Davis' (1980) and Lamb & Kallal's (1992) models was composed pf six courses in order to fit the previous structures of FDP models (Table 1), (Table 2).

Table 1 Davis' fashion design process

Set a goal	Visual references or cases on literature, culture, costume history, target consumers and markets researches should be conducted.
↓	
Examine outside influence	-Identities of products should be extracted through the analysis on the information gathered by the previous step.
↓	
Establish criteria	-The most suitable guideline of the products on the functionality, materials, structures should be configured through market researches.
↓	
Make the plan	-The application methods of materials, colors and designs should be planned according to the guideline.
↓	
Carryout the plan	-The design plans extracted in the previous step should be realized.
↓	
Evaluate the product	- Realized product should be evaluated to release final products.

Table 2 Lamb & Kallal's Fashion design process

Problem identification	Problems should be understood to Invest possible solutions .
↓	
Preliminary ideas	Case study, survey, brainstorming and sketches should be conducted to extract design samples.
↓	
Design refinement	Tasks of realizing and improving design variations should be conducted.
↓	
Prototype development	Design selecting and making prototype should be performed.
↓	
Evaluation	Prototypes should be evaluated by the three criteria; 'Functional', 'Expressive' and 'Aesthetic'.
↓	
Implementation	Designs should be arranged by the result of the evaluation until the deadline of mass-production.

Watkins' (1988) and Regan and Kicade et al.'s (1998) models were designed as seven steps similar with Koberg & Bagnall's case (Table 3), (Table 4).

Table 3 Watkins' Fashion design process

Acceptance	The motivation for the investigation of design problems and solutions should be comprehended.
↓	
Analysis	Basic study on the market and consumers should be conducted. Inspirations to find out solving methods should be investigated through problem definement and interviews.
↓	
Definition	The most appropriate idea should be selected for the problem solving.
↓	
Ideation	Concept ideas based on the idea in the previous step should be generated.
↓	
Idea selection	Specific design concept should be configured by synthesizing results of the previous ideation
↓	
Implementation	Design variations should be extracted based on the design concept as a criteria. Prototypes should be made to realize the designs.
↓	
Evaluaion	The prototypes should be evaluated by the criteria. The points of the improvement should be gathered for the improve the quality of the product. The final products should be established to release them to markets.

Table 4 Regan et al.'s Fashion design process

Problem recognition	- Defining problems, generating basic ideas and arranging ideas should be conducted.
↓	
Problem definition	- Directions of the product design, information of human-material resources and ranges of the products should be researched and analyzed.
↓	
Exploration of problem	- Consumer information, product demands, re-order strategy and market circumstances should be investigated.
↓	
Search of alternative	- Product lines should be edited and suggested to synthesize the experiences on the needs and conditions about designs of the previous season.
↓	
Evaluation & decisions	- The results of the previous step should be assessed by the criteria which consist of the perspectives on aesthetics and salability.
↓	
Specification of solution	The result of the evaluation should be synthesized and analyzed to suggest the best product lines and quantity for production management.
↓	
Communication of solution	- Linguistic and visual guidance about the products, manufacture and distribution should be confirmed and conveyed to the department of management and sales.

Regarding the reviews, FDPs suggested from 1980s to 1990s could be defined as the methodologies which were developed to be applied into the industrial mass-production for existing brands or companies. On the other hand, in FDP for creative practices of Education, the industrial efficiency and logic are not only significant, but the leading role is also essential to stimulate students' sophisticated ideation as well as making iterative efforts for the achieving design goal and establishing own design identities [31], [47]. Regarding this, the Design Cycle (hereunder, TDC) as a FDP could be referred to meet the academic needs, which induce trainees to promote their creativities, continuous thinking and practicing. Its inventor underlined the importance of Philosophy beyond the visual elements. To achieve above conceptual tasks, TDC was designed to help designers' iterative self-evaluation and process-tasking by the circular structure [31], (Fig. 3).

1st, according to Dieffenbacher (2013), in 'IDEA' category of the process, 'context' stage was suggested to find out the clue of the inspiration from diverse sources. 'Explore' stage was suggested to put trainees thinking forward. For the task, it is highly recommended to seek the clue of their ideas from their direct experiences and memories through taking photo, interviews or surveys rather than indirect sources such as magazines, the internet or video clips. 'Interpret' stage was suggested to synthesize the result of the previous steps.

2nd, according to Dieffenbacher (2013), in 'CONCEPT' category of the process, 'reflect & question' stage was suggested to clarify design problems and make basis for definition of ideas through the specification of the problems by using indexes of 'what', 'who', 'where', 'when', 'why and 'how'. Following 'investigate' stage was suggested to solve the problems specified in the previous step through the deeper investigation using various literature or visual materials to exceed existing concepts. 'Reinterpret' stage was suggested to translate the results of the previous investigation from trainees' distinctive perspectives. At this step, trainees should physically do the variety of tasks such as collage, drawing, collecting, writing and arranging resources on their research notes to be distinctive from existing concepts of others.

3rd, according to Dieffenbacher (2013), in 'DESIGN' category, 'reinvent' stage was suggested to create design variations of new silhouettes and forms. 'Recognize' stage was suggested to refine and elaborate designs by considering new design elements generated from the design task. 'Finalize' stage was suggested to fix materials, colors and details according to the reinvented design theme and 'establish' stage was suggested to present the distinctive identity of the designer as well as the signature style of the collection.

Sine this study has aimed to investigate the methodology to assist convergence design practice combining Fashion's aesthetic perspectives and Electronics' digital functions from trainees' distinctive identities or perspectives, it was decided to reflect the Design Cycle into this study's design method rather than the others based on EDP.

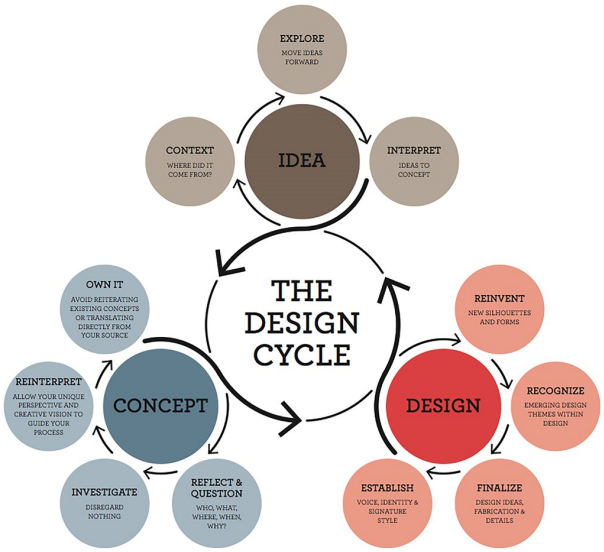

Fig. 3 The Design Cycle [31]

2.3. IDP referred in this study

In general, Interaction design has traditionally dealt with interactions between humans, between humans and things, and between things. The boundary of Interaction design has been expanded and subdivided by the growth of IT-technologies. In the present, Interaction design is generally recognized as the design area dealing with the human-interactions with diverse of products, services, systems and social components [48, 49, 50].

Regarding the users' needs and properties of the design results, Interaction design pursues the way of the harmonization among the diverse academic, social or industrial areas such as Psychology, Computer science, Electronics, Engineering science and so on. Interaction design has studied on the both of two directions; substantial interaction of things such as the physical interaction between human and electronic products as well as intangible interactions such as services in virtual spaces or invisible system algorithm of websites [48]. In Interaction design, there have been 4 directions; 'user centered design', 'action centered design', 'system centered design' and 'genius design' [51], (Table 5).

Table 5 The Conceptual Approaches of Interaction Design by Purpose

Approach	Outlines
User Centered Design	A conceptual direction regarding that every design problem and requirement such as function, structure and value would be up to consumers.
Action Centered Design	A conceptual direction focused on 'action' including consumers' behavior and decision making for the goal to use product or service rather than consumers' aesthetic tastes.
System Centered Design	A conceptual direction focused on the serial of the processed phenomenon occurred by users' activities or the context and structure of systems to generate the processed phenomenon.
Genius Design	A conceptual direction focused on designers' individual talents or skills. This is the most popular direction throughout of the academic and industrial areas and many industries such as 'Apple' has kept this direction to secure their now ideas of products or services.

Following the directions, Interaction design process generally consists of four stages [48], [51]. In the 1st 'Identifying alternative needs and establishing requirements' stage, investigation and analyzation tasks are performed to establish design strategy. The investigation task is performed to understand design problems and users' needs. The analyzation task on the problem and needs is conducted to extract the structured insight. Based on the results of the two tasks, designers create new alternatives(designs) differed from existing designs and clarify 'requirements' which should be mainly considered in every stage of the process. At this step, the 'requirement' is generally organized as the form of self-question and answer. In the question and answer, designers should specify target users, purpose of functions, users' activities and operability of designs.

In the 2nd '(Re)Design' stage, diverse of the alternatives which can satisfy the 'requirement' are created. The designing tasks should be not only focused on visual aspects, but the actuation principle and context of system operation are also fully considered together. In this stage, if drawbacks of the alternatives according to 'requirement' as the criteria are detected, designers should return to the previous stage and re-perform the investigation of market, users' needs and the analyzation of the 'requirement'.

In the 3rd 'Building interactive version' stage, the development of prototypes which should be interactive with evaluators is conducted to evaluate its operability. If there are negative finding such as errors on the interaction between users and prototypes, designers should back to the previous stage to supplement the issues.

In the 4th 'Evaluate' stage, prototypes are evaluated to judge whether design problems are solved or not. If the problems are cleared and the 'requirement' is met successfully, the prototypes are permitted as the final product. However, if there are drawbacks on usability of the prototypes, designers should back to the 2nd stage to re-investigate appropriate structure and actuation principle of alternatives. Moreover, if there are critical errors on the context of system operation, designers should back to the initial stage of the process to re-understand the 'requirement' completely.

Through the above tasks, Interaction design process encourage designers to have flexible thinking and attitude returning to the previous tasks to refine their works repeatedly when they judged that the result of the process fulfillment is inadequate to achieve ultimate goals.

3. THE INVESTIGATION ON THE METHOD OF THE PRACTICE FOR CONVERGENCE FASHION PROTOTYPE DEVELOPMENT

3.1. Primary study on the convergence practice

Primary Framework of Practice model for Convergence Fashion Prototype Development (CFPD)

It was previously attempted to grasp conceptual elements related to specific steps and members' tasks required to realize substantial convergence. The participants who have interested in the convergence tasks were recruited for the harmonized cooperation. The length of the workshop was configured for 10 weeks and the class hour was configured three hours per one day in each week since the workshop was intended to evaluate whether the process could be adapted in the actual design practice of the education briefly (Fig. 4).

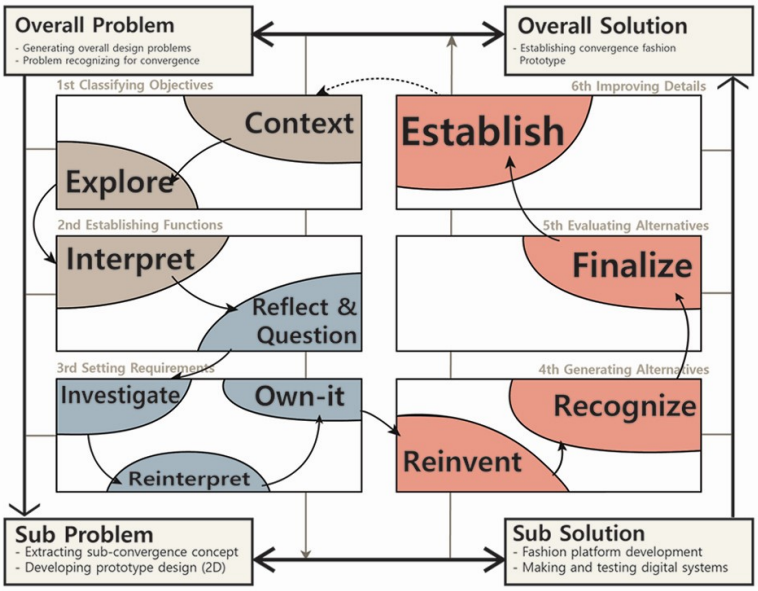

Fig. 4 Timetable and Design Process Components consisting of HM and TDC for Primary study on Convergence Fashion R&D practice

At the 1st 'Clarifying objective' stage, the concept of 'contest' and 'explore' in 'IDEA' category of TDC were applied to lead the participants (designers and engineers) seek 'Overall problems' under the context of the creative-logical thinking together. At the 2nd 'Establishing functions' stage, the concept of 'interpret' and 'reflect & question' in 'IDEA' and 'CONCEPT' categories were applied to encourage engineers to participate in discussions actively about designers' ideas and usable technologies. At the 3rd 'Setting requirements' stage, the concept of 'investigate', 'reinterpret' and 'own-it' in 'CONCEPT' categories were applied to promote trainees extract concrete designs concepts, 'Sub-problem'. At the 4th 'Generating alternative' stage, the concept of 'reinvent' and 'recognize' in 'DESIGN' categories were applied to induce designers to create design variations and improve them through self-evaluations to define 'Sub-solution'. At the 5th 'Evaluation alternatives' stage, the concept of 'finalize' in 'DESIGN' categories was applied to lead the trainees to understand and supplement the insufficiency of prototypes. At the 6th 'Improving details' stage, the concept of 'establish' in 'DESIGN' categories was applied to present the established prototype as 'Overall solution'.

Participants in primary workshop

In order to verify the usability of the primary practice model, a convergence fashion design and development workshop was conducted with 3 designers and 3 engineers and the range of their ages were from 23 to 25 who had been interested in the convergence works without the experience. The participants were grouped as three teams and each team composed of one designer and one engineer. In order to investigate the wide usability of the practice model for low-leveled students, the recruitment of participants was limited to gather junior level rather than senior, but the experience of taking actual making classes such as 'Construction' in

Fashion course and ‘Circuit design and processing’ in Electronic engineering course was required to the participants in order to test the usability as the R&D practice model. At last, all trainees (participants) were requested to discuss actively and share their specialty each other.

Procedure of primary study’s workshop

This primary workshop continued for 10 weeks from March 10, 2016, to May 12, 2016. Early in the workshop, conception was practiced by instructor’s guideline in order to embody the general context of the idea to develop convergence fashion prototypes.

At first stage, introduction on the goal of convergence practice, process tasking and discussions on the practice processing were conducted to figure out the basic context of the convergence fashion prototype development (hereunder CFPD). And two basic directions; 'lighting’ for aesthetic expression through a combination of garment and system utilizing the light source technology and 'complex’ to construct complex expression through lights and shape changes were configured.

At second stage, with instructor’s advice, each development team specified ideas through sketches: operation scenarios of the applied technologies and system requirements were written down according to the six principles (what, who, where, when, why, and how) and the four basic components of digital system; input, output, control and power.

At third stage, designers were encouraged to collect a diverse of references to configure design concepts and analyzed them from their own perspectives. And, each team synthesized the results of the previous processes to clarify the specific outlines of the development concepts of the prototypes on aesthetic fashion and technological expressions (Fig. 5).

Fig. 5 The example image on the processing of designers (left) and engineers (right) in third step

At fourth stage, drawing on the digital expression provided by the sample circuits, each designer was promoted to balance the intensity of the expressions between Fashion and Digital technology, since it was discovered that lighting expressions would be much stronger than the visual of the garments. After the refinement, designers modified the flat patterns according to instructor’s advices so that the device should not be revealed outward without causing any adverse effect on the human body. And engineers reorganized the system according to the actual size of the garments and elaborated codes to embed systems inside of the garments platforms temporarily (Fig. 6).

Fig. 6 The example images on the practicing in fourth step

At fifth stage, the aesthetic characteristics of the prototypes and the operability of the systems were evaluated. The trainees and instructors evaluated together whether the intended expression through the embedded systems was performed in harmony with the concept or not. With the wearability of the garment and the operability of the system as the criteria, each prototype was assessed and tested. Thereafter, light drawbacks needed to be improved were also found out (Fig. 7).

Fig. 7 The testing and evaluating process of each prototype in fifth step

At sixth stage, each R&D team completed the prototype in reflection of improvements suggested in the previous step. After the refining tasks were finished, the established prototypes were presented at the last period of this practice process (Fig. 8).

Design Results of Primary study's workshop

As the result of the primary study on CFPD practice, three prototypes have been designed, refined, made and established. At 3rd stage, overall design variations were created<Table > and from 4th to 5th stage, the designs were elaborated to balance the visual expression between fashion and electronic technology<Table 6>.

Table 6 Overview of the Design Development and Technological Application in each prototype

Prototype design	System Device		Ideas of Prototype Developments
 Street wear	Input	Bluetooth Text System	The motif of this system is one street artist's using graffiti as a way of self-assertion. The wearer can display a message by reflecting light on the surface of the hip-hop style garment like a screen.
	Output	High-brightness LED Panel	
	Control	Arduino Mega	
	Power	12V	
 One-piece dress	Input	Illumination Sensor	The main concept is Taiwanese depiction. The skirt pattern changes into the image of a Chinese traditional hanging lantern. The lighting inside the decorative object of a traditional handicraft style is turned on and represents light and shape changes, emphasizing "spatial senses."
	Output	Red 3π LED, Step Motor & Wire tube	
	Control	Arduino Nano	
	Power	5V	
 Floral robe	Input	Illumination Sensor	The artwork of a flower image on the robe surface responds to the brightness of the surrounding: If the surrounding is bright, it blossoms with the light source inside the pistil and flower structure turned on. The light and shape change, emphasizing the decoration of a flowery image.
	Output	White 3π LED & Micro Motor	
	Control	Arduino Nano	
	Power	5V	

In the case of R&D team A, designer A developed the street-styled two-piece; the lose fitted T-shirts and wide pants applying the textile pattern inspired from graffiti-art to balance the expressions between the fashion platform and technology. Engineer A developed and refined Bluetooth texting-displaying communication system for the message-lighting expression. At last step, they combined the platform and systems to establish 'Street-wear'. In the case of R&D team B, designer B developed the Chinese styled dress applying the textile pattern of Tai-Pei inspired from photo-montage technique. Engineer B developed LED lighting and shape changing systems composed of red LEDs, step motors and wire-tubes attached on inner-surface of the dress to transform the shape of the skirt part like Chinese lanterns. At last step, they assembled the platform and the electronic system to establish 'One-piece dress'. In the case of R&D team C, designer C developed the rob-styled dress applying the flower pattern. Engineer C developed LED lighting and shape changing systems composed of white LEDs and micro motors and transparent wires embedded in the flower objects on the surface of the dress which could open and close the leaf parts of the flower objects reacting the brightness of the environment. At last step, they assembled the platform and the complex system to establish 'Floral robe' (Fig. 8).

Fig. 8 The established three prototypes; 'street-wear', 'one-piece dress', and 'floral robe' in the primary study

Learning outcome from the convergence workshop in primary studies

From the primary study on CFPD practice, designers were encouraged to improve the prototypes' aesthetic and structural problems continuously throughout of the process and they followed the guidelines to make the iterative efforts independently when they figured out the problems on the visual stimuli for example. Thus, the problem on the unbalanced role playing which has been generally found in convergence R&D projects was eased to a degree. However, such continued conception and modification for improvement could be achieved within the boundaries of each professional area: design and engineering. Designers concentrated to enhancing the visual expressions of the garment platforms by their graphic skills and engineers only concentrate achieving the working systems of the prototypes by their expertise. Therefore, based on the experience of the primary study, it was confirmed that there was the necessity of refining the design process and practice model of CFPD which could underline the in-depth cooperation which the trainees actively share their expertise, knowledge and skill each other such as usages of the technology from the design perspective or systematic garments design from the engineering perspective.

3.2. Elaborated study on the methodology of CFPD practice

Refined Framework for the CFPD model reflecting the Concepts of IDP and TDC

Based on the results of the primary study, this study's practice model was re-designed to promote both of two sorts of trainees sharing expertise willingly and lead their processes interactive. It was sought to improve the convergence fashion design process (practice model) focusing on the concept of the interaction between users and convergence products.

Convergence fashion products would be completed by the fusion between structures of fashionable platforms and electronic systems for functions. Accordingly, principles and properties of human-computer or human-machine interfaces could be reflected in the final product. In addition, as the platform that embraced the interactive system was the medium of 'garments,' the products should be attractive aesthetically to users. Although the convergence fashion prototypes of the primary study were developed to achieve balanced visual expressions between Fashion and Electronic engineering, they were inventors focused functions and their input mechanisms were up to the environmental stimuli rather than the interaction with their wearers. Therefore, to encourage the ideation, research and development of wearer(user) focused convergence fashion, it was considered that the concept of Interaction design process(hereunder, IDP) could be helpful for CFDP about two point; consideration on the interactivity of garment systems and aesthetic fashion concepts. As TDC consists of the circular structure for the improvement of design results, there were the structural and conceptual similarity with Interaction design process. The iterative process fulfillment is also underlined in IDP to deal with user-and-function-oriented design thinking. Including the similarity, the user-focused or function-oriented design thinking by the combined method may give the new vision on design researches and the motivation for the in-depth cooperation to the trainees who are not familiar with complex design thinking or cooperating each other. For the purpose, IDP as a overall base-mission and TDC as a specific sub-mission were combined regarding their structural similarity as well as this study's goal (Fig. 9).

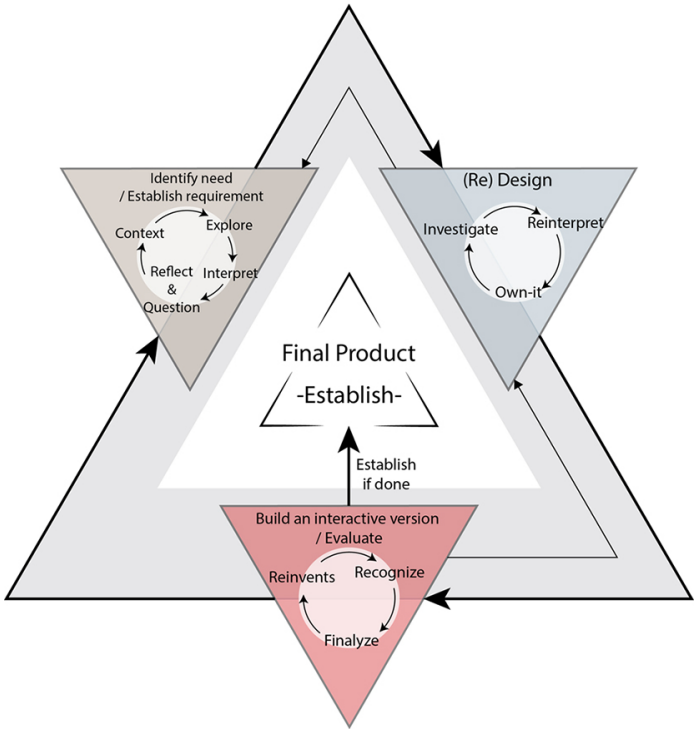

Fig. 9 The Timetable and Specific Tasks of CFPD practice model combining the concepts of IDP and TDC

In the 1st 'Identity needs & establish requirement' stage, the concept of 'context' and 'explore', 'interpret' and 'reflect & question' steps in 'IDEA' and 'CONCEPT' stages of the Design Cycle were applied for combining the two directions; understanding design problems from the Interactive and analytical perspective of IDP and the aesthetic perspective of TDC. At this step, instructor should require the in-depth investigation on the background information of design problems and users' needs had to be performed to extract the 'requirement' for the interaction, design concept for guidance of garments design and technology concept for digital function by electronic engineering. Also, they were needed to be organized as texts, diagrams or photos specifically.

In the 2nd '(Re)design' stage, the concept of 'investigate', 'reinterpret' and 'own-it' in 'CONCEPT' stage were applied to suggest the guideline for the specific ideation on 'aesthetics', 'originality' and 'interactive functionality' to extract the alternatives. At this step, instructor should promote all trainees to organize ideas according to the three aspects and create design sketches or scripts indicating the structures of garment-platforms and actuating scenarios or situations of electronic systems.

In the 3rd 'Build an interactive version' stage, the concept of 'reinvent', 'recognize' and 'finalize' in 'DESIGN' stage were applied to guide the optimum integration of garment-platforms and electronic systems since the integration achieved by the iterative experiment. Instructor should require trainees to arrange their results regarding the fashion factors; colors, materials, forms and the wearability as well as the engineering factors; operability and stability. Also, designers and engineers need to share their processes of making and experimenting to discover better means in each task before they combine the platforms and systems.

In the 4th 'Evaluate' stage, the usability and wearability of the interactive prototypes were evaluated to judge whether the 'requirement' is met or not If the 'requirement' was cleared, the prototype would be established as the final product. However, if there were any problems on the completeness of the prototypes, trainees had to back to the previous stage to solve the problem. Since, this study aimed to integrate Fashion-platforms and Electronic functions, it was considered that two sorts of problems in each subject had to be solved conjunctly. Thus, in this study, the evaluation and refinement processes in IDP were integrated.

Participants in the refined workshop

To investigate the usability of the practice model of CFD consisting of IDP and TDC, four designers and four engineers participated in the convergence fashion product R&D workshop. All participants were newly recruited to verify objectively whether the practice model could be followed up by the inexperienced students who do not have experiences in convergence design practices. The range of the recruited participants' ages in sophomore and junior level in each department were from 22 to 25 and each R&D team was organized as four teams grouped a design with an engineer who were in the same academic level, since this study had been planned to verify the usability of the model for wide range of students' grade levels. At the same with the participants in the primary study, there was one condition of the participants recruitment that the experience of taking a making classes; for example, 'Construction' in Fashion course and 'Circuit design and processing' in Electronic engineering course, was required since this study aimed to research the substantive method of product development practicing in Fashion design education.

Procedure of CFPD workshop with the refined practice model

The workshop was held for 15 weeks from May 8, 2017, to August 14, 2017. The length of workshop was extended longer than first workshop since the applicability of second process was needed to be verified more structurally systematically in order to adapt in design practice program of Fashion design education.

At 1st 'context', and 'explore' steps, each trainee conducted the ideation and discussion on design problems related to target users and functional concepts for the users focused on the interaction among the users, garments and systems.

At 2nd and 3rd interpret' and 'reflect & question' steps, each R&D team organized the result of the previous research on the needs and then they organized ideas by the six principles of TDC (Table 7).

Table 7 The Example of the organized Outlines of Prototype Development Ideas by the Six Principles

What	Where	When	Who	Why	How
Touchable-wear	outdoor space such as streets	When its users are walking or moving.	Hearing-impaired people.	To encourage the people's active and safe outdoor activities.	Through sound sensor and vibration motor systems, the garment detects and notice danger factors approaching from the rear side of its users.

At 4th 'investigate' step, to select the prototype development concepts, the survey investigation was conducted to assess the necessity of the ideas by 56 students who consisted of diverse majors and age groups. After the respondents had understood the outlines of each idea, they were led to select only one idea which was thought the most appropriate for themselves or other

people. Consequently, four R&D ideas in each designer were extracted as the prototype development concept (Table 8).

Table 8 The Result of the User Preference Survey (selected ideas in the shaded blocks)

Designer 1			Designer 2		
Memory Wear	Sound Hood Shirt	Touchable-wear	GPS Life Vest	Heating Gloves	Taser-coat
6	3	12	4	3	8
Designer 3			Designer 4		
Couple Wear	Aroma Therapy Wear		Neon-sign T-shirt	Solar-cell Wind Breaker	Self-EMS Vest
1	5		1	5	8

At 5th 'reinterpret' step, each team had configured devices by the 4 criteria; input, output, control and power (Table 9). They then made specific data sheets of the devices on performances, sizes, and weight.

Table 9 The Outline of System Devices in Each Prototype Development Idea

	Touchable Wear	Taser-coat	Aroma Therapy Wear	Self-EMS Vest
Control	Arduino nano	Arduino nano	Arduino nano	Arduino nano
Input	Sound Sensor, AUX Cable	Ultrasonic Sensor, Camera, Switch	Heart-beat Sensor	Toggle Switch
Output	Vibration motor, Woofer Speaker	LCD Display, LED, Conductive PLA Panel	Air Pump	Air Pump
Power	5V Battery	12V Battery	5V Battery	5V Battery

At 6th 'own-it' step, each designer was encouraged to create the design variations of the garment-platforms based on their R&D concepts and the equipment methods of system devices (Fig. 10). Engineers searched usable electronic parts drawing on designers' works. After the designs were fixed through tutorials, each team designed the diagram of the entire of system circuits and investigated the installation methods using Velcro-tapes of the system devices into the garment-platforms (Fig. 11).

Fig. 10 The generated design variations and fixed designs (in the red circles) of each garment platform

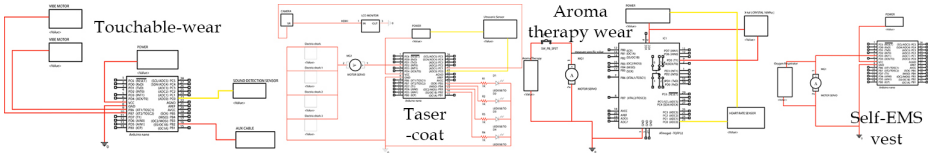

Fig. 11 The diagram of the system circuit of each prototype

At 7th 'reinvent' step, each team researched the locations of the system installation and then drew diagrams to organize the results (Fig. 12). Each designer drew flat patterns for muslin basting. They were required to mark the locations of the systems on the bastings to measure the real size and length between system devices and wires in order to adjust flat patterns regarding the measured data for the aesthetic completeness of the garment-platforms as fashion items. Engineers initially simulated the operability of the systems to comprehend the adaptability of the spec of the devices what they had selected to realize the interactive functions or not (Fig 13). And problems on the sizes, weights and actuation principles of output devices of Touchable-wear, Aroma therapy wear and Self-EMS vest were detected. Consequently, each team was requested to re-think and design the actuation principle on the direction to adapt lighter, more accessible parts for the reliability. After that, engineers developed the refined system circuits based on the measured data from muslin busting to make the whole devices and circuit wires detachable from each other through equipping socket-joints. And 3D-printing technology was used to make covers of each hardware developed by the designers were assembled on each system devices to enhance durability of the systems and the protection of users' skins (Fig. 14).

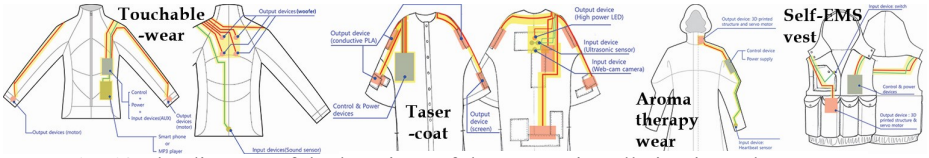

Fig. 12 The diagram of the locations of the system installation in each prototype

Fig. 13 The muslin basting process

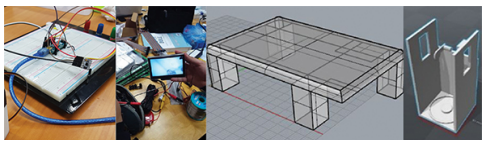

Fig. 14 The system development process in each prototype and 3D modeling for system cases and the output devices

In the cases of Aroma therapy wear and Self-EMS vest, the structures of their output device modules containing servo motors which the rotating angles could be controlled precisely by users' intentions were three dimensionally printed to realize the actuation principle (Fig. 15). At last period of this stage, pre-finalized garment-platforms and the system circuits were temporarily assembled to evaluate the completeness (Fig. 16).

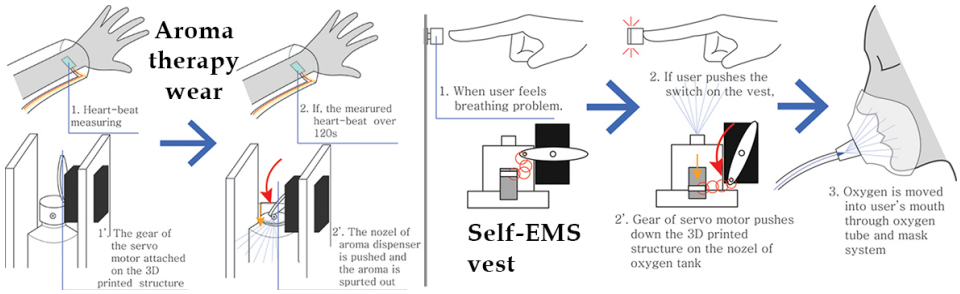

Fig. 15 The image of developed operating principles by the designers with their engineers' advices

Fig. 16 The developed each prototype at the Stage of 'Build an Interactive Version'

At 8th 'recognize' step, through the evaluation on the wearability, and usability of the prototypes with the instructor, drawbacks were discovered from each prototype. As a result, several drawbacks needed to be refined in systems.

First, From Touchable wear, there were two problems related to the range of the sensitivity of the sensor and embedding location of the sensor. The range of the sensitivity had to be narrowed down to react to the decibel degree of klaxon sounds of vehicles since the system had reacted to the sounds of low decibel levels such as people's talking sounds beside of its wearer. And there was a miss-operation of the function due to the location of the sensor. As the sensor was equipped on the inner side of the rear hemline, the sensor reacted to sounds caused by the friction of the inside fabric unexpectedly. Second, from Taser-coat, there was an error on the usability of the system, When the quantity of the conductive PLA panels exceeded 4 pieces, the electric shock function did not operate properly. Third, from Aroma therapy wear, it was discovered that the form and volume of the 3D printed output device module were not suitable to embed in the upper side of bodice. And the installation way of the input device was also inappropriate to measure the vital sign constantly as the sensor was attached on the inside of the wrist part of the sleeve. Fourth, from Self-EMS vest, it was found that the location of the on/off switch and the structure of the output device module should be refined. As the switch was embedded in the inside of the out pocket containing Oxygen mask, the switch was not easily

pushed to activate the function and there was more concern of the miss-operation by the embedded location. If the user does some intensive movement or action, it could cause that the mask may be moved and push the switch by the user's activities. And, also, the structure of the nozzle pressing part of the 3D printed output module should be extended to push the nozzle of Oxygen tanks effectively.

At 9th 'finalize & establish' steps, the tasks of the refinement in each prototype were conducted to solve the discovered drawbacks in the previous step (Fig. 17). The prototypes were re-tested and established as the final products of this R&D practice.

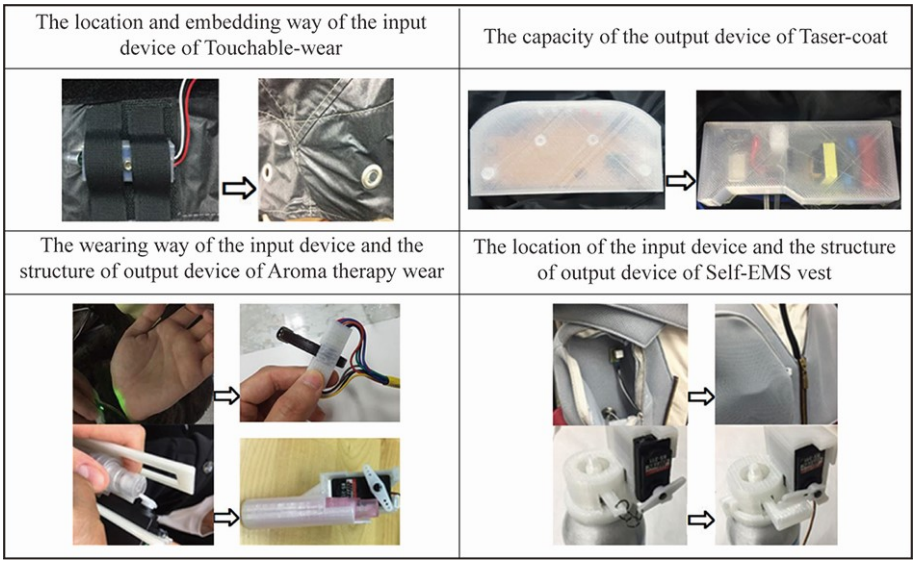

Fig. 17 The refinement of the system operability in each prototype

Design of convergence fashion prototypes in refined practice

At initial process of the R&D workshop, the participant established the fundamental direction of the convergence fashion practice which aimed to develop prototypes providing user-focused functions for specific needs. The outlines on designs and systems of the established prototypes were stated below (Fig. 18).

Fig. 18 The established convergence fashion prototypes and their operation principles

First, 'Touchable-wear' was designed to indicate the sportive image since the garment would be worn for outside activities such as walking on the street or jogging on tracks. The prototype was planned to provide strong vibration as warning signals through sound detecting for the hearing-impaired people's safe moving on streets. For example, when its user was walking on streets, a sound sensor continuously perceives user's rear side. If the certain sounds which were the same decibel of sounds of vehicles such as booming or klaxon sounds of vehicles were detected, the system occurs the vibration through vibration motors to lead its user paid attention to the source of the sound. Also, when the system was connected to a smart phone by AUX cable, its user could physically feel beats of the music through weaker vibrations generated by woofer speakers although the user could not hear the music. The main system was embedded in the left-down-side of the chest to ensure the movability, the four micro-vibration motors for feeling music was located on the middle part of the back and the two coin-typed vibration motors were embedded in each left and right wrist part for the warning function.

Second, 'Taser-coat' was designed as an oversized coat to cover its user's whole body and contain the various of input and output device; ultrasonic sensor, micro-camera, LCD display and conductive PLA panels effectively. The prototype was planned to provide safety ensuring function for career women who work until late at night. Through the super-sonic sensor, micro camera, high-brightness LED and LCD display system, its user could observe that what or who was behind of the person visually. And, if some suspicious people tried to touch the user's body, the high-amplified electronic shock from the conducted PLA panels attached on the garment was provided to escape from the location. The main system devices consisting of a processor, a LED, and a hyper-sonic sensor were located on the upside of the back and the display module was located on the downside of the left arm. six of conductive PLA panels were attached on the both sides of shoulders, arms, back and waist parts. Regarding the complex connection of the system devices, the circuit wires were then located in the side seam lines and center back line

which were considered that the range of the movement of the both two parts was relatively narrower than other parts such as waistlines.
Third, 'Aroma therapy wear' was designed as an oversized coat applied the high neck collar and hood parts to keep the aroma as longer as possible. And the light brown color was applied to induce its user feel warm for the psychological stability. The prototype was planned to provide the emotion-stabilizing function for people suffering from the depression or panic disorder. Through heart-beat sensing and air pumping technologies, the garment recognized user's vital signs and released the aroma scent having the stress relieving efficacy to decrease user's stress level when the system detected irregular signals from the heart-beat sensing data. The control, power and 3D-printed output device module were located on upper side of the left chest. The input device was made of the independent module like a watch connected to the main control system by the minimized length of circuit wires to wear it directly on users' wrists to ensure the efficiency of the heart-beat sensing.
Fourth, 'Self-EMS (emergency medical service) vest' was designed to be an outdoor wear applied huge out pockets since there was the needs to carry Oxygen tanks as many as possible to extend the duration time of the function. The prototype was planned to provide the emergency medical care function to treat the attack of asthma or respiratory diseases caused by PM(particle matter) which was one of the biggest emerging issue in Korean society. Through air compression and pumping technologies to convey the air current, users could be supplied the Oxygen to relieve their symptom. Since the output devices; Oxygen mask, Oxygen supply module composed of the 3D-printed frame a servo-motor and Oxygen tanks were concentrically located in the right side of the bodice, the control and power devices were located in the opposite side of the body to balance the weight and the stability of the systems.

Discussion on the refined practice

The observed tendency of this study's CFPD practice of the participants consisting of designers and engineers is stated below:
First, team D developed 'Touchable wear': designer A firstly ideated the sound-rear-detecting function, engineer A ideated the operation system and secondly suggested the additional function to feel sound physically through the vibration. At evaluation step, the designer and engineer detected the drawbacks on the system operation together. The designer suggested the possible solution about the equipping method of the sensor and the engineer provided the other solution about the use of the alternative output device of the sound feeling function instead of woofer speakers.
Second, team E developed 'Taser-coat': designer E ideated the function of the gender-crime prevention and engineer E designed the complex inter-connected input system consisting of a sensor and a camera, and output system composed of a LED, LCD screen and the electric shock systems. At the experiment and evaluation processes, the engineer comprehended the electric power issue on the number of the conductive PLA panels pointed out by the instructor and the engineer fixed the issue re-developing the new power compressing circuit.
Third, team F developed 'Aroma therapy wear': designer E ideated the stress-relieving function and engineer E ideated the initial system design. At experiment and evaluation processes, they detected the problems in the physical aspects of the initial system, especially output devices, and the efficiency of heart-beat measurement through the heart-beat sensor. To fix the issue, the engineer once re-searched new air-pumping device and replace the old one, but the designer suggested the design of the output device module consisting of 3D-printed frame containing servo-motor system during the group tutorial with team G and the instructor (Fig. 13, left-side).

Then, the designers' idea was adapted. On the other hand, to improve the efficiency of sensing data, the engineer suggested a solution to wear the sensor like a watch independently.
Fourth, team G developed 'Self-EMS vest': designer G ideated the emergency medical function, engineer G supported to research the operation principle of the respirator and designed the reliable manual control method. The designer had initially ideated an automatic operation system, the engineer suggested the manual control method through switches instead of sensors concerning the reliability and miss-operation of automatic-sensor-input-system since the function focused on a medical usage which had to be reliable and stable. At experiment and evaluation processes, the designers also suggested to construct 3D-printed frame containing output devices which was directly connected to Oxygen tanks instead of air-pumps drawing on the group tutorial with team G and the instructor (Fig. 13, right-side).
Through the experiment of the CFPD practices, a meaningful tendency on the possibility of the cooperation between the participants stated above was observed and discovered:
As shown in the case of team D's cooperation, if there was more expandability of the potential of the selected technology than the designer's expectation, the engineer shared the expertise to the designer to introduce more possible usage of the technology which could be generate the further synergy of the convergence. This case can be understood that the trainees' role-plays of initial ideation period was balanced to fuse designer's idea and engineer's expertise to promote their project to further stages.
On the other hand, like the case of 'Taser-coat', it was found out that overall tasks of the R&D process would be promoted by engineers, if the ideated R&D concept by designers, especially functionality, required too much high expertise on Engineering. It could cause the negative convergence practicing that designers just follow engineers' processing passively; designing and adjusting fashion platforms only depending on the developed engineering systems by engineers. But, in this study's practice, according to the instructor's intervention, the designer investigated and selected the spec of electronic components needed for the functionality, locations and means of the system installation himself in order to increase the trainee's knowledge and meaningful experience of the convergence cooperation. It was the educational action in order to minimize the side effect of the reduction of designers' roles for the balanced convergence practice in Design education.
Also, when it was figured out that the initially selected devices were inappropriate to use, the different tendency of the problem management between designers and engineers were detected. Like the cases of Aroma therapy wear and Self-EMS vest, engineers tended to re-find more suitable device newly to solve the problem. On the other hand, designers tried to design alternative operating mechanisms or additional structures using more accessible technology for them to complement the problem as well as the limitation of accessible technologies. This cases' tendency of problem solving can be comprehended as one of the positive direction of CFPD practices that designer can achieve the their ultimate goal of the development of convergence fashion products to invent alternative operation principles or structures using basic technologies through the in-depth researches on the mechanism or operation principles of electronic components themselves with the minimized engineering experts' supports.
Therefore, through this kind of convergence R&D practices using basic technologies, interacting with engineers, providing instructors' guidance to promote balanced ideation between design and engineering perspectives and forcing the in-depts process tasking, it can be expected that fashion majors' sense of difference or repulsion to apply Electronics in Fashion design can be neutralized and their knowledge and skill on Electronic engineering can be improved to achieve the goal of the convergence practices ultimately through the stepwise

experiences of the R&D practices which the level of technologies adapted in the practices would be gradually ungraded step by step according to the trainees' levels in Fashion education areas.

4. CONCLUSIONS

The current phenomena on the emergence of IT-centered convergence products adapting the form of fashion implies the possibility of the expandability. Traditionally, fashion items, especially clothing, serve for the wearer's protective and expressive needs. However, both protective and aesthetic functions are readily augmented or extended through modern technology. Clothing is physically the closest medium to human body and spends the longest time with users comparing to other mobile devices. Here is the biggest benefit of Fashion as a platform to embrace technologies and the convergence could create the potential synergy in the advance of markets and technologies. Thus, this study was planned to seek the systematical methods for the convergence between Fashion and Engineering which could exceed the fundamental gap of academic properties in the different two areas.

Focusing on the plan, this study aimed for Fashion design education, and experimental investigations on the convergence fashion design practice were conducted in order to investigate the method of CFPD that could contribute to expand the base of Fashion through convergence with Electronics in line with the tendency in modern industries. For the purpose, in the primary study stage, the structures and concepts of the Cross' HM utilized in the Engineering and TDC focused on the iterative processing to establish the design identity were combined. The practice model was tested in terms of process applicability through the primary workshop. As a result, it turned out that although prototype designs were elaborated continually, the interactions of expertise and inter-connected practicing were insufficient between the participants' thinking. As the needs to improve the methodology for more thorough convergence between Engineering and Design was emphasized, the refined practice model was designed based on IDP and TDC to support the inter-connected practicing.

When the 2nd workshop was conducted in utilization of the re-designed methodology, 2 significant tendencies distinguished from the first workshop were found out with regards to participants' thinking, tasking and properties of the created products.

First, the convergence of Fashion and technologies was sought in the primary study to achieve technical expression of designers' aesthetic perspectives. In contrast, the second workshop sought a way of convergence to provide particular functions for target users in reflection of learning outcomes from the interactive co-investigations conducted by both of two sorts of trainees. It is seemed to be the effect of the characteristic of IDP reflected in the refined practice model since initial stage of ideation in IDP focuses on specific needs of certain users and problems of existing products and the conceptual tasks of TDC was supported the trainees' thinking processes.

Second, there was difference between the primary and elaborated workshops in terms of cooperation tendencies of the trainees. In the primary study, designers and engineers elaborated the prototype design and system continually in playing their given separate roles, but exchange of knowledge and techniques among developers was insufficient. In the elaborated workshop, in contrast, designers sought to embody the idea of interactive functionality as derived by themselves. They actively learned from engineers about applicable technologies and operation principles of components rather than merely accepting the systems developed and recommended by engineers. Designers were more active in designing the operation principles of output devices for the functionalities of the systems to realize them. Since engineers had to develop a system securing functionality suggested by designers utilizing limited resources, they tried to comprehend designers' accurate intentions actively to suggest and teach designers the usability

or performance properties that they suggested. As trainees recognized the technical limitation in addressing special design issues for certain users, they tried to combine design thinking and engineering thinking to exceed the realistic limitations by making full use of operation principles of available technologies, which implies a better tendency of cooperation.

For R&D of CFPD in the field of Fashion education, if the experience of this kind of practices sharing the specialty between the majors would be accrued step by step, it is expected that the realistic difficulty of the existing academic formation could be supplemented to grow the prepared designers who have sufficient potential to deal with the convergence trends in current industries in Fashion design education areas, which the method and instructors encourage trainees sharing the specialties, balanced-interactive-role-playing and mediate trainees' whole cooperation to force them do not depend on only one-side. Regarding this point, although this study has been focused on Fashion application, it is expected that this study's approach for the convergence practices could be applied in design practices of other product or hardware design majors such as instrument design, furniture design and interior design. Through the cooperation, design students could actively and physically realize their creative ideas that need the knowledge and techniques of engineering aspects. And it could be connected to the invigoration of design educations to participate in the convergence trend of Industrial 4.0 and advance of the wearable as well as embedded technologies ultimately.

This study mainly focused on elaborating the methods of CFPD practice compare to developing products in the utilization of the limited budget by design education institutes. The workshops were conducted among only a limited number of applicants. Thus, it is the limitation of this study that the effectiveness of the methodologies could not be verified through practices among large numbers of students from various groups. So, there are further research plans that the cooperative R&D project will be organized in regular fashion design class to verify the effectiveness of this study's convergence practice methodology by regular numbers of students. And, in the regular class, the expansive cooperation R&D with diverse Engineering majors, especially Electronics and Advanced material engineering, will be conducted to pursue the result of the convergence to be more like traditional clothing by the sophisticated-technological applications of wide ranges of engineering areas. Also, it would be worth for design students to broaden their knowledge and skills on how to construct fashion items as platforms and how to apply technological components in their designs.

At last, it is hoped that the processes and findings of this study are utilized as a basis for the development of convergence fashion design processes and practice programs in cooperation with experts of Engineering areas particularly at a design school where has realistic difficulty to provide design majors with Engineering related educations, which is the major significance of this study.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea(NRF) Grant funded by the Korean Government(MSIP)(No. Grant Number - 2015R1A5A7037615)

REFERENCES

[1] Yoon, S. I., & Kang, H. S. (2013). The Type and Development of Hybrid fashion's Convergence – Focused on convergence of 21st century technology and design. *Design Forum*, Society of Korea Design Trend, 38, 299-308.

[2] Quiin, B. (2002). *Techno Fashion*. Oxford: Berg.

[3] San Martin, M. (2010). *Future Fashion: Innovative Material and Technology*. Palermo: Promopress.

[4] Myint, C. Z., Barsoum, N., & Ing, W. K. (2010). Design a Wearable Device for Blood Oxygen Concentration and Temporal Heart Beat Rate. *AIP Conference Proceedings Series*, 1239, 213-219.

[5] McCrindle, R. J., Williams, V. M., Victor, C. R., Harvey, A. P., Nyman, S. R., Barrett, J., Hogarth, H., Levene, P., Smith, R., & Panek, P. (2011). Wearable Device to Assist Independent Living. *International Journal on Disability and Human Development*, 10(4), 349-354.

[6] Wei, J. (July, 2014). How wearables intersect with the Cloud and the Internet of Things: considerations for the developers of wearables. IEEE Consumer Electronics Magazine, 3(3), 53-56.

[7] Mann, S. (1997). Smart Clothing: The wearable computer and wearcam. *Personal Technologies*, 1(1), 21-27.

[8] Cho, G. S., Lee, S. S., & Cho, J. Y. (2009). Review and Reappraisal of Smart Clothing, *Journal of Human-Computer Interaction*, 25(6), 582-617.

[9] Dunne, L. (2010). Smart Clothing in Practice: Key Design Barriers to Commercialization. *Fashion Practice*, 2(1), 41-66. DOI: 10.2752/175693810X12640026716393.

[10] Alhumaid, K. (2020). The use of mobile technology for teaching and learning. *International Journal of Education*, 5(1), 1-18.

[11] Yoon, S. I. & Kang, H. S. (2013), The Type and Development of Hybrid fashion's Convergence– Focused on convergence of 21stcentury technology and design. *Design Forum, Society of Korea Design Trend*, 38(-), 299-308.

[12] Lee, H. S., & Lee, J. J. (2018). A study on the development of the functional convergence fashion prototype applied the Low-tech-Focused on the convergence between fashion and electronic technology-. *Journal of the Korean Society of Costume*, 68(2), 98-115.

[13] Hanlon, M. (2004). Our Clothes are Getting Smarter. *New Atlas*. Retrieved from https://newatlas.com/go/1586/

[14] Suh, M. Y., Carroll, K., & Cassil, N. (2010). Critical Review on Smart Clothing Product Development. *Journal of Textile and Apparel, Technology and Management*, 6(4), 1-18.

[15] Bearne, S. (2015, August 8). Is wearable technology set to take over our wardrobes?. *The Guardian*. Retrieved from https://www.theguardian.com/small-business-network/2015/aug/03/wearable-technology-wardrobes-smart-fashion

[16] Kim, J. H. & Kim, Y. S. (2018). Application types and meanings of fashion engineering in fashion brand CuitCircuit. *Fashion & Textile Research Journal*, 20(3), 245-256.

[17] Dunne, L. E., Ashdown, S. P., & Smyth, B. (2005). Expanding Garment Functionality Through Embedded Electronic Technology. *Journal of Textiles and Apparel Technology and Management,* 4(3).

[18] Black, S. (2010). Reconciling Electronics and Fashion: Cute Circuit's Francesca Rosella and Ryan Genz in Conversation with Sandy Black. *Fashion Practice*, 2(1), 105-120. DOI: 10.2752/175693810X12640026716519.

[19] Knowles, K. (2018, March 29). Meet CuteCircuit: The British Fashion Tech Brand Loved By Fergie And Katy Perry. *Forbes*. Retrieved from https://www.forbes.com/sites/kittyknowles/2018/03/29/cutecircuits-fantastic-fashion-tech-world-firsts/#4fa1724e1ee6

[20] Hartmans, A. (2018). 9 of the most beautiful, expensive luxury smartwatches you can buy. *Business Insider*. Retrieved from https://www.businessinsider.com/smartwatches-expensive-stylish-beautiful-2018-7

[21] Lee, S. (2004). Fashioning the Future: Tomorrow's Wardrobe. New York: Thames & Hudson.

[22] Sarah E., Braddock C., & Marie O, (2007). TechnoTextile2 *: Revolutionary Fabrics for Fashion and Design: Bk. 2*. New York: Thames & Hudson.

[23] Sabine, S. (2008) Fashionable Technology: the Intersection of design, Fashiion, Science, and Technology. New York: SpringerWien.

[24] Na, M. J., & Park, S. C. (2012). A Study on the IT Technology Convergence in Contemporary Fashion Design. Journal of the Korean Society of Design Culture, 18 (3), 129-140.

[25] Suh, S. E., & Roh, J. S. (2015). A study on smart fashion product development trends. The research journal of the costume culture, 23(6), 1097-1115.

[26] Lee, H. S., Kim, Y. H., & Lee, J. J. (2016). A Study on the Fashion Accessory Design Applying Wearable Technologies -Focusing on the Aesthetic Design and Technological Application of the Image of the Light. Journal of Korean Society of Basic Design & Art, 17 (2), 383-398.

[27] Lee, H. S., & Lee, J. J. (2018). A Study on the Development of the Functional Convergence Fashion Prototype Applied the Low-Tech-Focused on the Convergence between Fashion and Electronic Technology-. Journal of the Korean Society of Costume, 68(2), 98-115.\

[28] Quinn, B. (2002). *Techno Fashion.* Oxford: Berg.

[29] Gepperth, J. (2012). Smart Things: Wearables & Clothing. *Advances in Media Technology*, *Technische Universität München Institute for Media Technology*, *München,* ISSN 2191-8015, 41-48.

[30] Cross, N. (2000). *Engineering Design Method: Stategies for Product Design (3th ed)*. Chichester: John Wiley & Sons.

[31] Dieffenbacher, F. (2013). *Fashion Thinking: Creative Approaches to the Design Process*. New York: AVA.

[32] Ertas, A. (1996). *The engineering design process (2nd ed.)*. New York: John Wiley & Sons.

[33] Kim, K. H. (2007). A Study on the Development of Design Process Model Converging 4C and 4P of Design Marketing. Doctoral Thesis, Kyunghee University, Seoul.

[34] Rau, E. P. (2000). The Adoption of Operation Research in the United State during World War II. System, Expert, and Computers: The System Approach in Management and Engineering, World War II and After, https//:DOI: 10.7551/mitpress/978026208285 3.001.0001

[35] Park, H. C. (2006). A Study on a Historical Context of the Design Methodology Movement with an Emphasis on its Relations to Cyborg Sciences. *Journal of Korean Society of Design Science*, 19 (5), 105-118.

[36] Roozenburg, N. F. M., & Cross, N. G. (1991). Models of The Design: Integrating across the Disciplines. *Design Studies*, 12 (4), 212-220.

[37] Shin, J. H. (1997). A Study on Design Process with Flexibility for Product Development. Master Thesis, Korea Advanced Institute of Science and Technology, Daejeon.

[38] Kim, E. (1995). A Study on the information system for integrated product design process: with emphasis on interface process between design and manufacturing. Master Thesis, Korea Advanced Institute of Science and Technology, Daejeon.

[39] Seo, J. H. (1995). A Story on User Participatory Process on Product Design. Master Thesis, Korea Advanced Institute of Science and Technology, Daejeon.

[40] Regan, C. L., Kincade, D. H., & Sheldon G. (1998). Applicability of the Engineering Design Process Theory in the Apparel Design Process. *Clothing and Textiles Research Journal*, 16(1), 6-46.

[41] Ramirez, S. A. (2014). Slow Fashion: Developing a Conceptual Apparel Design Process. Master Thesis, Louisiana State University, Baton Rouge.

[42] Dimant, E. (2010). *Minimalism and Fashion: Reduction in the Post Modern Era*. New York: Collins Design.

[43] Davis, M. L. (1980). Visual Design in Dress. London: Prentice-Hall International.

[44] Watkins, S. M. (1988). Using the Design Process to Teach Functional Apparel Design. *Clothing and Textile Research Journal*, 7 (1), 10-14.

[45] Lamb, J. M., & Kallal, M. J. (1992). A Conceptual Framework for Apparel Design. *Clothing and Textile Research Journal*, 10 (2), 42-47.

[46] Lee, Y. K., & Delong, M. (2016). Improving Creative Design Skills-The Effects of Past Experiences on Apparel Design Education-, *Journal of the Korean Society of Clothing and Textiles*, 40 (2), 397-408.

[47] McKelvey, K., & Munslow, J. (2003). *Fashion Design: Process, Innovation &Practice*. Oxford, UK: Wiley-Blackwell.

[48] Saffer, D. (2012). *Designing for interaction: creating innovative applications and devices (2nd ed)*. Berkeley: New riders.

[49] Fallman, D. (2003). Design-oreiented human-computer interaction. Designing Design, 5(1), 225-232.

[50] Huang, K. Y. (2009). Challenges in human-computer interaction design for mobile devices. *Proceedings of the World Congress on Engineering and Computer Science 2009 Vol. 1, Oct. 2009. San Francisco, USA: WCECS 2009,* 1-6.

[51] Preece, J., Rogers, Y., and Sharp. (2015). *Interaction Design: beyond Human-Computer Interaction (4h ed)*. Chichester; John Wiley & Sons.

Authors

Hyunseung Lee.

Research Professor, Modular Fashion Platform Research Centre, Kookmin university, Seoul, Republic of Korea (South).

Ph.D. Dept. of Fashion Design, Graduation School of Techno Design, Kookmin university, Seoul, Republic of Korea (South).

MA. Applied Imagination in the Creative Industries, Central Saint Martins College of Art and Design, UAL, London, UK.

BA. Dept. of Fashion Design, Graduation School of Techno Design, Kookmin university, Seoul, Republic of Korea (South).