CPI Learning in Clothing Thermal Computational Design

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Abstract. This paper proposes a CPI (conceptual-procedural-integrative) learning method for textiles and clothing university students to learn the computational design for clothing thermal functions and performance on knowledge, skills and application levels. First, the CPI learning method is discussed. Second, three proposed learning approaches (virtual trial learning, 3M learning, F/P-oriented design learning) on knowledge, skills and application in clothing thermal computational design are described. Third, the paper describes a course design and user study of a one-semester university apparel functional design course. The data of a pre-post study were collected. The results showed that the students achieved significant improvement in theoretical academic content on knowledge, skills and application.

Keywords: CPI learning · Pedagogy · E-learning · Clothing thermal computational design

1 Introduction

With the advancements in computational technology, apparel product design, distribution and computation in the world of textiles and clothing have been changed fundamentally. Computational technology has been transforming and overturning the old practices of the whole apparel supply chain by connecting apparel design, fabric production and garment manufacturing with the lifestyle-oriented consumption patterns of consumers. The global apparel industry is demanding graduates with hybrid skills in the arts, science and technology. To educate the new generation of textiles and clothing students to meet the new job requirements of knowledge, skills and application abilities arising from the new trends in the apparel industry and lifestyle changes in society, e-learning using computational technology has been introduced into the existing apparel functional design curriculum.

Consumers are increasingly concerned about the thermal functions and performance of clothing, which in turn encourages universities and companies to conduct research

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in this area. Clothing thermal functional design (CTFD) is a functional design process for creating conceptual or prototype apparel that achieves desirable thermal functions and performance for people living in a range of climates and weather conditions. The conventional procedure for CTFD, without computational technology, is based largely on the designers' experience and intuitions, which have the following disadvantages: experience-based design; long-time process of making interactive decisions; and incapability in predicting parametric design before the real product is completed. With the development of clothing thermal computational design CAD software [1], computational design has already started to have a place in the apparel functional design curriculum. Different from the traditional CAD technologies which aim at pattern design and physical fitting simulation, the clothing thermal computational design CAD software focuses more on 'design' in terms of the thermal functions and performance of clothing than on fashion. Based on the advanced mathematical models of textiles and clothing studies and engineering technologies, it provides a computational design tool for university students of textile and clothing. In order to keep the students up to date with the new knowledge before they go into the industry, it is necessary to keep the pedagogy up to date.

The authors of this paper have discussed a creative educational use of Virtual Reality technology by using the case of a virtual laboratory in Second Life to facilitate students to learn CTFD in previous study [2]. In the further study, the authors of this paper proposed an innovative educational technology, a virtual wear trial which is based on the combined technologies of virtual try-on and computational simulations [3]. However, in the previous studies the authors only discussed the development of the educational environment and technology without specifying the pedagogical purpose, strategy and approach by using the Virtual Reality technology.

In this paper, based on the theoretical framework of experiential learning theory [4, 5], learning with virtual laboratories [6, 7], learning with computer simulations [8, 9], and project-based learning [10, 11], we propose a CPI (conceptual-procedural-integrative) learning method for textiles and clothing university students to achieve knowledge, skills and application abilities about computational design in CTFD. The CPI learning method had the following characteristics:

(1) It employed the only virtual wear trial laboratory in the world with avatars exploring the virtual wear trials in a 3D virtual wear trial environment. The virtual wear trial was developed on the basis of the technologies of virtual try-on and computational simulations. The aim of the virtual wear trial was to prepare students' conceptual understanding of computational design in CTFD at the knowledge level.
(2) It employed the only clothing thermal computational design CAD software in the world to help students to conduct computational design simulations in CTFD. The aim of the computational design simulations was to prepare students' procedural understanding of computational design in CTFD at the skills level.
(3) It used an apparel product computational design project to help students to apply the knowledge and skills of computational design in CTFD to develop new products. The aim of the computational design project was to prepare students' integrative understanding of computational design in CTFD at the application level.

(4) It employed the integrated e-learning strategy to enrich students' learning with deep integrative (both quantitative and qualitative) understanding compared to the conventional methods that only focus on qualitative understanding.

2 CPI (Conceptual-Procedural-Integrative) Learning

In this study, the CPI (conceptual-procedural-integrative) learning method (Fig. 1) for textiles and clothing university students' learning of computational design in CTFD was proposed. It included three sections:

(1) Conceptual learning of knowledge: The purpose of this was to help students to learn the knowledge of computational design in CTFD. Based on the virtual environment technology, the virtual trial learning approach was developed for students' conceptual learning. The virtual trial learning approach employed the virtual wear trial laboratory to help conceptual learning through exploration experience and connective thinking cognitive processes.
(2) Procedural learning of skills: This was to help students to learn the skills of computational design in CTFD. Based on the computer simulation technology, the 3M (multi-level/theme/scale) learning approach was developed for students' procedural learning. The 3M learning approach employed the computational design simulations to help procedural learning through the simulation experience and critical thinking cognitive processes.
(3) Integrative learning of application: This was to help students to develop the ability to apply computational design in CTFD. Based on the computer-aided design (CAD) technology, the F/P-oriented (Functions/Performance-oriented) design learning approach was developed for students' integrative learning. The F/P-oriented design learning employed the computational design project to help integrative learning through creation experiences and creative thinking cognitive processes.

The CPI (conceptual-procedural-integrative) learning method proposed in this study has the following features:

(1) The CPI learning is a career-oriented learning method. The discipline of textiles and clothing is an applied science. In order to prepare the students well to begin their future careers, the CPI learning method was developed to help improve their ability to apply the latest knowledge and skills of computational design in CTFD to solve practical problems in designing new apparel products.
(2) The CPI learning is a domain-upgraded learning method. Clothing thermal functional design (CTFD) is a developing research area. Through the development of the CPI learning for CTFD education, the domain knowledge in textiles and clothing is expected to be upgraded at both theoretical and practical levels.
(3) The CPI learning is an innovation-driven learning method. Innovation is the most important motivation for the development of the textiles and clothing discipline. One of the key aims of the CPI learning method is to improve students' creativity ability. By providing new knowledge, skills, approaches, theory and tools, it was

expected in this study that the students would be motivated to develop innovative ideas while designing new apparel products.

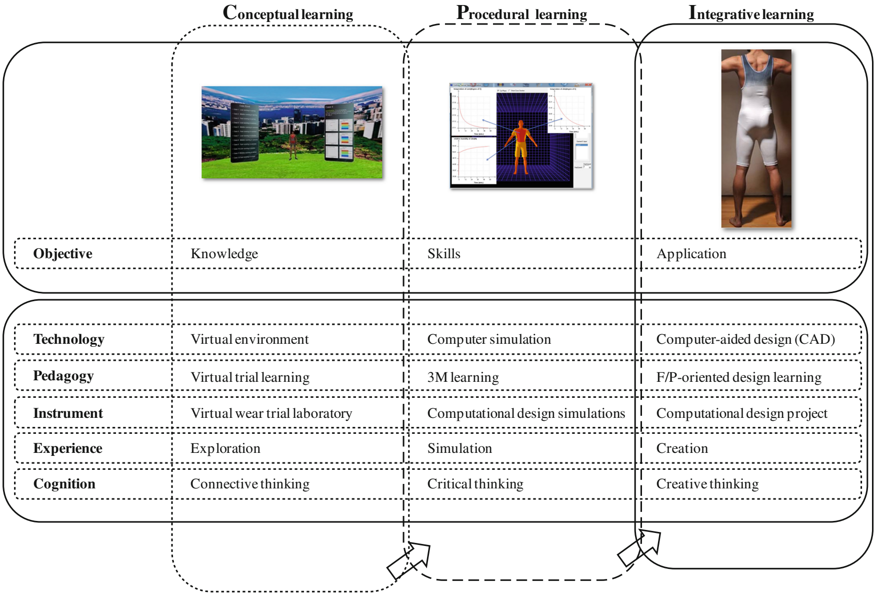

Fig. 1. CPI (conceptual-procedural-integrative) learning of computational design in CTFD

3 Virtual Trial Learning

In order to help students' conceptual understanding of the computational design in CTFD in the virtual wear trial environment, the virtual trial learning approach (Fig. 2) was developed. The aim was to help the students' conceptual understanding of the computational design in CTFD with virtual wear trials. There are three features of the virtual trial learning approach:

(1) It provides scenario-based context. The problem context is very important for the students to understand the computational design in CTFD through the virtual wear trials in the virtual wear trial lab (VWT-Lab). In the VWT-Lab, virtual scenarios have been designed to introduce the background information, including place, seasons and physical activities. Virtual places (i.e. Vancouver, Hong Kong and Basra) were developed to simulate three target markets with typical climatic conditions. Virtual seasons (i.e. spring, summer, autumn and winter) were developed to simulate the target apparel selling seasons for the target markets. Virtual physical activities (i.e. low-running, middle-running and high-running) were developed to simulate the physical activities with different intensity metabolism rates. With the well-structured scenarios, students are expected to have a conceptual understanding of computational design in CTFD through the virtual trial learning process.

(2) It employs VR-based simulation. The key feature of the virtual trial learning approach is that it employs the virtual wear trial simulations for students' learning. The biggest difference between virtual wear trial simulations and computational design simulations (CD-Sims) is that the former employ Virtual Reality (VR) technology to simulate the protocol and results of the computational design simulations, such as the scenarios, physical activities, and the final effects on the human body. The virtual trial learning provides a visual way to develop students' conceptual understanding of the key issues of computational design in CTFD.

(3) It integrates exploration-based experience. Experiential learning is concerned with knowledge constructed from the combination of grasping and transforming experiences in a context or a situation, which has some advantages for students' learning, such as providing a deeper understanding of learning contents and objectives, leading to long-term embedded memory of learning content, and achieving practical knowledge easily applied to real-world situations. In the virtual trial learning, students can explore the virtual wear trials by themselves to achieve the first-hand learning experience, which will help them to understand the key issues of the computational design in CTFD.

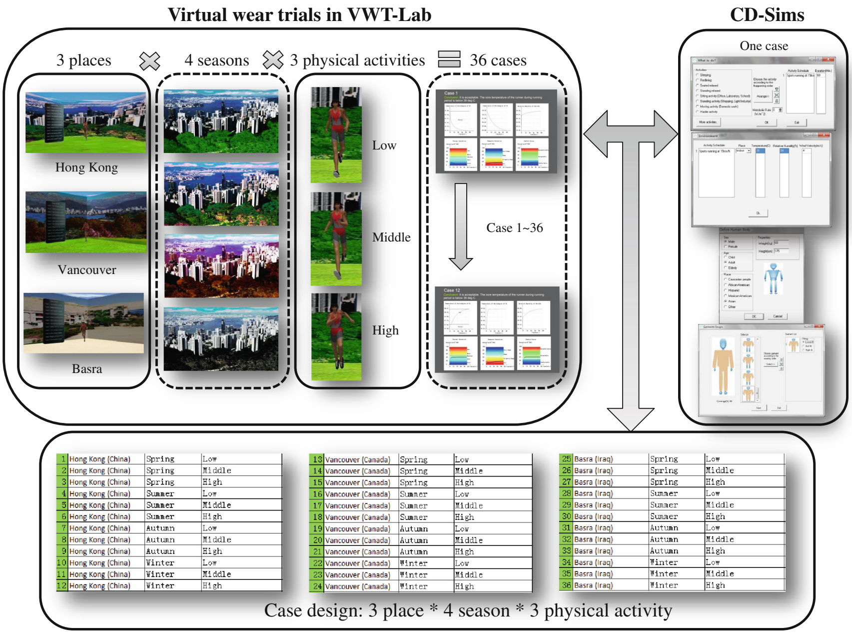

Fig. 2. Virtual trial learning approach

4 3M Learning

In order to help students' procedural understanding of computational design in CTFD through computational design simulations, the 3M (multi-level/theme/scale) learning approach (Fig. 3) was developed. The aim was to help students' procedural understanding of computational design in CTFD with:

(1) Multi-level skills: For the 3M learning approach, students are expected to practice multi-level skills of computational design in CTFD on three levels: operational, analytical and experimental. For each target level, one or more application cases are employed for students' learning, from low to high levels.
(2) Multi-theme application: The application case study is very important for students' procedural understanding of computational design in CTFD. In the 3M learning approach, the multi-theme application cases were designed with the aims of building application knowledge maps and providing specific application demonstration cases for each application theme.
(3) Multi-scale computational design: In order to help students to understand computational design in CTFD according to the physical scale of properties, all application cases can be divided into three-scale groups. Totally, there are three kinds of physical scale computational designs in CTFD, namely "Human Body & Garments – m scale", "Fabric & Yarns Scale – mm scale", and "Fibers – nm/μm scale".

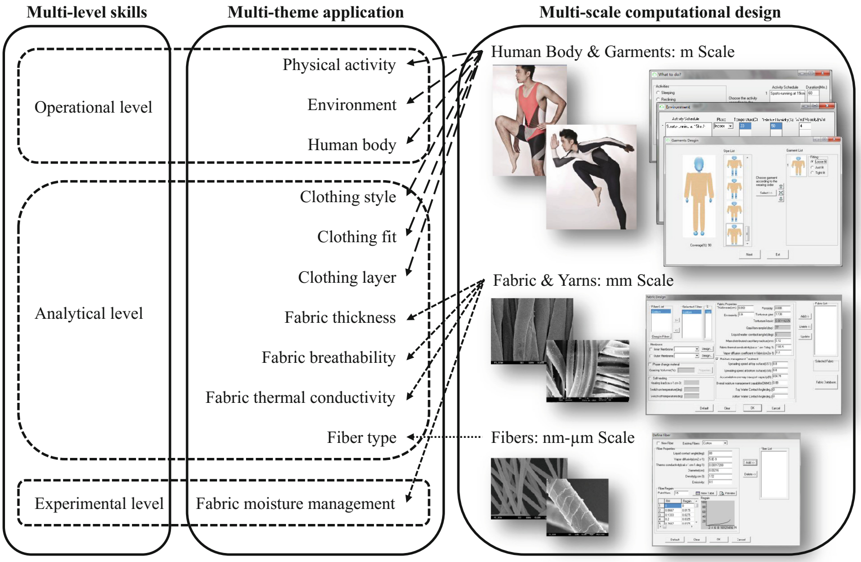

Fig. 3. 3M (multi-level/theme/scale) learning approach

5 F/P-Oriented Design Learning

In order to help students' integrative understanding of computational design in CTFD with a practical problem under the context of a real-life situation, the F/P-oriented (function/performance-oriented) design learning approach was developed. The aim was to help students' integrative understanding of the computational design in CTFD with the computational design project (CD-Project). There are three features of the F/P-oriented design learning approach:

(1) It's an engineering-based design learning approach. The computational design in the F/P-oriented design learning approach is an engineering-based design. It employs computational simulation technology to design apparel products with the aid of engineering design methods. The engineering design process involves a number of steps, and parts of the process may need to be repeated many times before the production of a final product can begin. In this study, the process of computational design for apparel development includes 5 steps: position (e.g. target function/performance), preparation (e.g. simulation protocol, case design, fabric sourcing/testing, data collection), simulation (e.g. computational simulaitons), evaluation (e.g. evaluation of simulation results), and realization (e.g. pilot product).
(2) It's a function/performance-oriented design learning approach. The computational design in the F/P-oriented design learning approach is function-performance-oriented design. This is a design process for achieving the target clothing thermal functions and performance. The key difference between the computational design in this approach and the traditional fashion design is that the former focuses on functions and performances influenced by technology and engineering, while the latter focuses on appearance and aesthetics influenced by cultural and social latitudes.
(3) It's a quantitative-guided design learning approach. The computational design in the F/P-oriented design learning approach is a quantitative-guided design. The overall structure of the quantitative design is based on scientific methodology. It employs deductive reasoning, with the designers forming a hypothesis, collecting data in an investigation of the problem, and then using the data from the investigation, after the analysis is done and the conclusions shared, to investigate the hypotheses.

6 Course Design

The course was organized over a 14-week period. A three-hour class was taught each week. The course schedule was divided into 6 sections: introductory class; virtual trial learning; 3M learning; F/P-oriented design learning; project presentation class; and, course review class. The formal teaching and learning classes included three sections: virtual trial learning (2 weeks); 3M learning (5 weeks); and F/P-oriented design learning (4 weeks). The key three learning modules are described as the following:

(1) Virtual trial learning: A virtual wear trial laboratory was developed to prepare students' conceptual understanding of computational design in CTFD. Three virtual chambers (fabric chamber, garment chamber and scenario chamber) are employed to teach the key elements of CTFD to students. There are specific learning tasks for three virtual chambers: collect and compare the fabric functional properties of 6 selected fabrics; collect and compare the design specifications of 4 kinds of high-performance sportswear; and collect and analyze data of 36 virtual wear trial

simulation cases in three simulated market environmental situations. Figure 4(a) shows some students' studying in the virtual wear trial laboratory.

(2) 3M learning: The computational design software is employed for students' procedural learning of computational design in CTFD. In a typical computational design case, there are some steps which should be processed: select the activity and its duration; specify the environment for the activity; set up basic information about the human body; design style, fit and layer, fiber and fabric properties of the garment. Multi-level/theme/scale cases are distributed across several classes for students to practice the skills of computational design: operational level - 'activity' and 'environment' cases; analytical level - 'clothing style', 'clothing fitness', 'fibers' and 'fabric thickness' cases; and experimental level – 'fabric moisture management (MMT)' case. Figure 4(b) shows some students studying with computational design software in the computer lab.

(3) F/P-oriented design learning: An apparel product design project with computational design method learned in this course was used for the students to practice the knowledge of clothing thermal functions and skills of computational design learned in the previous two modules. The students were randomly allocated into 3/4/5-persons groups to conduct the project. They were required to: submit a proposal report for topic discussion between teacher and students; submit a conceptual design report for pre-experimentation discussion between teacher and students; and, submit final prototype product and project report with a presentation. The final project included two phases: Phase I - product concept development and Phase II - product realization. In Phase I, the students were required to complete the following tasks: project group formation; market gap/market niche analysis; user requirement analysis; product concept development; and product positioning. In Phase II, the student project groups were required

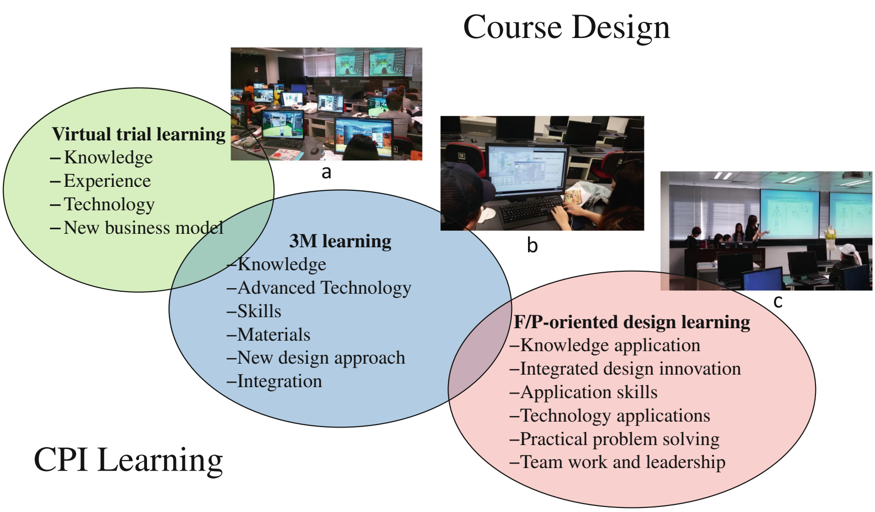

Fig. 4. Course design with CPI learning, a: virtual trial learning; b: 3M learning; c: F/P-oriented design learning

to complete the following tasks: fabric sourcing; fabric testing; thermal functional design computational simulation; product design feature and rational; product prototyping; and product demonstration. Figure 4(c) shows that they demonstrated the product prototype developed and how the computational software was used to design the product.

7 User Study

The CPI learning method was employed in one subject, 'Design for Functions and Performance' (N = 28), to teach clothing thermal computational design for textiles and clothing undergraduates from The Hong Kong Polytechnic University. A pre-test was employed in the first week, before the form learning. A post-test was employed after all learning modules at the end of the semester. Comparisons were made of the pre-test and post-test scores on knowledge, skills and application questions. Knowledge-level questions focused on the principles and knowledge of computational design in CTFD, and fabric functional knowledge. Skill-level questions focused on the skills of computational design in CTFD by using CD-Sims. Application-level questions focused on applying the principles, knowledge and skills to solve practical problems in real-life situations. In total, the students showed significant improvements between the pre-test and the exam in the mean scores for the knowledge-level questions (mean scores: 50 ± 14 vs 80 ± 7, $p < .001$), the skills-level questions (mean scores: 71 ± 17 vs 87 ± 8, $p < .001$), and the application-level questions (mean scores: 43 ± 22 vs 82 ± 14, $p < .001$) after the CPI learning.

In summary, this paper has described a CPI (conceptual-procedural-integrative) learning approach employing virtual laboratory, computational design simulations and project to help textiles and clothing university students' learning of clothing computational design technology. Future work on the CPI learning will focus on more educational implementations via additional user studies and potential development of new educational platform based on more pedagogical theories and practices.

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