Educational Virtual-Wear Trial: More Than a Virtual Try-On Experience

Mingliang Cao
The Hong Kong Polytechnic University

Yi Li
University of Manchester

Zhigeng Pan
Hangzhou Normal University

Josephine Csete, Shu Sun, Jie Li, and Yu Liu
The Hong Kong Polytechnic University

Developments in computer capabilities, networks, mobile devices, and social media have enabled researchers and educators to increasingly employ blended strategies when developing new learning technologies. In addition, there is a growing need to develop discipline-specific learning technologies as result of expanding research in various domains. The study reported here was conducted in the context of a textiles and clothing higher education course. The key aim was to develop a new learning technology for university students, specifically to help them learn about clothing thermal functional design (CTFD).

Nowadays, researchers in textiles and clothing are paying a great of attention to the comfort and performance of clothing. Computational modeling for human body-clothing-environment (HCE) systems has become a necessary tool to explain the heat and moisture transfer from clothing materials to the human body, or thermo-moisture interactions between the human body and the environment. However, a computational modeling approach may be too complex for undergraduates to understand. Especially difficult areas include developing a conceptual understanding of abstract knowledge, complex implementations when modifying parameters, and practical applications for product design.

Although the clothing industry has benefitted from the use of clothing thermal computational design CAD software,[1] it has some weaknesses for educational purposes. For example, as a professional design tool, the software focuses more on abstract functional simulations than the more traditional virtual try-on simulations[2–4] with which students are more familiar. The general idea of traditional virtual try-on simulations is to track the users' motion, in either 2D or 3D, and synthesize clothes that can be overlaid on the user's image. In a previous study, we discussed a creative educational use of VR technology that utilizes a virtual laboratory in Second Life to help students learn CTFD.[5] In that study, we offered some tips for employing Second Life for educational purposes: incorporating new domain research output and new learning technologies into Second Life, and considering some issues before employing Second Life, such as the subject and objectives, the pros and cons of existing learning technologies, and student backgrounds. However, that paper didn't define well the "virtual try-on" technology for CTFD using database, computational-simulation, and virtual world technologies. Meanwhile, the pedagogical design and content when using the virtual laboratory were not fully defined.

Here, we describe a virtual-wear trial application that is based on the combined technologies of virtual try-on and computational simulations. In other words, virtual-wear trial simulations use

 0272-1716/15/$31.00

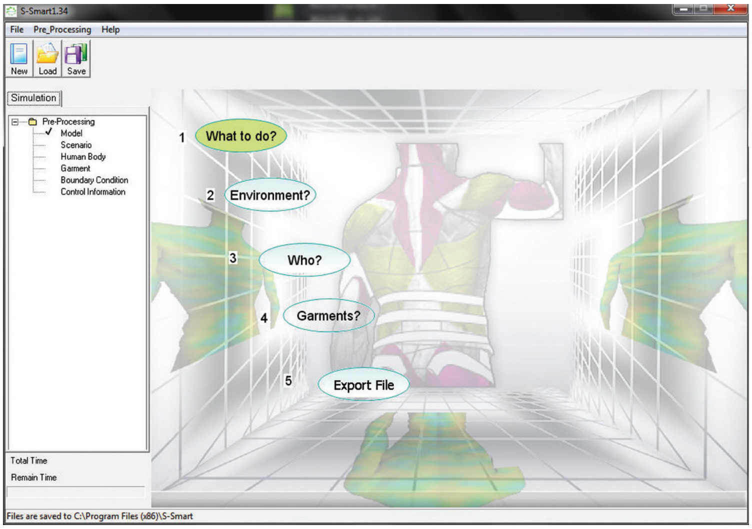


Figure 1. Clothing thermal computational design CAD software interface. In the first step, the user must provide details in four categories.

calculations to determine how a garment will feel on a body as opposed to virtual try-on simulations, which function more like a mirror and focus on the garment's appearance on a body. The virtual-wear trial proposed in this study has three key features:

- The virtual-wear trial is connected with virtual scenarios that simulate the wearing conditions and trial protocol in a practical wear trial chamber.
- The key difference between the virtual-wear trial and a traditional virtual try-on application is that the former focuses on thermal functions caused in the human body as opposed to the physical fit.
- The virtual-wear trial in this study integrates clothing thermal computational and virtual try-on simulations. Computational simulations provide the quantitative protocol and simulation result data for further development. Combined with data provided through first-stage computational simulations, virtual try-on simulations were developed further to simulate the virtual-wear trial in the virtual scenarios.

Based on this new technology, we developed a virtual laboratory in the virtual world Second Life to teach CTFD concepts to university textiles and clothing students. To the best of our knowledge, this work is unique in that it is the first study with a virtual-wear trial and it describes the only virtual-wear trial laboratory in the world to teach CTFD.

Virtual-Wear Trial Laboratory

To teach CTFD to university textile and clothing students, we created our virtual-wear trial laboratory using avatars in a 3D virtual environment. The key difference between virtual-wear trial and traditional virtual try-on is that the former employs the protocols and simulated trial results data processed by computational simulations. Therefore, the unique part of the virtual-wear trial is that it focuses more on the clothing thermal functions and performance on the human body rather than on the physical appearance demonstrated by traditional virtual try-on technologies. In other words, the virtual-wear trial focuses on how the clothing feels rather than how it looks.

Virtual-Wear Trial for CTFD

The virtual-wear trial process can be described as three steps. First, computational simulations are conducted with the clothing thermal computational design CAD software.[1] This software requires a number of preprocessing steps to calculate the results. Specifically, the user must provide details in several categories:

- "What to do," the activity and its duration;
- "Environment," the environmental conditions for the activity;
- "Human body," the basic human body property information; and
- "Garment," the clothing style, clothing fit, and the garment's fiber type and fabric material properties.

As an example, in step one a student may select "fast running" as the activity with "30 minutes" as the duration. The student would then input the temperature as part of the environmental conditions as well as data such as gender, age, and weight to define the user's body type. Finally, the student would then indicate the garment details, such as a tightly fitting garment made of 100 percent cotton. Figure 1 shows the CAD interface with these steps.

Second, the CAD software conducts computational simulations based on the input data, and the results are analyzed and output in charts. As part of this process, the salient information is selected and summarized as the key factors and results of the virtual-wear trial simulations. For example, the software may show a rapid increase in body temperature because of the poor suitability of the garment type for the climate, body type, and level of exercise. That could result in adverse outcomes for the individual wearing the outfit, such as a collapse due to hyperthermia.

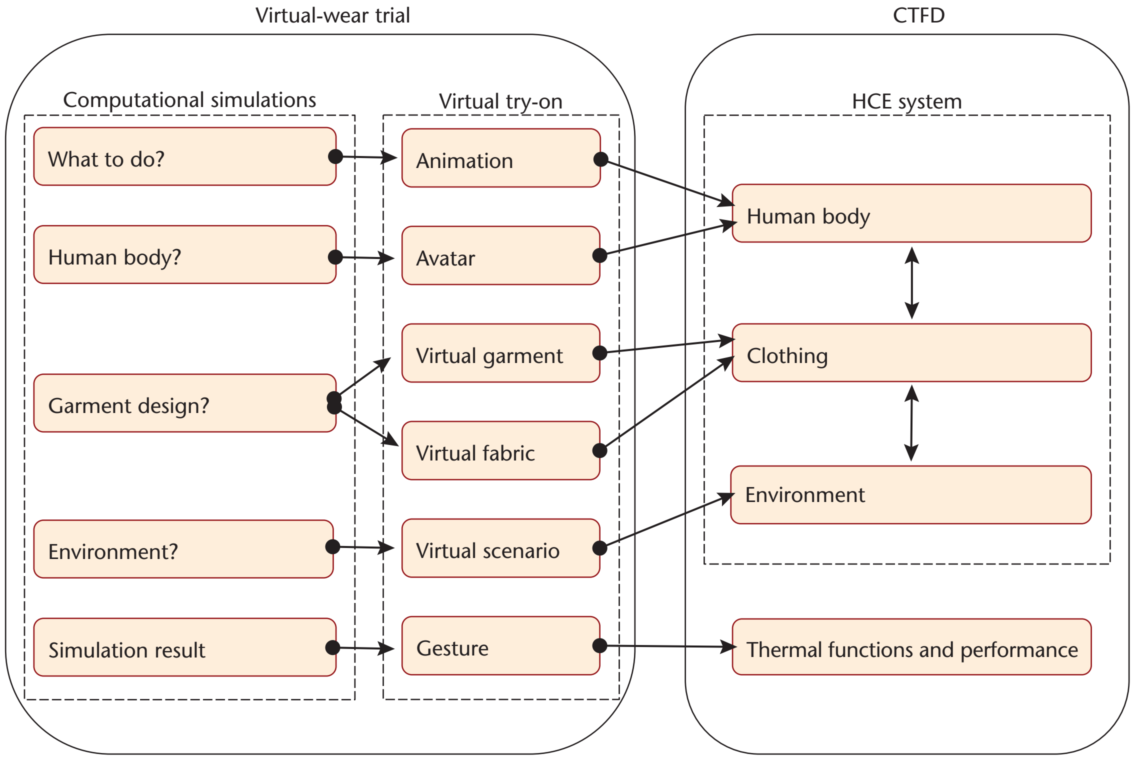


Figure 2. Virtual-wear trial for CTFD. Relationship between the computational simulations, virtual try-on, and CTFD.

Lastly, in step three, the key factors and results of the virtual-wear trial simulations are demonstrated using the virtual try-on technology. The mathematical results from step two are translated into an animation in Second Life, where the avatar selected by the student wearing the garment he or she designed performs the activity in the selected environment. In the hyperthermia example we described earlier, for example, the avatar would collapse. Figure 2 shows the relationship between the computational simulations, virtual try-on, and CTFD.

Virtual Laboratory Construction

To construct the virtual laboratory in a systematic way, we assigned all the content to one of four levels: chamber, scenario, case, and simulation. The first level for constructing the virtual laboratory is the chamber level. In total, there are three virtual chambers:

- The *virtual fabric chamber* includes six virtual fabric samples, selected for their properties to help students learn the functional properties of fabrics.
- The *virtual garment chamber* uses four virtual forms of sportswear (running, cycling, rowing, and windsurfing), which have been developed on the basis of real sportswear data to help students learn the functional design concepts for sportswear.
- The *virtual scenario chamber* incorporates three virtual scenarios simulating different climatic target markets (Vancouver, Hong Kong, and Basra), which we selected to help students learn about CTFD through virtual-wear trial simulations.

Figure 3 shows the chambers for constructing the virtual laboratory.

The second level of constructing the virtual laboratory is the scenario level, which goes into more detail once the user inputs the parameters for the basic scenario in the first level. We designed the three location-based scenarios (Vancouver, Hong Kong, and Basra) to simulate the target markets with typical climatic conditions (low, middle, and high temperatures). Environmental conditions are one of the key factors in CTFD because they can sometimes endanger the human body when people attempt high-intensity physical activities. For each scenario, an avatar can explore a number of virtual-wear trial simulations. Figure 4 illustrates the virtual scenario chamber for each of the three available climates.

The third level of constructing the virtual laboratory is the case level. We designed 36 virtual-wear trial cases using the CAD software based on these factors:

- *Place*: Vancouver, Hong Kong, or Basra.
- *Season*: spring, summer, autumn, or winter.
- *Physical activity*: low running, middle running, or fast running.

Figure 3. Chamber-oriented level. (a) Virtual fabric chamber, (b) virtual garment chamber, and (c) virtual scenario chamber.

These 36 cases are then subdivided into three groups that simulate three target, climatic-specific places. Figure 5 shows the case level for constructing the virtual wear trial cases.

The fourth and final level of constructing the virtual laboratory is the simulation level. A typical virtual-wear trial case is a combination of these elements:

- place,
- season,
- physical activity,
- computational simulation results, and
- virtual simulation effects.

The background images have been designed to simulate both place and season. Three kinds of avatar animations have been used to simulate the physical activities (low, middle, or high running). Similarly, three kinds of virtual gestures have been designed to simulate the final effects on the human body (including shiver, comfortable, and hyperthermia). Importantly, the computational simulations result images are provided at the end of each virtual-wear trial simulation to help students understand the qualitative conclusions of their quantitative results. Figure 6 displays the simulation level for constructing the virtual-wear trial simulations.

Educational Uses for Teachers and Students

The virtual-wear trial laboratory offers teachers four instructional functions (see Figure 7). Using the multilevel content in the virtual laboratory, teachers can introduce concepts such as thermal conductivity, thermal insulation, thermal protection, air permeability, and water vapor permeability; demonstrate implementation scenarios using the six fabric samples, four kinds of high-performance sportswear, and three virtual scenarios; describe situational context (such as environmental conditions and physical activity); and display the virtual-wear trial simulations.

For students, the virtual-wear trial laboratory can be used to achieve multilevel learning (see Figure 8). The aim of learning in this virtual-wear trial laboratory is to prepare students' conceptual understanding of CTFD. At the lowest level, students can gain functional knowledge about the six fabric samples. Then, using a real sportswear project, students can compare four kinds of high-performance sportswear. Higher-level learning tasks include analyzing the simulation data from 36 virtual-wear trial cases from the available climatic conditions.

User Studies

An undergraduate course at the Hong Kong Polytechnic University, "Advanced Textile Studies," used the virtual laboratory to teach 30 students CTFD concepts. The students demonstrated significant improvements in pretest to posttest mean scores for the fundamental CTFD concepts (3.0 ± 1.4 versus 8.5 ± 1.5, $p < 0.001$).

In addition, we administered an open question feedback survey to assess the students' attitudes toward the learning benefits of using the virtual laboratory. The following are excerpts from the students' comments about the virtual laboratory:

> It is interesting because we can test the garment performance online.

> The topics are quite inspiring and the Second Life game is interesting.

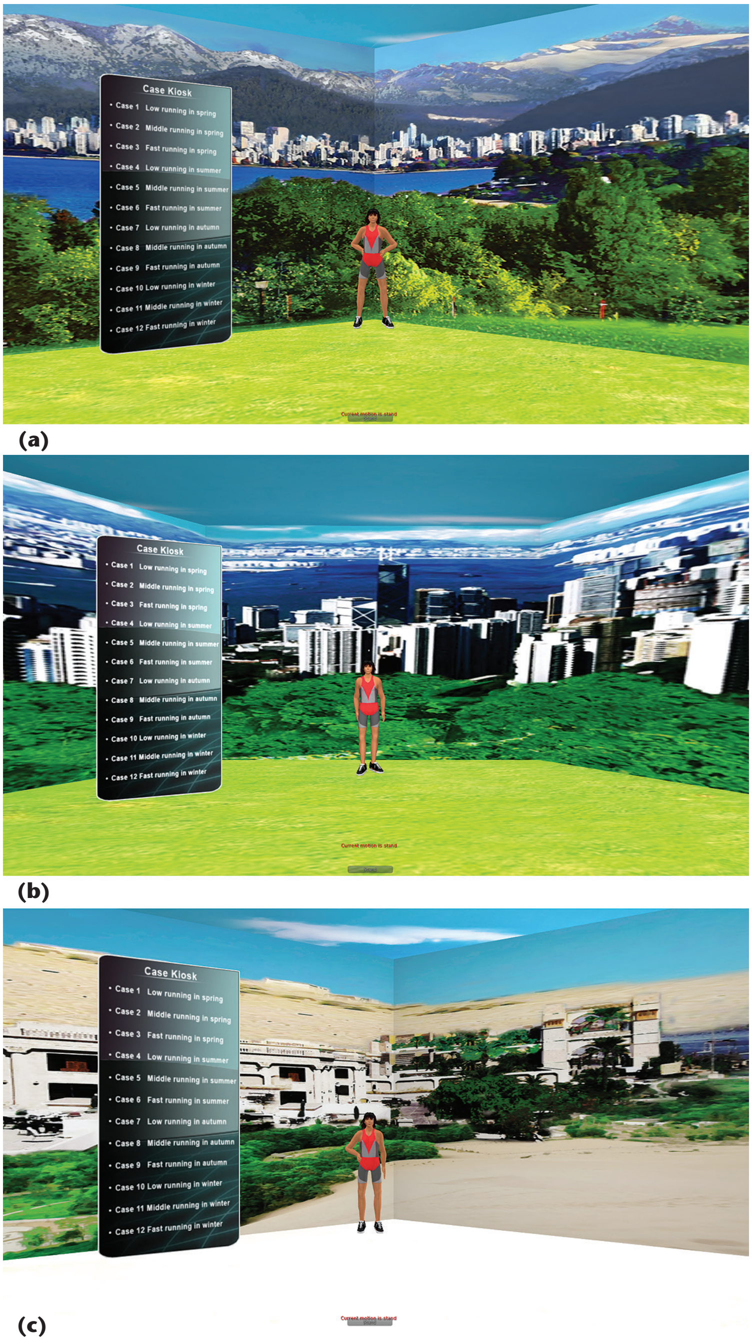
> Second Life is a world-wide map game. The freedom of Second Life is very high. Through conducting the activities in Second Life, we can learn knowledge of textiles in another way not just teaching.

> It's hard at the beginning as I didn't have the same experiences from doing textile evaluation online and through any virtual software. However, after practice for a few lessons, I got basic knowledge about handling the software so that I could get any information I wanted and reach the sites I had to. Generally, it's interesting. But I do feel it could be done better by increasing the practical time, as I am sure the user will not feel interested if they cannot handle it well.

> Second Life is interesting in showing me a virtual world with cartoons and animation, and there are lots of e-links. It is a powerful programme with complex formulae and data integration and it allows the user to simulate the end-use feeling and performance. However, it still has certain limitations that the chambers in the virtual lab require more fabric samples and even allow the users to examine different fabrics and get results on individual body parts.

Based on the students' comments, it is clear that they think the virtual laboratory is an interesting and useful learning tool.

The students also pointed out areas to improve learning with the virtual laboratory. For example, there could be a benefit to allowing more practice time, providing more fabric samples, and letting students examine different fabrics on individual body parts. Thus, future work on the virtual laboratory will focus on improving and extending its functionality. We also plan to evaluate its educational implementation via additional user studies.

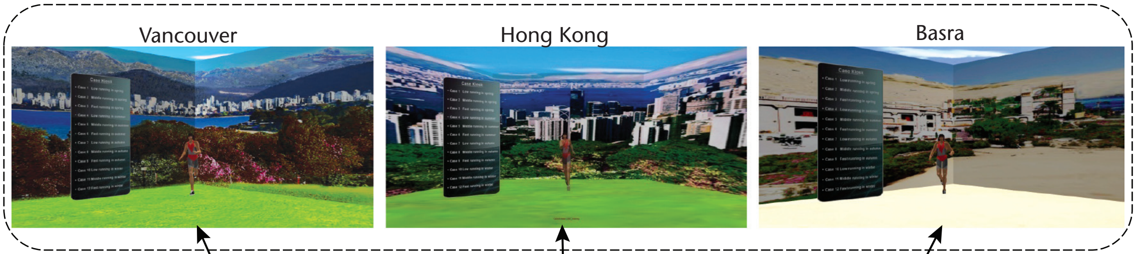


(a) (b) (c)

Figure 4. Scenario-oriented level for the three available locations: (a) Vancouver, (b) Hong Kong, and (c) Basra.

Acknowledgments

We thank the Hong Kong Innovation and Technology Commission and the Hong Kong Research Institute of Textiles and Apparel for providing funding support for this research through projects ITP/002/07TP, ITP/030/08TP, and ITP/015/11TP, as well as the Hong Kong Polytechnic University through the 8CGT Project. Also, we acknowledge the support of the Guangdong Provincial Department of Science and Technology through the Guangdong-Hong Kong International Textile Bioengineering Joint Research Center



No.	Place	Season	Physical Activity
1	Vancouver	Spring	Low running
2	Vancouver	Spring	Middle running
3	Vancouver	Spring	High running
4	Vancouver	Summer	Low running
5	Vancouver	Summer	Middle running
6	Vancouver	Summer	High running
7	Vancouver	Autumn	Low running
8	Vancouver	Autumn	Middle running
9	Vancouver	Autumn	High running
10	Vancouver	Winter	Low running
11	Vancouver	Winter	Middle running
12	Vancouver	Winter	High running

No.	Place	Season	Physical Activity
1	Hong Kong	Spring	Low running
2	Hong Kong	Spring	Middle running
3	Hong Kong	Spring	High running
4	Hong Kong	Summer	Low running
5	Hong Kong	Summer	Middle running
6	Hong Kong	Summer	High running
7	Hong Kong	Autumn	Low running
8	Hong Kong	Autumn	Middle running
9	Hong Kong	Autumn	High running
10	Hong Kong	Winter	Low running
11	Hong Kong	Winter	Middle running
12	Hong Kong	Winter	High running

No.	Place	Season	Physical Activity
1	Basra	Spring	Low running
2	Basra	Spring	Middle running
3	Basra	Spring	High running
4	Basra	Summer	Low running
5	Basra	Summer	Middle running
6	Basra	Summer	High running
7	Basra	Autumn	Low running
8	Basra	Autumn	Middle running
9	Basra	Autumn	High running
10	Basra	Winter	Low running
11	Basra	Winter	Middle running
12	Basra	Winter	High running

Case pool: 3 place * 4 season * 3 physical activity

Figure 5. Case-oriented level. A total of 36 cases were assigned to three scenario chambers.

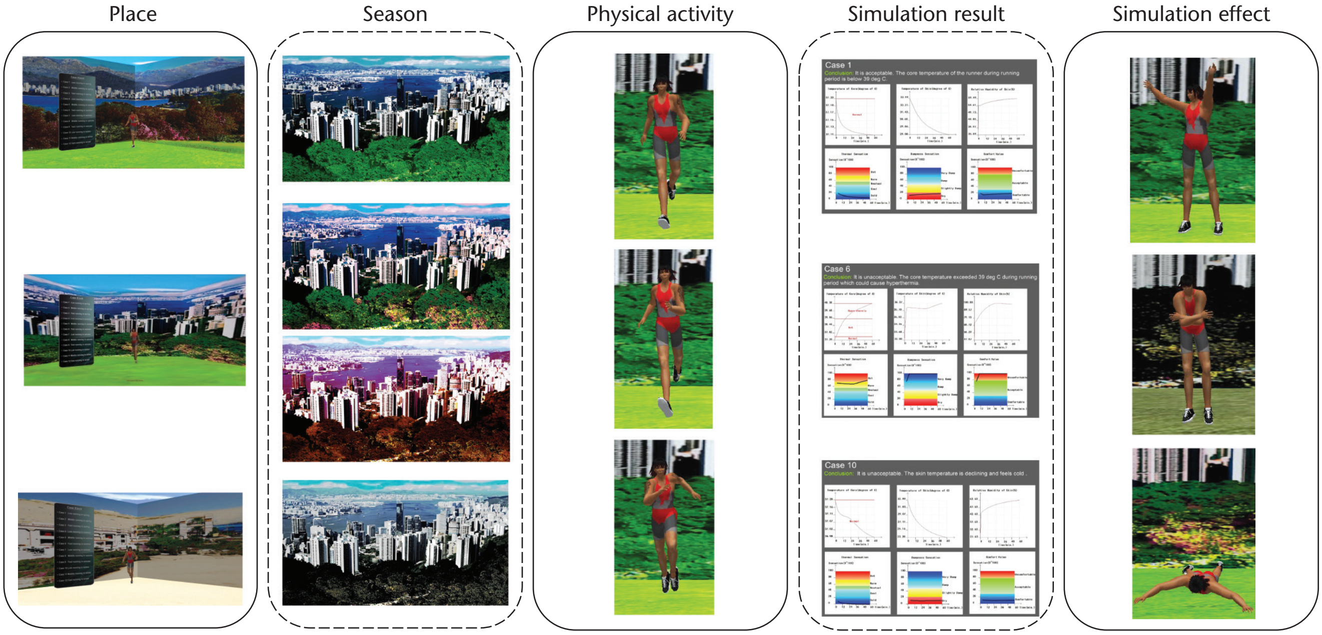


Figure. 6 Simulation-oriented level. Computational simulation result images are provided at the end of each virtual-wear trial simulation to help students understand the qualitative conclusions of their quantitative results.

with project code 2011B050300023, and the key national NSFC project under grant 61332017.

References

1. Y. Li et al., "P-Smart: A Virtual System for Clothing Thermal Functional Design," *Computer-Aided Design*, vol. 38, no. 7, 2006, pp. 726–739.
2. J. Li et al., "Technical Section: Fitting 3D Garment Models onto Individual Human Models," *Computers and Graphics*, vol. 34, no. 6, 2010, pp. 742–755.
3. Z. Zhou et al., "Image-Based Clothes Animation for Virtual Fitting," *SIGGRAPH Asia 2012 Tech. Briefs* (SA '12), 2012, article no. 33.
4. S. Hauswiesner, M. Straka, and G. Reitmayr, "Virtual Try-On through Image-Based Rendering," *IEEE Trans. Visualization and Computer Graphics*, vol. 19, no. 9, 2013, pp. 1552–1565.
5. M. Cao et al., "Creative Educational Use of Virtual Reality: Working with Second Life," *IEEE Computer Graphics and Applications*, vol. 34, no. 5, 2014, pp. 83–87.

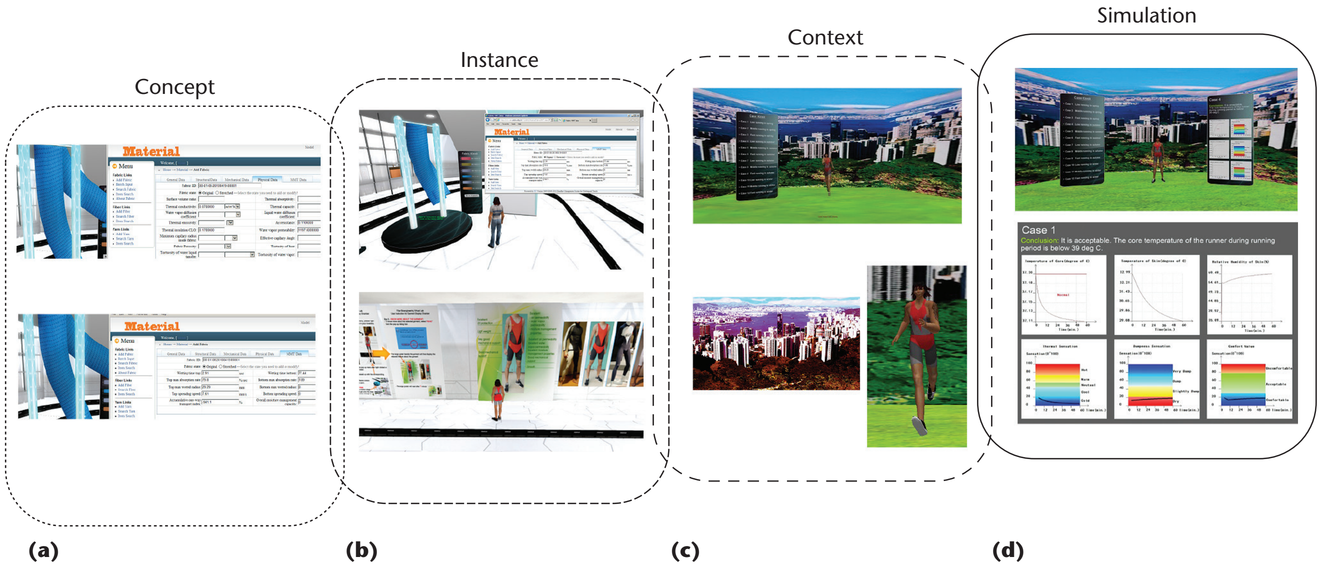


Figure 7. Multilevel content taught by teachers. (a) Concept, (b) instance, (c) context, and (d) simulation.

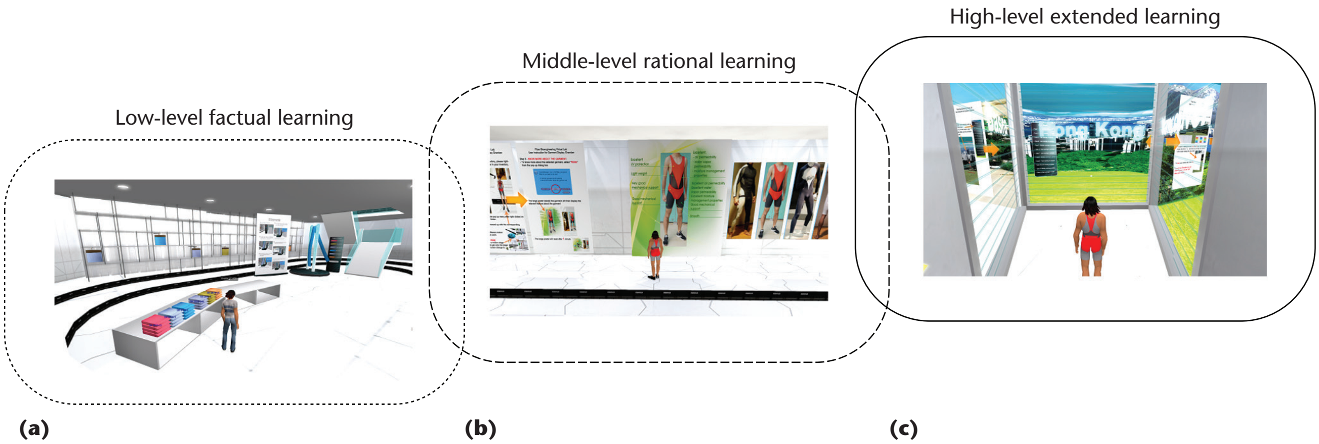


Figure 8. Multilevel learning for students. (a) Low-level factual learning, (b) middle-level rational learning, and (c) high-level extended learning.

__Mingliang Cao__ is a research assistant at the Hong Kong Polytechnic University's Institute of Textiles and Clothing. Contact him at merlin.cao@connect.polyu.hk.

__Yi Li__ (corresponding author) is a professor in the University of Manchester's School of Materials. Contact him at henry.yili@manchester.ac.uk.

__Zhigeng Pan__ is a professor at Hangzhou Normal University's Digital Media and Interaction (DMI) Research Center. Contact him at zgpan@cad.zju.edu.cn.

__Josephine Csete__ is a senior educational development officer at the Hong Kong Polytechnic University's Educational Development Center. Contact her at josephine.csete@polyu.edu.hk.

__Shu Sun__ is a research assistant at the Hong Kong Polytechnic University's Institute of Textiles and Clothing. Contact her at suesunhk@gmail.com.

__Jie Li__ is a research assistant at the Hong Kong Polytechnic University's Institute of Textiles and Clothing. Contact him at jerryleechn@hotmail.com.

__Yu Liu__ is a research assistant at the Hong Kong Polytechnic University's Institute of Textiles and Clothing. Contact him at takylor@163.com.

Contact department editor Gitta Domik at domik@uni-paderborn.de and department editor Scott Owen at sowen@gsu.edu.