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An AI-based Clothing Design Process Applied to an Industry-university Fashion Design Class

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Abstract

This research aims to develop based clothing design process tailored to the industry-university collaborative setting and apply it in a fashion design class. into three distinct phases: designing and organizing our fashion design class, conducting our class at a university, and gathering student feedback. First, we conducted a literature review on employing new technologies in traditional clothing design processes. We consulted with industry professionals from the Samsung C&T Fashion Group to develop an AI-based clothing design process. We then developed in-class learning activities that leveraged fashion brand product databases, a supervised learning AI model, and operating an AI-based Creativity Support Tool (CST). Next, we setup an industry-university fashion design class at a university in South Korea. Finally, we obtained feedback from undergraduate students who participated in the class. The survey results showed a satisfaction level of 4.7 out of 5. The evaluations confirmed that the instructional methods, communication, faculty, and student interactions within the class were both adequate and appropriate. These research findings highlighted that our AI-based clothing design process applied within the fashion design class led to valuable data-driven convergent thinking and technical experience beyond that of traditional clothing design processes.

***Key words*:** AI technology, Clothing design process, Creativity support tool, Education, Industry-university

I. Introduction

Recent efforts have been made to launch AI technology education in various fields (Holmes et al., 2019). Since 2015, South Korea has applied software learning to elementary, middle, and high school curricula; AI technologies, including machine learning and artificial neural networking, are being applied to classes (Kim et al., 2020; E. Lee, 2020). Since 2018, the United States, Britain, Singapore, and Finland have published AI textbooks for educational programs such as Scratch, App Inventor, Python, and Snap in use in elementary through high school classes (Kim et al., 2019). In the fashion sector, where technological innovation takes place rapidly, a university-level education curriculum must incorporate fourth industrial revolution innovation technology (Merryman & Lu, 2021). AI projects are also in progress in the field of fashion design, where designer sensibility is considered important. There are two primary pathways for fashion majors to participate in AI projects. The first is the participation of fashion students in the development of AI technology and building a data set for supervised learning (An & Park, 2021; Zhao et al., 2021); the second is teaching AI-utilization skills as fashion-education content (An & Park, 2021; Arthur, 2018; W. Lee, 2020). However, although these pathways have helped students encounter the working

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principles of AI technology, when students participation is limited to data collection and classification of fashion image datasets, it is difficult for students to use AI technology within the overall clothing design process. In fashion design class, students develop ideas and designs according to the clothing design process that include problem identification, conceptualization, prototyping, and solution presentation (Parsons & Campbell, 2004). Therefore, in order to effectively integrate new technology into fashion design classes, it is necessary to conduct a theoretical review of the traditional clothing design process and develop a systematic fashion design hands-on activities integrates AI technology. By experiencing and understanding AI technology in the classroom, students can enhance their capacity as future designers to effectively integrate diverse information and create innovative designs. In addition, AI tools utilized in previous fashion education efforts were primarily developed for other purposes, such as automatic image generation or product recommendation. Consequently, these AI tools have often produced random images or provided excessive information that does not align with the intended design concept. Therefore, AI tools that can enhance students' ability to solve design problems creatively must be developed within the curriculum.

Applying AI technology in fashion education presents a challenge for educational institutions to research and implement independently. It requires the utilization of advanced tools, such as fashion databases, supervised learning technology, and creativity support tool (CST) for in-class activities. CST refers to tools that use computer techniques to enhance creative thinking (Nakakoji, 2006). Recently, there has been a rise in research focused on CSTs, with the integration of AI to aid individuals in fashion design. These tools play a significant role by helping designers generate new ideas and perform design tasks more efficiently when they encounter design fixation in the design process (Jeon et al., 2021). Therefore, the study recognizes the need for an industry-university fashion design class and aims to develop an AI-based clothing design process specifically tailored to this collaborative setting. Two objectives have been proposed: (a) to conduct a theoretical review of new technologies and the traditional clothing design process, with the goal of developing an AI-based clothing design process, and (b) to implement that process in an industry-university fashion design class and analyze students' evaluations of the class. Through close cooperation with Samsung C&T, South Korea's leading IT company, the study designs and operates an AI-based CST in classroom learning activities. We analyze students' evaluation of this industry-university class to derive academic and practical implications that can induce innovative changes in fashion design education.

In developing ways to work with AI technology in clothing design, the study focused on developing clothing for specific target markets rather than creating art-to-wear. As university faculty members, the study's authors were not able to document the industry-developed algorithm of AI technology directly. It was possible, however, to apply the technology and track the technical issues in each phase of the clothing design process. There was an intentional effort to document the process of implementing the new technology as well as the resulting products.

II. Literature Review

1. AI-based Clothing Design Environment

With the demands of the Fourth Industrial Revolution (Industry 4.0), designers are seeking new opportunities and tools that allow for AI collaboration to demonstrate creativity and lead design innovation (Jeong & Kim, 2018). In the realm of clothing design, AI incorporates a diverse set of technologies such as supervised learning, neural networks, and deep learning. These technologies are primarily built upon a process of learning, wherein AI models acquire knowledge by analyzing labeled examples present in the training data, resembling the human learning process (Dudley & Kristensson, 2018). Notably, supervised learning datasets are recognized as valuable resources for developing AI algorithms in the fashion industry

(An et al., 2023; Liu et al., 2016). In this approach, AI models learn to recognize or represent concepts through repeated exposure to relevant fashion images, alongside their corresponding outputs, under the guidance of fashion experts. By leveraging supervised learning datasets, AI algorithms can classify complex fashion design elements to identify characteristics. Stitch Fix collects a variety of customer preferences, such as favorite colors, styles, and other details, to provide personalized fashion service using supervised learning algorithms (Colson, 2013). Google's Project Muze provides an AI-powered service that allowed individual customers to design and produce their clothing based on their preferences and tastes (Rietze, 2016). Recently, the Hong Kong AiDLab has developed AiDA, an AI-based fashion design software, to speed up the clothing development process. AiDA automatically generates designs for fashion items and generates unlimited design prototypes (Campbell, 2022). The fashion design tool, Designovel, leverages deep learning technology to automatically generate new artworks by applying specific styles, colors, and textures to fashion products (Chung & Choi, 2022). Moreover, in the academic field, AI clothing design systems that enhance the efficiency of the design process through the automation of fashion design sketches are being investigated. Yan et al. (2022) developed an AI-based framework for fashion design, which includes a sketch-generation model that learns the mapping between textures and sketches, enabling the completion of fashion design rendering tasks.

As the paradigm shifts, efforts are being made to incorporate AI technology in the field of fashion education. To actively engage fashion major students in such educational programs, the use of tools incorporating a user interface (UI) that enables input data into computers and the representation of results. UI plays an important role in enabling fashion students to intuitively utilize AI models without having to understand complex technicalities. For instance, in a fashion project focused on developing a supervised learning image dataset, labeling tools were provided to fashion students, allowing them to input design elements for unprocessed fashion photos, thereby enhancing work efficiency (An et al., 2023; Zhao et al., 2021). In addition, a class that utilized image-searching AI models to plan fashion styling services provided a UI to input item types and monitor the recommended products and quantities generated by AI (An & Park, 2021). In another class that utilized image-generation AI models for fashion image generation, the Deep Dream Generator (deepdreamgenerator.com) UI was employed to transform students' fashion design sketches automatically. Students uploaded images and utilized the menu options of Deep, Thin, and Deep Dream styles, along with buttons to adjust the intensity of each style in order to transform the images (W. Lee, 2020). Although these efforts helped students to understand the operating principles of AI technology, such tools were initially developed with a specific focus on tasks such as product recommendation and image generation. Consequently, the direct application of these tools to in-class activities of the clothing design process poses challenges, and a systematic design for integrating AI technology into the fashion design class is necessary.

2. The Clothing Design Process and Technology

The design methodology and process have been explored in many studies within the field of clothing design (LaBat & Sokoloski, 1999; Lamb & Kallal, 1992; Regan et al., 1998). These studies focused on the design process that derived from problems or questions and organized the clothing design process into three standard stages: (a) problem definition and research, (b) creative exploration, and (c) implementation. The problem-definition and research stage included the development of a preliminary problem statement, setting objectives for the project, planning for the research and market needs, and establishing design criteria. The creative-exploration stage of the design process prompted idea generation, conceptual design development and refinement, prototype development, and prototype evaluation. The implementation stage required the execution of the design solution into a final product.

The increased use of technology has opened a constantly expanding range of design and production possibilities and created a complex and multifaceted set of decision points in the design. Bye and DeLong (1994) stated that much of the art of pattern grading has been lost because pattern grading is now quick and inexpensive using CAD (Computer-aided design) methods. Digital textile printing and 3D printing technology can make more changes within the existing design and production process; this technology has led designers to work within multi-disciplinary fields in a cooperative mode to ensure effective communication with technicians across and within the supply chain (Bye, 2010; Tyler, 2011; Shahrubudin et al., 2019). Parsons and Campbell (2004) discussed how the design process changes when designers confront new technologies; the process evolves as designers become more skilled in applying new technology to the design process. These existent studies have underscored that the new role of the designer is to push the limits of new technologies to search for ways to expand creative possibilities.

In clothing design, designers utilize various supporting practices (e.g., collecting, sketching, experimenting) and triggers (e.g., sources of inspiration, images, primary generators) for framing design directions (Laamanen & Seitamaa-Hakkarainen, 2014). Designers are frequently confronted with broad ideas and opportunities for a design that require decisions. Past or existing solutions are often available; designers may be aware of those solutions or seek them out (Jansson & Smith, 1991). Designers are also often aware of prior interpretations of the problem and methods of developing solutions (Crilly, 2015; Crilly & Cardoso, 2017). These different forms of prior knowledge may have positive consequences (in terms of making the design process faster) or negative consequences (in terms of stifling or limiting creativity). In recent years, there has been researched and conducted in the field of clothing design to develop tools based on AI that assist in generating and refining design ideas and concepts. Jeon et al. (2021) conducted a study where an AI-based CST was implemented in the fashion design ideation process to facilitate divergent and convergent thinking. Previous research on the clothing design process and application of technology have indicated that designers define problems and explore and generate ideas prior to implementation. AI-based CST can play a significant role when designers encounter design fixation during ideation, exploration, and evaluation. CSTs can provide diverse perspectives during ideation, support experimentation in the exploration phase, and offer feedback during evaluation to overcome design fixation's limitations associated with repeating key attributes from sources. Including CST in every design process are unnecessary; applying it to a single process is also of decisive importance (Frich et al., 2019). One of the ways in which an AI-based CST supports fashion is by eliciting design elements or requirements, using new approaches that leverage big data and computational capabilities to facilitate the design work. This study adopted these insights and guidelines in consultations with industry professionals, which allowed for the design of a in-class activities that applied an AI-based CST in the clothing design process.

3. Industry-university Collaboration in Fashion Education

Technology convergence is essential in current-day fashion education. Professors must provide a wide range of information and technology for students and expand students' experiences by offering real-world fashion projects. Industry-university collaboration is a form of partnership between academic institutions and private enterprises or industries. It involves joint efforts in research and development, innovation, and commercialization of products and services (Perkmann et al., 2013). Through this collaboration, universities gain access to resources, industry expertise, and real-world problems, while industries benefit from the academic knowledge, technical skills, and innovation of universities. The industry side gleans insight into how educators work, and people from the academic side learn more about existing needs from industry figures (LaBat & Sokolowski, 1999). The partnership provides a foundation with which students can apply fashion knowledge and new technology, helping them discover and solve the fashion industry's current problems (Christel, 2016).

To create a successful collaboration between industry and university, involving an external advisor is a common method, and it is important to prioritize a stable class structure that focuses on establishing common expectations and goals, developing a project plan, and systematically monitoring the development (Barnes et al., 2002; Butcher & Jeffrey, 2007). The Fashion Institute of Technology (FIT) teamed up with IBM and Tommy Hilfiger to explore how AI can enhance the design. FIT students were given access to IBM Research's AI capabilities, including computer vision and deep learning techniques specifically adapted for fashion data. The tools were applied to 15,000 Tommy Hilfiger product images, some 600,000 publicly available runway images, and nearly 100,000 patterns from fabric sites. IBM researchers helped translate the data into information about key silhouettes, colors, and novel prints and patterns that the FIT students used as inspiration to create designs (Arthur, 2018). An and Park (2021) operated a class that planned AI fashion curation services through an industry-university project-based learning. AI technology recommends styling as a combination of fashion items. The student's goal was to plan a new styling concept that reflected the latest fashion trends and develop datasets for supervised learning. Students compared and analyzed the before-and-after differences to determine if the fashion AI recommendation model embodied their planned style. That study presented the elements of success that should be considered when AI technology is applied in an industry-university class. These elements included consideration of:

(a) industries that support the technology needed for classes and that can conduct industry-academic classes organically;
(b) quick feedback from field workers;
(c) well-performing hardware, fashion databases;
(d) self-directed learning and team-time considerations for students; and
(e) continuous curriculum-quality-improvement activities.

These factors provide a useful framework for industry-university collaborations seeking to integrate AI technology into fashion design education, particularly for students in their final semester of a four-year program.

III. Methods

This study had three phases: class organization, application, and evaluation (Fig. 1). The authors developed an AI-based clothing design process for the industry-university class during the first phase through consultation. Consultations were conducted among two university professionals and two industry professionals from the Samsung C&T Fashion Group in South Korea. The consultations aimed to devise an industry-university collaborative class operation method that addresses the gap between the current fashion design curriculum and technology. The technical support from the company for the new clothing design process was discussed, including the utilization of fashion brand product databases, the CNN (convolutional neural network) model for supervised learning, and the operation of AI-based CST. The CNN is a deep learning model designed to process and recognize visual data, particularly fashion images, by automatically learning and extracting design features (Seo & Shin, 2019). Additionally, students engaged in the interactive process with the AI model were discussed: such as developing supervised learning datasets to train the CNN model and the trained CNN model providing relevant product data for students to apply to their design prototypes. Moreover, the roles of university and industry professionals within the industry-university clothing design process were classified and determined.

In the second phase, the study applied the AI-based design process to teach a 15-week industry-university class, Fashion Convergence Project (capstone design),

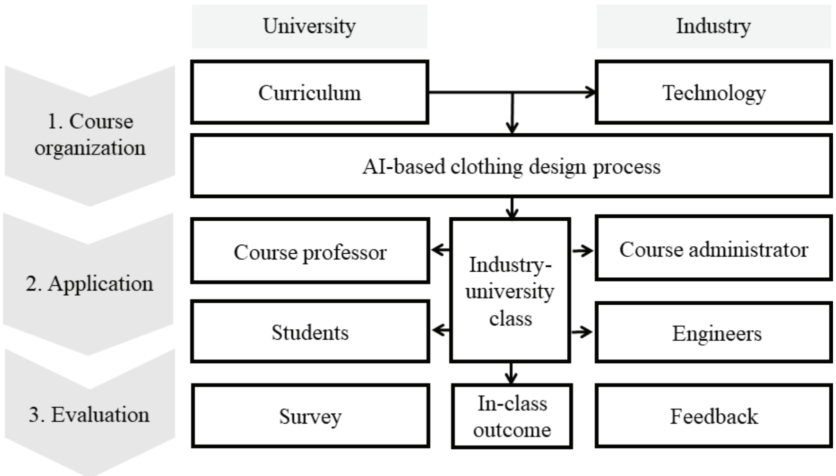


Fig. 1. Study phase.

from September 2021 to December 2021. One of the study's authors, a professor, led the class. One of the industry professionals, who participated in the consultations in the first phase of the study, acted as a class administrator. The two engineers from Samsung C&T Fashion Group provided technical support, such as granting the student access to the company server and utilizing the company's AI capabilities, including supervised learning techniques designed for fashion product searching. The class professor and the industry class administrator jointly led the class, applying practical methods and tools and offering student learning feedback. Each learner's practical output was evaluated comprehensively by considering the applicability (40%), creativity (40%), and presentation (20%) of the output; a total of 60% or more across the evaluation segments was set as a criterion for determining if learning outcomes were achieved.

During the study's third phase, at the end of the semester, a total of 12 students of the 14 students enrolled in the class completed evaluations. Most researchers believe that student ratings are a valid, reliable, and worthwhile means of evaluating teaching (Centra, 1977; Koon & Murray, 1995; Marsh, 1984). Students completed the current study's blind online survey that contained 21 statements with responses across a 5-point Likert scale. Seven sets of statements (with at least two items per set) based on the Student Instructional Report were applied (Centra, 1977, 1998/2005). The seven statement categories included in the rating were (a) class organization and planning, (b) methods of instruction, (c) effective communication, (d) faculty and student interaction, (e) assignments and examinations, (f) learning outcomes, and (g) student effort and involvement. Based on survey responses, student satisfaction was analyzed by converting the Likert scale values into a percentage. The content was analyzed subjectively for items with relatively low satisfaction, and plans for future improvement were discussed with academic and industry team members.

IV. Results

1. The AI-based Clothing Design Process

The company explained that the existing limitation of AI technology in the fashion industry is that it needs to be continuously trained for new fashion trends. Additionally, a supervised learning dataset for the lifestyle of the MZ generations (Millennials and Gen Z population) is necessary and could be established through an industry-university collaboration. This real-world fashion industry issue has emerged as an opportunity for academic research, student learning, and industry improvement.

The class was designed to focus on the specific target market: the consumers of Samsung C&T Fashion Group's fashion brands. The curriculum aimed for students to develop new design-planning skills by utilizing an AI-based clothing design process presented in <Fig. 2>. The problem-definition and research phase was approached as a team activity, taking into account the students' workload. Each team selected one fashion brand and researched the MZ generations and market trends to determine new TPO (time, place, and occasion) concepts. Students then labeled fashion items corresponding to the TPO design criteria to build a dataset for supervised learning. It was noted that to ensure a good performance of the AI model, numerous supervised learning datasets would be needed. However, because of the limited class time, it was impractical to produce multiple datasets; therefore, each team was asked to label 1,000-1,200 fashion items. Then, engineers applied the supervised learning datasets to the AI-based CST.

In the creative expansion phase, students were given access to the AI-based CST. <Fig. 3> shows the sequential operations of AI-based CST. A step-by-step explanation follows the figure. The first step is to determine the TPO, which was defined by the team in the early phase. Next, the item (e.g., coat, jacket, sweater, top, vest, dress, skirt, pants) that is expected to assess the need to be determined. After these steps, the AI model can search a database of 23,000 current products to match TPO and items. The AI product searching can utilize either a quantitative approach, which presents the number of matching products to assess item demands, or a qualitative approach, which presents images of matching products to assess design demands. The choice of which approach to use depends on the availability of data and the student's area of interest. If little data are available, but the student is interested in the item, then the qualitative approach would be advised. On the other hand, if significant data about the item is available, starting with the quantitative approach is appropriate. If a student has both interests in the design details (e.g., fit, collar, neckline, sleeve, length, etc.) assessment and significant data available about the item quantity, then the student will have to use individual judgment to decide which approach is best. Once the need for new product development has been identified, students can use this information to create original designs. If not, the process is repeated, and other items need to be examined. Finally, in the evaluation phase, the instructors and the industry representative jointly evaluated the team projects and the individual results presented by the students.

2. In-class Outcome

Fourteen students were divided into four groups to research current market and fashion trends for the MZ generations. Each group defined four new TPO concepts for the fashion brand managed by the company:

(a) Goleisure (stylish golf wear for young generations that can be worn on and off the golf course)
(b) Street Parisien (low-key and chic streetwear suitable for casual gatherings with friends near home during holidays)
(c) Work leisure (formal and casual attire, suitable for both work and leisure occasions)
(d) One-mile wear (versatile and suitable for various occasions, including homewear, outdoor walks, cafes, and dating)

Each TPO established design criteria for fashion items, including style, color, fabric, and prints. Each team created a dataset according to these criteria by tagging the product images provided by the company. This process required the teams to coordinate and communicate with each other to ensure accuracy. The students used Google Drive, an online, cloud-based storage system, to share real-time datasets. The AI-driven CST operated in a UI environment that could be accessed online; students accessed the tool via their respective accounts to explore the AI product searching results for their input TPO and item information. The item demand assessment compared the ratio of the

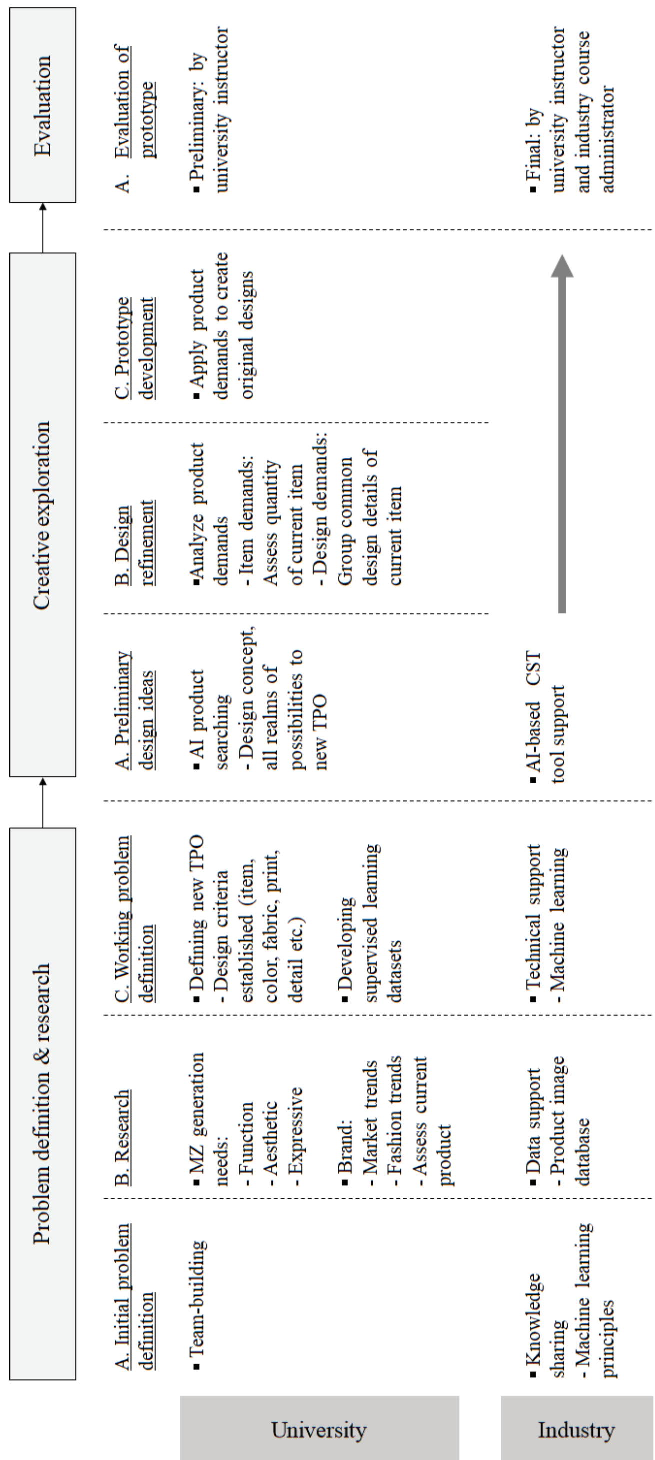


Fig. 2. Overview of the AI-based clothing design process within the industry-university class.

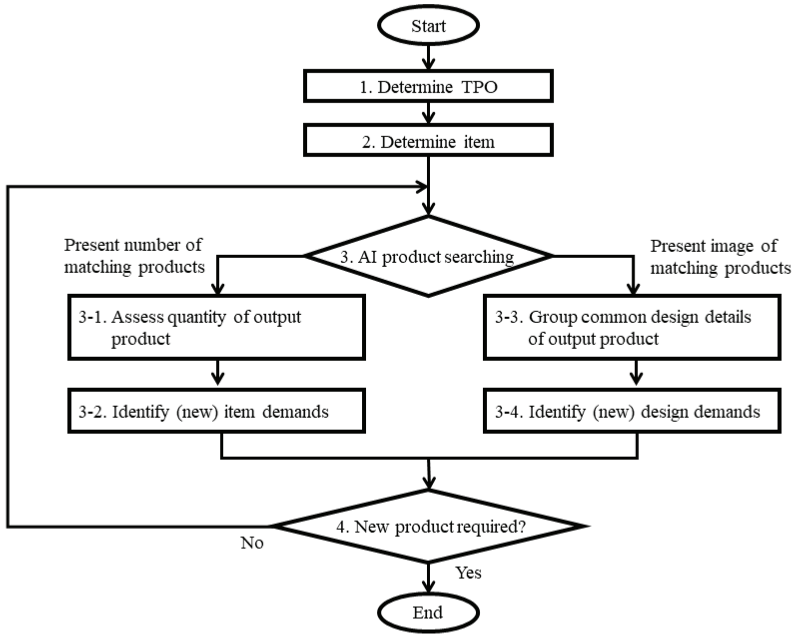


Fig. 3. The sequential operations of the AI-based CST.

total number of items obtained from the company's product database through AI product searches to the number of items applied in the supervised learning datasets used to train AI models. Data visualization was performed using bar graphs for the input and output numbers. If the ratio of output items was smaller than the ratio of the input items, the number of items for directing the new TPO was considered insufficient in the current product database. Through the design demand assessment, students analyzed the high-frequency design details of the output product image and were able to understand the current product design trends. They grouped similar design details and compiled them into a pie chart graph. In design development, students proposed new product designs for the upcoming season that would differentiate them from current products. A seasonal product lineup was formed based on item demand; illustrations and flat drawings of products reflecting the design demand were presented (Fig. 4). The class administrator, the industry representative, offered feedback on each student's mid-term and final presentation. The student presentations were conducted with other students, class professors, and class administrators as the audience. The background that led to the definition of the TPO, the derivation of the product demand according to data analysis and the final design prototype were presented.

<Table 1> and <Fig. 5> provides a detailed overview of the in-class activities and results for each team. Three of the four teams produced results that reflected the brand identity and TPO characteristics comprehensively; they received favorable reviews for creating an appropriate product for young customers of the MZ generation. However, for one team, inconsistent and too many design details were included in the supervised learning dataset than previously defined. As a result, the 15,315 products (approximately 66% of the total database of 23,000 products) were derived from AI product searching, and there were challenges in incorporating the design demand for the TPO into the designs. The students on this team received feedback from the industry participants that more specific design criteria were needed in the dataset production.

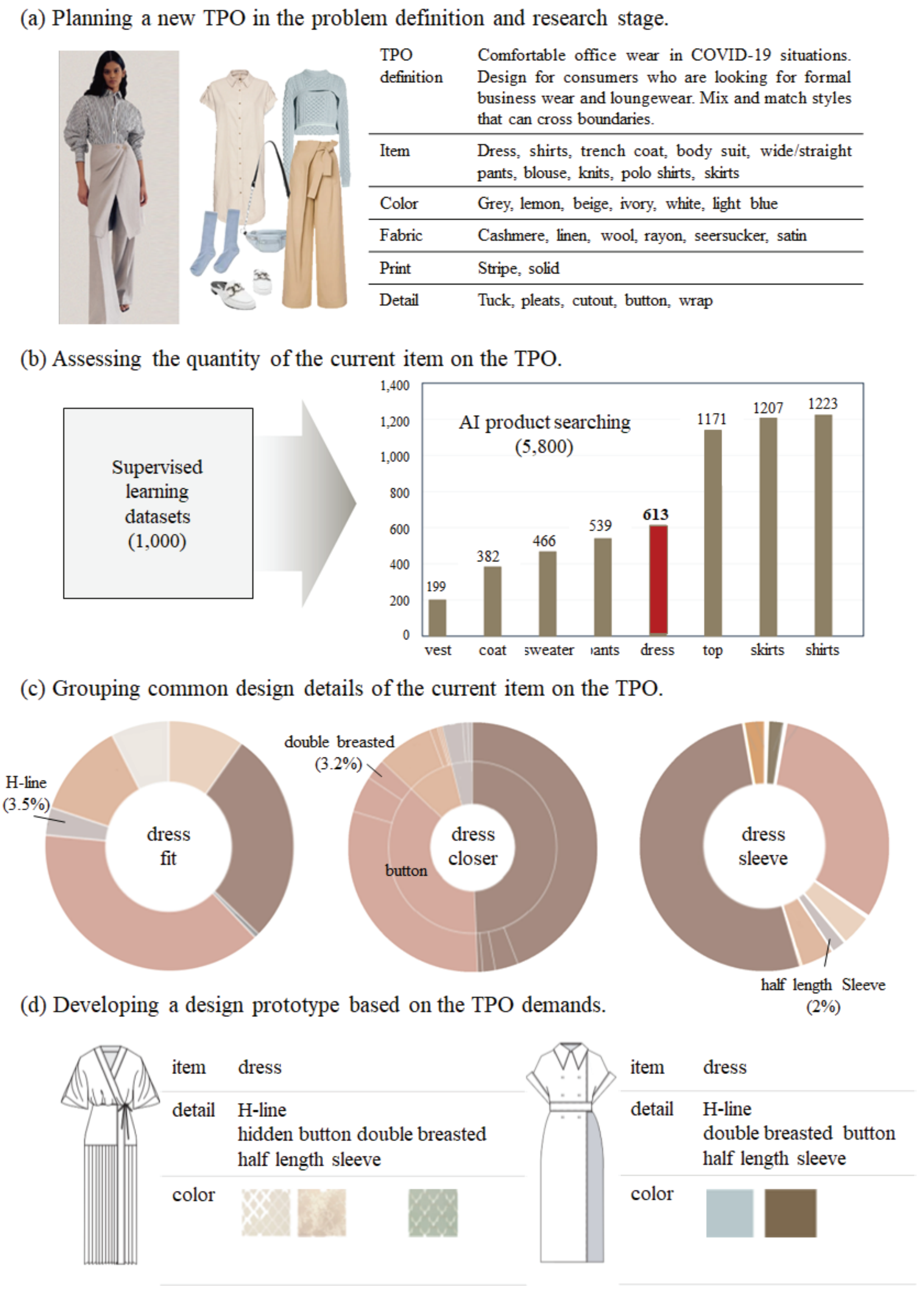


Fig. 4. Student learning activities in a class applying AI-based clothing design process.

Table 1. In-class activities and results of each team

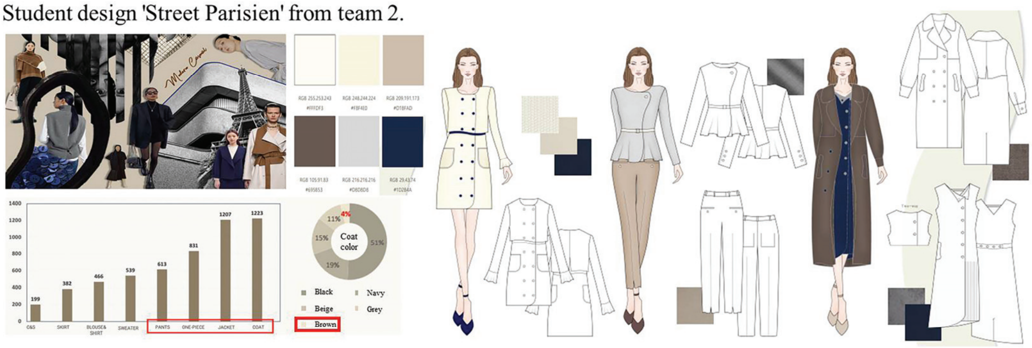
	In-class activity	Team 1	Team 2	Team 3	Team 4
week 1-2	Team building	Team of five students	Team of four students	Team of four students	Team of four students
	Choice of fashion brand	Beanpole Golf	KUHO	STUDIO NICHOLSON	AMOMENTO
	Research on current trends for the target market	Golf-wear trends for women in their 20s to 30s.	Low-key and minimal lifestyle trends for women in their late 20s to early 50s.	Hybrid of work and leisure occasion trends for women in their late 20s to 30s.	Home wear trends during the COVID-19 pandemic for women in their 20s to 30s.
week 3-4	New TPO proposal	Goleisure	Street Parisien	Work leisure	One-mile wear
	Establish design criteria for the TPO	Sporty casual style, matching outfits, vivid colors, checked prints, cotton fabrics, etc.	French chic style, classic items, solid colors, wool and cashmere fabrics, etc.	Genderless style, oversized items, black and ivory colors, wool fabrics, etc.	Normcore style, cropped length items, solid colors, wool and mohair knit fabrics, etc.
week 5-7	Dataset creation for the TPO	Labeled on 1,250 products	Labeled on 1,123 products	Labeled on 1,021 products	Labeled on 753 products
week 8-10	Utilize AI-based CST to analyze product demands: - The quantity of current items that align with the TPO - The common design details among the searched items	- Out of the 15,315 products searched by CST, t-shirts (56%) had the highest frequency. - Muted colors and various prints were recognized in t-shirts.	- Out of the 5,460 products searched by CST, coats (22%) had the highest frequency. - Black color, belted closures, and oversized fits were recognized in outer items.	- Out of the 7,998 products searched by CST, pants (34%) had the highest frequency. - Black color, wide fit, and minimal details were recognized in pants.	- Out of the 2,337 products, searched by CST, coats (3%) had the least frequency. - Normal fit, half length silhouettes were recognized in outer items.
week 11-14	Interpret item/design demand to develop design prototype	The demand for items other than t-shirts has been confirmed, but each item has shown varied design demands.	The demand for structural details and closure methods has been incorporated into the design.	The demand for wide-fit pants with functional details has been incorporated into the design.	The demand for short-length outerwear items for one-mile wear has been incorporated into the design.
week 15	Presentation and feedback	Students were unable to apply the interpreted results to create matching outfits for the TPO.	Each student completed three outfits for the TPO.	Each student completed three outfits for the TPO.	Each student completed three outfits for the TPO.

3. Students' Evaluation on Class

After the class ended, student satisfaction with the class was investigated through questions with possible responses based on a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree). <Table 2> presents an overview of the survey. The average satisfaction level for the class was 4.7 (94.8%), a score considered high overall.

Feedback on class organization and planning included “the lecture was conducted systematically” and “opportunity for laboratory sessions was offered efficiently,” indicating high satisfaction rates of 95% and 96.6%, respectively. Other feedback confirmed

(a) Student design 'Street Parisien' from team 2.



(b) Student design 'Work leisure' from team 3.

(c) Student design 'One-mile wear' from team 4.

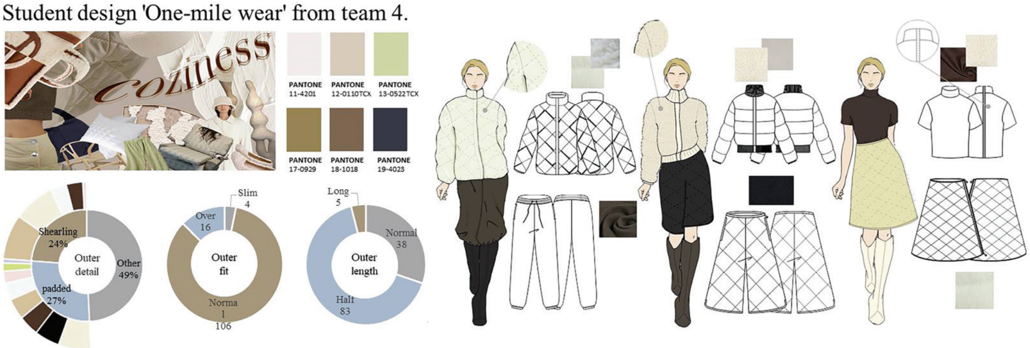


Fig. 5. Design prototypes developed by students
(Design work by Yeeun Kim, Soomin Lee, and Yoonje Cho from top to bottom, 2021).

that the learning process was smooth through weekly practice. In terms of instruction methods, “the teaching methods,” “laboratory sessions,” and “class materials” reflected high satisfaction rates (95%), indicating that the teaching methods for both the team activities and the individual activities were considered to be appropriate. It was also confirmed that the application of interactive online platforms such as the AI-based CST and Google cloud positively impacted students' understanding.

In terms of communication, queries about “the instructor(s) explained the objectives of laboratory sessions clearly,” and “interactions with students were well conducted” were all rated at 95% to 96.6% satisfaction. For student effort and involvement, students reported high levels of satisfaction, 95% to 96.6%, for the survey items listened carefully to the instructor(s), “performed given assignments diligently,” and “participated actively in class activities.” Note that the university instructor continuously checked the students' progress while the class administrator explained the usefulness of AI technology to the class. In addition, two company engineers were available immediately to help students when there were technical problems related to accessing the AI-based CST. This division of roles between personnel from the university and personnel from the company enabled quick feedback on problems, which helped students fully understand the learning content. Producing datasets for supervised learning negatively affects class satisfaction if the process is time-consuming or lengthy and there is no collaboration between team members (An & Park, 2021). Therefore, this study set the required datasets at a minimum amount and allowed an appropriate degree of self-directed learning and team activity. Blinded peer evaluations among the students encouraged individual team members to participate.

These methodology decisions were likely factors in increasing student involvement. Survey results related to the assignments revealed that 93.4% of respondents believed that the “appropriate tasks were assigned and helped with learning.” Learning outcome satisfaction

Table 2. Student survey results

Category		Mean	Ratio
Class organization/ planning	The syllabus was presented in detail (e.g., class organization, requirements, and goals).	4.58	91.6
	The lecture was conducted systemically.	4.75	95
	Laboratory sessions/experiments/practice opportunities were sufficient.	4.83	96.6
	The class was done without a defect.	4.83	96.6
Instruction methods	The teaching methods were appropriate for students to understand the content of the study.	4.75	95
	The laboratory sessions/experiments/practices contributed significantly to my understanding of lectures.	4.75	95
	The class materials helped me understand the lectures and acquire knowledge.	4.75	95
Effective communication	The instructor(s) explained clearly the objectives of laboratory sessions/experiments/practices.	4.75	95
	Interactions with students, such as an opportunity for questions and exchange of opinions, were well-conducted.	4.83	96.6
Faculty and student interaction	The instructor(s) considered the students' understanding and learning level across the class.	4.75	95
	The instructor(s) offered individual help (answering questions on/off-line, consultations, etc.) to students having difficulty in class.	4.83	96.6
	The class was conducted without gender discrimination or human rights violations.	4.83	96.6
Assignments and examinations	Appropriate tasks were assigned and helped with learning.	4.67	93.4
	The evaluation was fair, and I received feedback on the evaluation results.	4.58	91.6
Learning outcomes	The lecture helped me to develop significant knowledge.	4.75	95
	The knowledge and skills gained from this class will be of practical help.	4.75	95
	I'm satisfied with this class.	4.75	95
	I recommend this class to other students.	4.5	90
Student effort and involvement	I listened carefully to the instructor(s).	4.75	95
	I performed assignments diligently.	4.75	95
	I participated in class activities enthusiastically, contributing active questions and to discussions.	4.83	96.6

was 95% based on responses to the following survey items: “The selection helped me to develop significant knowledge,” “The knowledge and skills gained from this class will be a practical help,” and “I am satisfied with this class.”

Survey items that reflected relatively low satisfaction, 91.6% or less, included:

- “The syllabus was presented in detail,”
- “The evaluation was fair, and I received feedback on the evaluation results,” and
- “I recommend this class to other students.”

Fuller explanations were provided through short-answer responses. Feedback included these comments: “It was difficult to follow the lecture at the beginning of the class because it was my first experience with this type of class,” and “Initially, I struggled to grasp the class structure, but with ongoing feedback from the professor, I eventually understood.” This feedback confirmed that more detailed explanations of the class organization, class requirements, and the evaluation process were needed from the launch of the class. Presenting an AI-based clothing design process comprised of both team and individual contributions in a syllabus was shown to be advisable. It was also important to inform students of the differences in evaluation criteria between universities and companies and encourage them to carry out the project with applicable evaluation criteria in mind.

V. Discussion

The study originated an AI-based clothing design process within the industry-university fashion design class and analyzed student's evaluation on the class. The AI-based clothing design process consisted of (a) problem definitions and research (“initial problem definition, “research,” “working problem definition”), (b) creative exploration (“preliminary design ideas,” “design refinement,” “prototype development”) and (c) evaluation of specific learning activities that were developed in the process. Student evaluation of the AI-based design process within the class was 4.7 out of 5 (94.8%), a high evaluation. The review confirmed that the instruction methods, effective communication, faculty member interactions, and student interactions were all suitable. Another finding was that more precise standards for evaluation need to be established.

The study had several significant contributions that distinguished the AI-based clothing design process from the traditional approach and highlighted its advantages in the industry-university class. First, the AI-based clothing design process introduced in the class deviated from the conventional method by incorporating AI-based CST. Through this approach, students were exposed to creative problem-solving methods that allowed them to derive design needs by effectively reviewing a large number of products (23,000) from the company database. This data-driven approach was found to be beneficial as it empowered the students to make design decisions based on objective information, thereby helping them overcome the common challenge of design fixation, which often arises when designers heavily rely on subjective opinions and intuition in the traditional design process (Alipour et al., 2018). Second, students expanded their knowledge and experience in digital fashion design and strengthened their convergent thinking by integrating new technology. The AI-based clothing design process involved the development of supervised learning datasets in the problem definition and research phase, and using trained AI models in the creative exploration phase to derive product prototypes from a data-driven and efficient approach. Building upon this class incorporating AI technology, students understand the utilization of AI through supervised learning techniques in the fashion industry and enhance their capacity as future designers capable of collaborating with AI. Third, through the industry-university collaboration, AI technology was utilized to explore the vast product databases held by the partner company. Within the classroom setting, students assumed the role of brands' fashion designers. Using AI technology, they analyzed the product demands of the target brands and planned their designs accordingly, leading to a more effective and market-oriented clothing design process. This practical experience bridged the gap between knowledge of clothing design and the practice of technology, providing valuable insights into real-world scenarios. In summary, the AI-based clothing design process applied in the industry-university fashion design class offered a distinction from the traditional clothing design process by providing data-driven convergent thinking and practical technical experience. The integration of AI-based CST and practical practice with industry provided students with valuable skills and experiences to tackle contemporary challenges in the fashion design field.

The educational efforts developed in this study were distinct from existing programs that apply AI technology (An & Park, 2021; Arthur, 2018; W. Lee, 2020). By designing and utilizing a fashion design education tool, AI-based CST, this study established guidelines for digital clothing design production. The AI-based CST has been shown to assist students in developing their ideas further by big data analytics. Also, the AI-based CST supports the industry by setting design direction in sustainable ways. The industry is now facing a growing demand for faster production and more sustainable production. An AI-based design process would significantly reduce overproduction and overstock by creating customized design products based on quantitative product demands. This study's AI-based clothing design process was a first attempt and will serve as the cornerstone for future automated design planning using AI.

VI. Conclusions and Future Research

The study developed and applied an AI-based clothing design process within the industry-university fashion design class. First, the traditional design planning and development processes were newly defined in an AI-based clothing design environment. Specifically, the study contributed to innovation in a placing new technology into the clothing design process. Designers can utilize AI technology to map the product database with the consumer's needs for products in real-time, enabling them to determine the design direction. Second, this study was conducted in close collaboration with Korea's leading IT company. Through this successful industry-university collaboration, we were able to develop the framework for integrating AI technology into the fashion design education and implement in-class activities. Third, results from the study have the potential to guide curriculum innovation in the fields of fine art, architectural design, and product design, fields where design planning and development also take place.

There was also a practical contribution resulting from the study. First, the study presented a design planning strategy that leverages AI convergence to enhance design efficiency. The AI-based CST enables a data-driven approach to design. By analyzing a vast amount of fashion image data, designers can rely on objective information and trends rather than subjective opinions or intuition. This promotes a more accurate understanding of market demands and helps designers align their designs with consumer preferences. Second, this study enhanced the skills of future designers in planning creative designs using AI. By utilizing quantitative design demand data, designers can minimize risk and improve the product-design process, further strengthening their abilities to deliver innovative and effective designs. Third, the study demonstrated the application of AI-based fashion-information extraction, leading to practical advancements within the fashion design field. Designers gain a deeper understanding of the significance of customized design planning, enabling them to adapt to market trends and fulfill the specific needs of consumers.

This study had limitations, and future research could address them. One major limitation was that most participating students had no prior knowledge of AI or coding experience. While the study provided a basic knowledge of supervised learning principles and how to use AI-based CST in the clothing design process, some learners needed help understanding the mechanism of supervised learning, which prevented them from including AI product searching results in their final portfolio. The portfolio goal was adjusted based on the learners' understanding levels, but the lecture time could not be adjusted much due to the standard university education practice framework. However, the study found that if learners' understanding is high, lecture material can be adjusted to provide a more intensive learning experience, whereas, for those with low understanding, the class can be conducted as an experience-oriented lecture. These findings suggest that targeted efforts to increase students' understanding of AI technology in fashion can lead to practical convergence education. This study's second limitation was the production of a supervised learning dataset based on the TPO concepts that students had planned. Since the students were only allowed to use the product image from the partner company, it was challenging to provide a variety of styles, which limited the range of TPO concepts that the students could implement. Thus, to encourage more creative design planning in the future, it is crucial to offer open datasets that can incorporate the various TPOs that the students want to apply. Third, the study's author led the class as a university instructor in South Korea and collaborated with experts from a partner company in South Korea to design the class. The methods of operation were determined based on the respective environmental and technical conditions within the university and the partner company. Specifically, in order to apply the AI-based clothing design process, the industry-university class's operation method should be adjusted to reflect the situation of the partner company. Fourth, while the study examined student ratings of instruction and their relationship to student learning to evaluate the class, we emphasize the need for further research to specifically evaluate the learning outcomes associated with the AI-based design process as a limitation. In future research, we will include defining indicators to assess learning outcomes, comparing groups that utilize the AI-based design process with those that do not, and measuring performance at each stage of the instructional process to evaluate the learning outcomes. Moreover, the developed AI-based clothing design process is expected to ensure reliability and validity through analyzing more data from various environmental and technical conditions and a larger number of students. Additionally, we intend to develop more comprehensive technical guidelines for operating the AI-based apparel-design process, which will support practical applications of the study results in other educational fields.

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2. Ethics and consent

Not applicable

3. Availability of data and materials

Not applicable

4. Conflicting interests

Not applicable

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6. Authors' contributions

HA originated the research idea. HA carried out the research and drafted the first manuscript. MJ helped with interpretation and improvement of the manuscript. All authors read and approved the final manuscript.

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