



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Research article

Effects of an online training program on cardiovascular health behavior modification on nursing students' health education competency

Xinyue Dong^{a,b,c,1}, Zhen Zhang^{d,1}, Xian Zhang^{b,c}, Minmin Lu^a, Yangyang Zhao^{b,e}, Ying Lin^{b,c,*}, Yuxia Zhang^{b,*}

^a School of Nursing, Fudan University, Shanghai, China

^b Department of Nursing, Zhongshan Hospital, Fudan University, Shanghai, China

^c Department of Cardiology, Zhongshan Hospital, Fudan University, Shanghai, China

^d Department of Nephrology, Zhongshan Hospital, Fudan University, Shanghai, China

^e Department of Critical Care Medicine, Zhongshan Hospital, Fudan University, Shanghai, China

ARTICLE INFO

Keywords:

CDIO model

Undergraduate nursing students

Health education competency

Perceptions of clinical decision-making

Cardiovascular health behavior modification

ABSTRACT

Objectives: The COVID-19 pandemic has forced many healthcare organizations to stop the placement of undergraduate nursing students. As a result, undergraduate nursing students need the necessary training and practice to increase their competency. Therefore, effective strategies are needed to improve the effectiveness of online internships. This study aims to evaluate the impact of online cardiovascular health behavior modification training on nursing undergraduate students' health education competency and clinical decision-making perceptions using the Conceive-Design-Implement-Operate (CDIO) model.

Methods: This study utilized quasi-experimental research with a non-equivalent control group design. Nursing students undergoing internships at Zhongshan Hospital, Fudan University, Shanghai, China, from June 2020 to December 2021 were enrolled in this study. The participants were allocated into two groups, experimental and control groups. All participants completed a course designed to promote healthy behavior modification. The experimental group participants completed four modules through an online training course based on the CDIO model. The control group was given theoretical lectures on the same topic online. Health education competencies and clinical decision-making perceptions were assessed before and after the training. Statistical analysis was performed using IBM SPSS 28.0.

Results: A significant difference was observed between these two groups in their performance on the theoretical test ($t = -2.291, P < 0.05$) and operational assessment ($t = -6.415, P < 0.01$). The participants in the experimental group scored better than those in the control group. Post-test results indicated that students in the experimental group demonstrated significantly better health education competency ($t = -3.601, P < 0.01$) and clinical decision-making perception ($t = -3.726, P < 0.01$).

Conclusion: The study found that online courses based on the CDIO model are compelling. The study concluded that online classes are needed during the pandemic as it does not limit time and space. Nursing students can take their internship from anywhere as long as they can access the internet. Also, the study found that the online course was interactive and collaborative.

1. Introduction

1.1. Background

The COVID-19 pandemic brought fast-moving and unexpected

impacts to various sectors worldwide. For instance, COVID-19 resulted in the closure of many schools and universities globally. As a result, schools and universities started using technology to improve student learning and reduce stress during the pandemic season (Chang et al., 2022; Lee et al., 2021; Yeo et al., 2021). The United Nations Educational,

* Corresponding authors at: Department of Nursing, Zhongshan Hospital, Fudan University, Fenglin Road 180, Xuhui District, Shanghai 200032, PR China.

E-mail addresses: dong.xinyue@zs-hospital.sh.cn (X. Dong), zhang.zhen1@zs-hospital.sh.cn (Z. Zhang), zhang.xian@zs-hospital.sh.cn (X. Zhang), lmm789@fudan.edu.cn (M. Lu), zhao.yangyang@zs-hospital.sh.cn (Y. Zhao), lin.ying@zs-hospital.sh.cn (Y. Lin), zhang.yuxia@zs-hospital.sh.cn (Y. Zhang).

¹ Xinyue Dong, and Zhen Zhang contributed equally.

Scientific and Cultural Organization (UNESCO) recommends implementing open educational resources and distance learning programs to ensure minimal disruptions to access to education (Huang et al., 2020). Consequently, many institutions offer online courses (Shehzadi et al., 2021). The change in medium is not a simple process, even though online instruction and face-to-face teaching are superficially similar (Henriksen et al., 2020). Therefore, unlike offline internships, online internships pose a significant challenge to instructors as their effectiveness is yet to be explored.

Promoting health behavior modification in cardiovascular patients has long been a major and challenging concern for healthcare professionals. Virani et al. (2020) state that cardiovascular diseases (CVD) are the leading cause of death globally among the middle-aged and elderly (Virani et al., 2020). Virani et al. (2020) state that more than a quarter of CVD deaths can be prevented yearly with proper preventive medical care (Virani et al., 2020). Many studies have shown that behavioral counseling facilitated by healthcare professionals can improve CVD risk behaviors and reduce outcomes for known CVD risk factors in adults (Kharmats et al., 2020). According to the 2019 American College of Cardiology/American Heart Association (ACC/AHA) Guideline on the Primary Prevention of Cardiovascular Disease, behavioral counseling should be used as the first line of treatment for promoting cardiovascular health behaviors and reducing risk factors (Arnett et al., 2019; Laddu et al., 2021). Health behavior education and counseling are the components of cardiovascular medicine nursing student clerkship and assessment. Typically, these components are taught individually during clinical practice because patients present different characteristics. Assessments and individualized health education should be provided to each patient.

Conception-Design-Implementation-Operation (CDIO) theory is based on “learning by doing” and is an educational model that integrates the cultivation of knowledge, ability, and quality. Zhang and Li (2021) state that CDIO is a significant achievement in the international reform of engineering education (Zhang and Li, 2021). Students can learn how to design engineering projects using problem-solving as the driving force by integrating theoretical knowledge into the practical operation of specific projects. Through teamwork and collaboration, students can better understand theoretical knowledge in the context of realizing projects. “Learning by doing” is realized, and learning, doing, and creating are integrated as one process (Robinson et al., 2013). The CDIO model emphasizes the use of “student-centered” teaching techniques. In the student-centered techniques, students are involved in the conception, design, implementation, and operation of projects, as well as the translation of theoretical knowledge into problem-solving methods (Svensson and Gunnarsson, 2012). Based on its success in engineering, the CDIO model has been gradually applied to the medical and nursing professional education system (Chen et al., 2021; He et al., 2021; Liao et al., 2016). In residency and nurse training, CDIO is used for physical and ancillary examinations, information assessment and summarization, diagnosis identification, diagnostic and treatment plans, and health education. This model has proven to be a valuable tool for training medical and nursing personnel in innovative and integrative techniques during clinical practice. Cardiovascular health behavioral education and counseling based on the CDIO model are rarely studied among undergraduate nursing students. To provide a reference for the future development of online specialty skills teaching, this study evaluates the effects of this model on nursing students’ health education competency.

1.2. Objectives

The study aims to evaluate the delivery and effectiveness of online cardiovascular health behavior modification training based on the CDIO model to improve nursing students’ health education competency and perceptions of clinical decision-making.

2. Methods

2.1. Design

This study used a non-equivalent, quasi-experimental design to compare pre-and post-test results (Polit and Beck, 2017). Polit and Beck (2017) state that the non-equivalent, quasi-experimental designs do not have a random assignment of participants or equal group sizes. The non-equivalent, quasi-experimental design is shown in Fig. 1.

2.2. Participants and setting

Nursing students enrolled at a university in Shanghai in 2016 and 2017 were consecutively recruited between June 2020 and December 2021. The participant inclusion criteria were (i) nursing students who were or will be entering clinical practice and (ii) no prior cardiology practice experience. Students received a recruitment notice from the school and recruitment-specific information by email. Students interested in participating in the study responded to the email and obtained the questionnaire. In the informed consent form, students were informed that they would be assigned to either the control or experimental group by grade level. In total, 87 fourth-year nursing students participated in this study. According to the year of internship, those included in 2020 are the control group, and those included in 2021 are the intervention group. Eventually, 45 were placed in the control group and 42 in the experimental group.

2.3. Intervention

The construction and implementation of experimental group training involved 10 professionals. Two professors of Fudan university revised the framework of the training program according to the CDIO model. Three cardiovascular education nurses serve as instructors for training and are also responsible for preparing training content, slides, and simulation cases. All three instructors are cardiac nurse specialists who have worked in cardiology for >10 years and have been certified as cardiac nurse specialists by the American Heart Association and the Chinese Nursing Association. All training materials were reviewed by the chief physician of the cardiology department and the chief instructor of the nursing department. After summarizing and discussing the research team’s comments and suggestions, a final training program was developed. Additionally, three standardized patients were involved in the teaching process.

Table 1 contains the implementation items, teaching content, methods, duration, and objectives of the training program for the experimental group. A total of 42 subjects participated in the experimental group. The researcher allocated them into 6 groups, 7 students each according to anonymous coding. The program coordinator added the members of each group to a WeChat group to facilitate communication, discussion and group learning within their own groups.

Fig. 2 shows the cases used in the experimental group. The research team created a case archive. It contained 40 cases of cardiovascular health behavior modification in five aspects: exercise, diet/weight management, smoking cessation, medication adherence, and psychological support/stress management. Fig. 2 presents a selection of cases from these five aspects in the case archive. Each case contains basic information about the patient’s disease, life situation, and health behavior problems, and has 2–3 questions for students. A summary of the five key aspects of the training is shown in Fig. 2. The training process is as follows.

Conceive. one week before the training, the program coordinator sent the training materials (slides, case materials, task list) to the students in the experimental group via email. Students find and read the literature before the training and have a group discussion on how to solve the health behavior problem of the case. Also, they created a

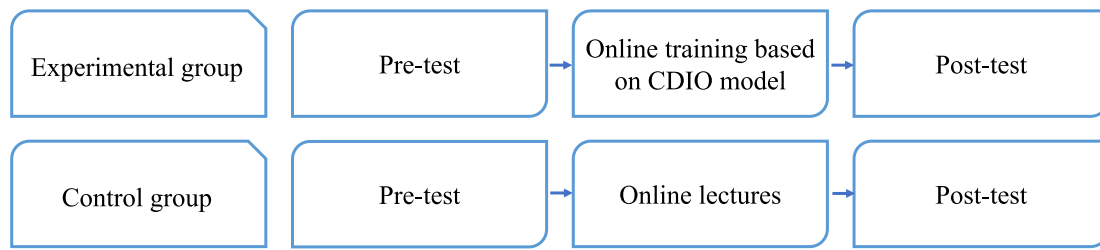


Fig. 1. Research design.

Table 1

The training program for online cardiovascular health behavior modification for nursing students based on the CDIO model.

Procedure	Teaching contents	Teaching methods	Class period	Teaching objectives
Conceive, C	<ol style="list-style-type: none"> 1. Provide cardiovascular health behavior modification cases and questions before the training. 2. Students conduct a literature search and have group discussions. 3. Behavior modification plan is developed based on the discussion. 	Case study based learning	Pre-lecture	<ol style="list-style-type: none"> 1. Develop specialized thinking in cardiovascular disease. 2. Improve students' literature search skills. 3. Enhance students' basic professional knowledge.
Design, D	<ol style="list-style-type: none"> 1. Students use slides to report on the behavior modification plan for the case briefly. 2. Teachers provide professional health behavior modification curriculum in five aspects: exercise, diet/weight management, smoking cessation, medication adherence, and psychological support. 3. The teacher answered the students' questions after the theoretical course. 	Participatory teaching and learning	6	<ol style="list-style-type: none"> 1. Improve health education competency. 2. To enhance perceptions of clinical decision-making.
Implement, I	<ol style="list-style-type: none"> 1. Through role play, students practice health behavior change education and counseling. 2. The teacher gives suggestions and comments 	Role-playing	1.5	<ol style="list-style-type: none"> 1. Training participants' communication and coordination skills. 2. Enhance the team consciousness of the participants
Operate, O	<ol style="list-style-type: none"> 1. Students work in groups to complete an individualized health education plan for the given case. 2. Communicate with SP and conduct education and counseling for health behavior modification. 3. The teacher provides comments throughout the process and summarizes the lesson. 	Scenario simulation	1.5	<ol style="list-style-type: none"> 1. Improve their problem-solving skills 2. Improve their practical ability under the guidance of the SP

brief slide show for the next phase of the online training to summarize the discussion results.

Design. The instructor began the training by inviting representatives from each of the six groups to report on how they addressed the health behavior issues in the case. Then, the instructor provided a complete health behavior-modified curriculum that covers five main aspects: exercise, diet/weight management, smoking cessation, medication adherence, and psychological support. The course outline is derived from the AHA and Chinese Nursing Association's Cardiac Nurse Specialist training. The instructor answered students' questions after presenting the curriculum.

Implement. Students had a chance to practice what they had learned through group role-playing. Six groups of seven students. 2 students were responsible for writing the script, and 3 students played the roles of patient, family member and health educator, and the other 2 acted as reviewers, responsible for reviewing the overall performance of their group and another group. While other students could also share their opinions. After that, the teacher gave suggestions and comments to help students improve their skills.

Operate. The teacher gave a simulated case (refer to Fig. 2) to each group. Students worked in groups to complete an individualized health education plan for this case. Each group has two representatives. 1 student briefly presents the health education plan developed by the group for 3 min, and another student communicates with the SP and completes education and counseling for health behavior modification (about 15 min). Based on the pre-defined tasks, the standardized patient will give students some challenges and guide them to provide more educational content. Finally, the teacher

provided comments throughout the process and summarizes the training.

2.4. Data collection

2.4.1. Phase I: recruitment and baseline data collection

Two nursing research assistants from the hospital's heart center participated in the study as program coordinators. They were responsible for distributing recruitment emails to students and following up on the mailing and receipt of re-evaluation results after the intervention. In June 2020, an email containing recruitment information, a consent form, and a link of the survey was sent to the students (T1). After agreeing to participate in the study, students were asked to complete the T1 survey. Also, the coordinators provided the participating students with training materials and links to the e-learning platform and ensured that each student engaged in the online training on time.

2.4.2. Phase 2: implementation of the intervention

After completing the T1 survey, students in the experimental group received program materials and links to net meetings one week before the online training. Under the guidance of clinical faculty, students were required to complete all online training and practice within two weeks. After the two-week training and practice, the students were sent a survey (T2) link to assess the quality of the program. Students were asked to reflect on their online training experiences and feelings on a program feedback form.

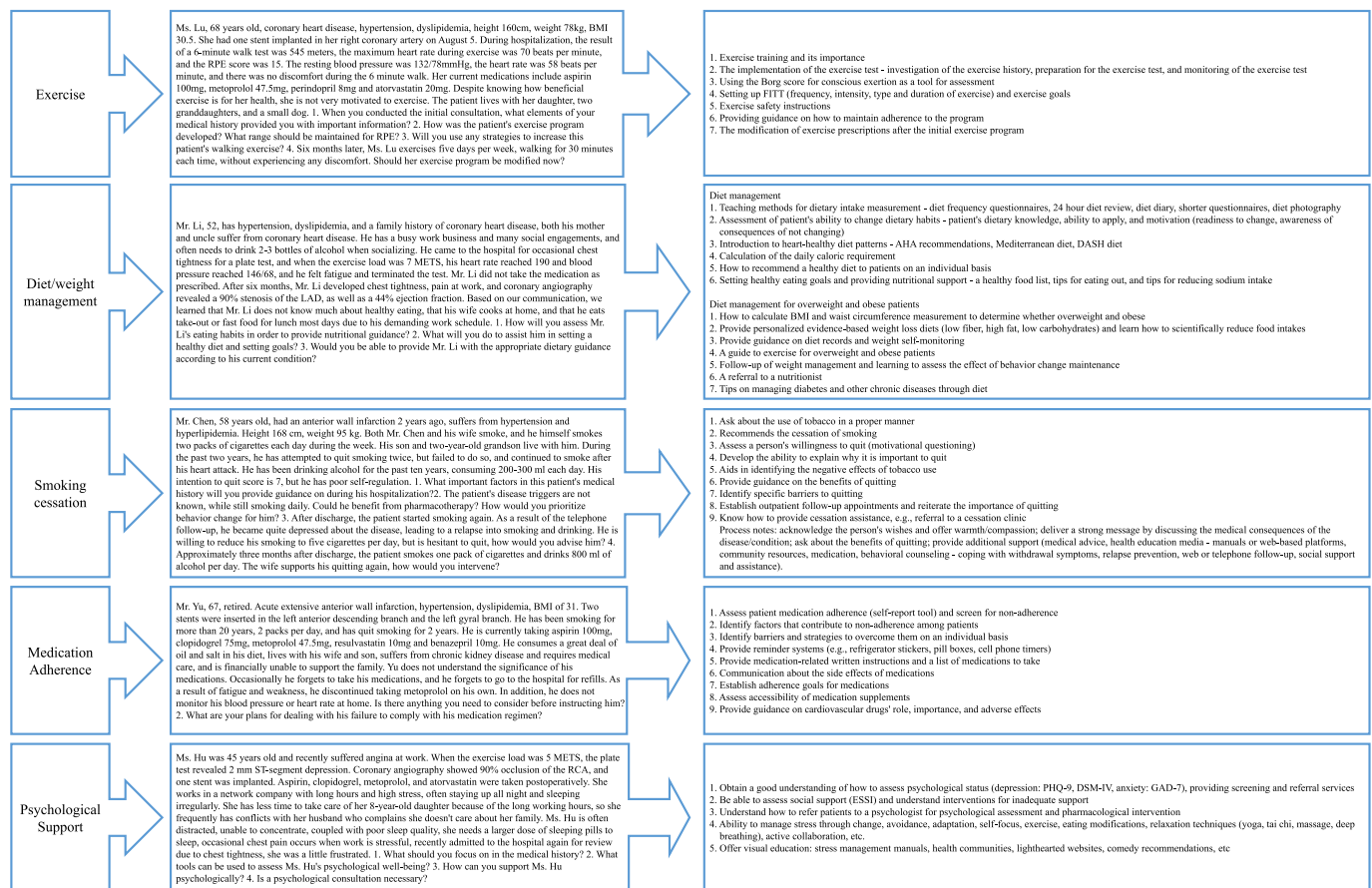


Fig. 2. Case studies and training materials for experimental groups.

2.5. Description of control conditions

Students in the control group listened to the theoretical lectures online through the same online meeting platform, and the instructor followed the course schedule. After the theoretical lectures, there was a Q&A session where students could ask questions about what they did not understand, and the instructor answered them individually. The course consisted of six class periods, with an average of 1.5 class periods per day. Students in the control group were also sent an email with the survey link before and after the course. For those students who forgot to submit the survey within the time limit, an email was sent by the program coordinator as a reminder. After completing the survey, students in the control group were provided a copy of the same case discussion and learning materials as the experimental group.

2.6. Outcome assessment

2.6.1. Theoretical and practical assessments

After the training, a test paper was used to assess and compare the theoretical scores of both groups. The test paper was marked out of 100 points; 60 points were for single-choice questions, 20 points for multiple-choice questions, and 20 points for four short-answer questions. In addition, both groups' practical skills was assessed using the hospital's cardiovascular health behavioral education score sheets after training. It includes 9 assessment items: assessment, clinical knowledge, consent, preparation, communication skills, patient interaction, insight, procedure management, and professional skills. The score range for professional skills is 0–20 points and 0–10 points for the remaining 8 items. Students are scored based on their ability to complete their education independently as well as their performance.

2.6.2. Scale of Health Education Competence for Nurses

Scale of Health Education Competence for Nurses is a self-assessment scale for nursing staff (Xu and Li, 2011). It was developed by Tong, a Chinese scholar, based on the 1985 American Public Health Association's health education procedures. Tong used various methods and strategies, including the literature review method and expert consultation, to create the scale (Tong and Li, 2010). Xu developed a revised version of the scale. The revised version included four dimensions and 36 items: assessment (9 items), planning (8 items), implementation (12 items), and evaluation (7 items) (Tong and Li, 2010). The Likert 5-point scale was used, with 1 being "not at all" and 5 being "completely". A higher score showed that the student could provide better health education. The internal consistency of Cronbach's α coefficient of the whole scale was 0.943, and the content validity (CVI) was 0.953. In this study, the Cronbach's α for the total scale was 0.964, and the CVI was 0.9.

2.6.3. Clinical Decision-Making Perceptions Scale

The Clinical Decision-Making Perceptions Scale is a self-report scale developed by Jenkins to assess nurses' perceptions of clinical decision-making (Jenkins, 1985). The scale has 40 items scored on a scale of 1 to 5 with an internal consistency of Cronbach's α coefficient of 0.83. Additionally, the scale has 18 reverse-scored questions and a total score of 40 to 200. Three levels of clinical decision-making perception were achieved, with 40.00 to 93.33 being considered low, 93.34 to 146.67 as moderate, and 146.68 to 200.00 as high. The scale comprises four dimensions: finding new information, specifying goals and values, finding alternatives, and multiple evaluations of results. He translated and tested the validity of the scale. The scale's content validity was rated 0.90, and its reliability was 0.78 (M. He, 2008).

2.7. Data analysis

Epidata 3.1 was used for data entry, and IBM SPSS Statistics 28.0 was used for data analysis. Data were expressed as frequencies, means ± standard deviation (SD), and percentages. Before performing statistical analysis, the data were normally distributed. Subsequently, count data tests were compared using the chi-square test, and measurement data were compared using independent samples *t*-tests for both groups. The significance for the outcome variables was set at $P < 0.05$.

2.8. Ethics

This study was approved by the Human Research Ethics Committee at Zhongshan Hospital, Fudan University. Participants were informed that participation was entirely voluntary before data collection. The program coordinator gave the participants an information sheet explaining the purpose of the study, the activities required, assurances of confidentiality, and the right to refuse or withdraw from the study at any time without penalty before obtaining consent. The data collection process began after participants submitted their informed consent forms.

3. Results

None of the 87 students in this study refused to participate or withdrew their consent. Students were recruited and retained throughout the study period, as shown in Fig. 3.

3.1. Participant characteristics

The mean age of participants in the experimental and control group was 21 years. The experimental and control groups were classified according to gender ($\chi^2 = 0.410, P = 0.522$), frequency of browsing professional journals using online resources ($\chi^2 = 0.066, P = 0.996$), willingness to work in a job related to their specialty ($\chi^2 = 0.257, P = -0.612$), number of departments where they had interned ($\chi^2 = 0.221, P = 0.895$), and credit performance points ($t = -0.462, P = 0.646$). The results in Table 2 show no significant differences between the experimental and control groups on the nurse staff health education competency scale, the nurse perceptions of the clinical decision-making scale, or the intrinsic dimension.

3.2. Comparative analysis of experimental and control groups

After the training, students' theories and skills were assessed, as shown in Table 3. The experimental group's theoretical and health behavior education skill scores were higher than those of the control group, and the differences were statistically significant.

The results in Table 4 show that the health education competency and clinical decision-making perception scores were higher for the control and experimental groups after the training than before. After the training, the experimental group scored significantly higher in all aspects of assessment, planning, implementation, and evaluation than before the training ($P < 0.01$). The percentage change in the total health education competency score (10.1 %), assessment (9.9 %), implementation (9.9 %), and evaluation (9.7 %) scores before and after

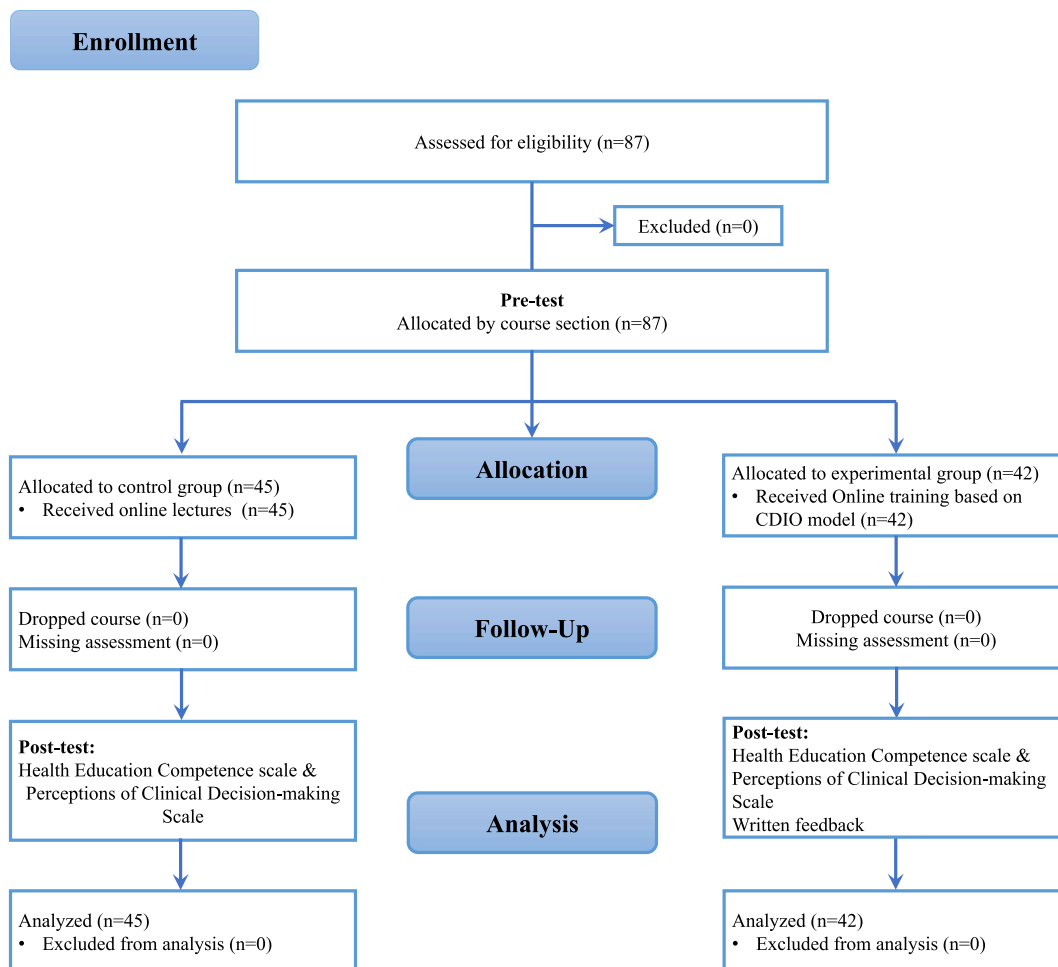


Fig. 3. Flow diagram of this study.

Table 2
Demographic and baseline homogeneity tests.

Variable	Experimental group (n = 42)	Control group (n = 45)	t or χ^2	P
Age	21.19 ± 0.71	21.16 ± 0.67	-0.236	0.814
Gender [N (n%)]			$\chi^2=0.410$	0.522
Male	3 (7.1 %)	5 (11.1 %)		
Female	39 (92.9 %)	40 (88.9 %)		
Use of online resources to browse professional journals on a regular basis (weekly)			$\chi^2=0.066$	0.996
Never	7 (16.7 %)	7 (15.6 %)		
1–2 times	25 (59.5 %)	28 (62.2 %)		
3–5 times	9 (21.4 %)	9 (20.0 %)		
Daily	1 (2.4 %)	1 (2.2 %)		
Willingness to work in a job related to this field			$\chi^2=0.257$	0.612
Yes	31 (73.8 %)	31 (68.9 %)		
No	11 (26.2 %)	14 (31.1 %)		
Credit GPA	2.88 ± 0.33	2.84 ± 0.37	-0.462	0.646
Number of departments you've interned in			$\chi^2=0.221$	0.895
1–2	18 (42.9 %)	20 (44.4 %)		
3–4	10 (23.8 %)	12 (26.7 %)		
5–6	14 (33.3 %)	13 (28.9 %)		

Variables	Experimental group		Control group		t-Test	P
	Mean	SD	Mean	SD		
Assessment	32.71	6.15	33.16	6.22	0.332	0.740
Planning	28.83	5.31	29.44	5.46	0.529	0.598
Implementation	42.26	7.81	43.46	8.26	0.633	0.528
Evaluation	24.71	4.71	25.33	4.82	0.605	0.547
Total health education competency score	128.52	23.21	131.29	24.15	0.544	0.588
Finding new information	16.69	2.71	16.89	2.72	0.340	0.734
Specifying goals and values	47.81	5.12	48.24	5.35	0.387	0.700
Finding alternatives	35.86	3.32	36.22	3.20	0.522	0.603
Multiple evaluations of results	33.00	4.12	33.60	4.45	0.651	0.517
Total clinical decision perception score	133.36	11.30	134.96	11.85	0.643	0.522

training was significantly improved in the experimental group. All dimensions of the clinical decision perception scale were significantly higher after the training than before the training in the experimental group ($P < 0.01$). A more significant percentage change was observed in finding alternatives (7.4 %) and multiple evaluations of results (7.5 %). After training, there was a significant difference in assessment ($t = -2.158$, $P = 0.03$), planning ($t = -2.650$, $P = 0.01$), and total health education competency score ($t = -2.063$, $P = 0.04$) between the two groups. A significant difference was observed between specifying goals ($t = -2.112$, $P = 0.04$) and total clinical decision perception score ($t = -2.293$, $P = 0.02$). In the control group, two dimensions of health education competency scores, assessment ($t = -2.211$, $P = 0.032$) and implementation ($t = -2.094$, $P = 0.042$), and one dimension of clinical decision-making perception, finding alternatives ($t = -3.590$, $P < 0.01$) showed significant improvements. In the control group, there was no significant difference in the scores of the other dimensions of the two scales.

Table 3
Scores of theoretical and skill assessment of the experimental and control groups after training

Group	Theoretical knowledge test scores		Practical skills assessment scores	
	M	SD	M	SD
Exp. (n = 42)	83.76	6.32	86.07	3.27
Cont. (n = 45)	80.24	7.86	82.07	2.53
t	-2.291*		-6.415*	

M = mean, SD = standard deviation.

* < 0.05 .

3.3. Feedback after learning

The 42 participants in the experimental group were requested to provide written feedback regarding the online cardiovascular health behavior change training based on the CDIO model. Five categories were extracted from the student text feedback as shown in Table 5: (1) knowledge of assessment through training, (2) awareness of health behavior change, (3) change in awareness of clinical decision-making, (4) future implementation, and (5) insight into professional responsibility in nursing. With this online training program, participants can assess patients independently and provide individualized education to help patients change their health behaviors. The online training program based on the CDIO model encouraged participants to take the initiative to learn and practice while the instructor provided advice and assistance throughout the process. The study found that students are more motivated and active while learning using the CDIO model than when learning theory using videoconferencing.

4. Discussion

This study examined how an online cardiovascular health behavior modification training program based on the CDIO model helped nursing students enhance their health education skills and clinical decision-making perceptions in professional counseling. The feedback from students in the experimental group showed positive perceptions and increased confidence in counseling health behavior modification. When applied to teaching, the CDIO model is a project-based learning technique that embodies the concepts of learning by doing (Armstrong, 2007). The CDIO model involves students in a cycle of model validation, systematizing work, and encouraging critical thinking about proposed solutions. Unlike traditional nursing teaching, the CDIO model is highly personalized in learning and research. Many studies state that

Table. 4

Pretest-posttest of health education competency and clinical decision-making perception scale scores within the experimental and control groups.

Variables	Experimental group (n = 42)				% change	t-Test	Control group (n = 45)				% change	t-Test
	Pretest		Posttest				Pretest		Posttest			
	M	SD	M	SD			M	SD	M	SD		
Assessment	32.71	6.15	35.95	3.92	9.9 %	3.489**	33.16	6.22	33.82	5.15	2.0 %	-2.211*
Planning	28.83	5.31	29.71	4.58	3.1 %	3.678**	29.44	5.46	29.71	4.58	0.9 %	-1.127
Implementation	42.26	7.81	46.43	5.08	9.9 %	3.434**	43.46	8.26	44.20	7.18	1.7 %	-2.094*
Evaluation	24.71	4.71	27.10	3.33	9.7 %	3.430**	25.33	4.82	25.82	4.22	1.9 %	-1.857
Total health education competency score	128.52	23.21	141.52	14.79	10.1 %	3.601**	131.29	24.15	133.56	20.55	1.7 %	-2.006
Finding new information	16.69	2.71	17.55	2.22	5.2 %	-2.210*	16.89	2.72	16.96	2.34	0.4 %	-0.293
Specifying goals and values	47.81	5.12	50.21	4.74	5.0 %	-2.479*	48.24	5.35	47.96	5.20	-0.6 %	0.485
Finding alternatives	35.86	3.32	38.50	3.68	7.4 %	3.544**	36.22	3.20	37.42	3.10	3.3 %	-3.590**
Multiple evaluations of results	33.00	4.12	35.48	3.40	7.5 %	3.587**	33.60	4.45	34.31	3.57	2.1 %	-1.794
Total clinical decision-making perceptions score	133.36	11.30	141.74	11.11	6.3 %	3.726**	134.96	11.85	136.64	9.59	1.2 %	-1.700

M = mean, SD = standard deviation.

* <0.05.

** <0.01.

exploration and practice complement each other, stimulating students' urge to apply new knowledge and foster their creative abilities (Nyka et al., 2020). When applied to nursing education, the CDIO model places students in a subjective and student-centered position. Teachers provide students with teaching cases and guidance while students solve problems through exploration, research, and collaboration. The teachers' primary responsibility in the CDIO model is to help students move from "learning" to "creating." A CDIO-based nursing education promotes students' active thinking and analysis, enabling them to make effective decisions in their future practice (Liao et al., 2016). As a new approach to education and training, CDIO enables students to integrate theory with clinical practice and facilitates lifelong knowledge acquisition skills (Wang et al., 2022).

During the COVID-19 outbreak, there was a rapid shift from traditional face-to-face instruction to online learning. Studies conducted during the COVID-19 pandemic found that 44.4 % of undergraduate nursing students found online learning stressful, and 47.2 % found it very stressful. Also, the studies found that 37 % of undergraduate nursing students were less satisfied with online teaching, and 46.3 % were moderately satisfied with online learning (Oducado and Estoque, 2021). This is similar to the findings of AlAteeq (AlAteeq et al., 2020). Traditional lecture-based courses are taught offline and transferring them directly to an online format may not be ideal. Clinical internships, which emphasize skill acquisition and flexibility, present more challenges regarding online implementation. The participants in the experimental group improved their health education skills and clinical decision-making perceptions more than the students in the control group in theory-related knowledge and practical application. As a result, it is assumed that the students in the experimental group improved because the instructor continuously pushed them to learn, analyze, explore, apply, and revise independently. (Noh and Kim, 2019).

The students in the control group were taught the theoretical aspects of health behavior change. Health education competency and clinical decision-making perceptions of control group students improved after training but not significantly compared to pre-training. The online lecture format may be too passive for students, making it difficult to control the results and effects. Web-based lectures are a passive process of listening to new knowledge. It is related to students' autonomous motivation and lacks a cycle of active thinking, internalization, and practice.

4.1. Limitations

Despite the positive results, this study had many limitations. First, there were difficulties in using randomized, double-blind studies.

Second, there was bias in selecting participants as the study included students entering their fourth year of college for two consecutive years. To minimize selection bias, students in the intervention and control groups were from the same university and followed the same curriculum and internship program. The study found no significant differences between the two groups in theoretical performance, internship experience, and willingness to learn. Additionally, there may have been a social expectation bias in students' self-reports. For this reason, student responses to emails were chosen to be anonymous and automatically matched with a code to encourage honest feedback. Due to funding and time constraints, a larger sample size and continuous follow-up were not possible for this study to determine long-term effects, including how much training impacts nursing students after graduation.

5. Conclusion

The COVID-19 pandemic has limited the opportunities for nursing students to gain direct nursing experience. Therefore, alternative programs are needed to supplement the limitations of nursing internships. Due to the recurring epidemic, online clinical practice may last for a certain period. Systematic and comprehensive training programs are also needed to facilitate learning in various nursing clinical contexts. Unlike offline learning, online learning is not constrained by time or space. Additionally, online learning is engaging, interactive, collaborative, constructivist, self-driven, and autonomous. The CDIO model provides a clear framework and implementation path for training. A CDIO-based cardiovascular health behavior modification program for nursing students enhances their health education skills, increases their perception of clinical decision-making, and optimizes their ability to conduct behavior change counseling. Clinical placements provide a valuable transition from theoretical knowledge on campus to the start of a nursing career. The absence of this phase may produce career transition shocks for nursing students, resulting in slow skill improvement and psychological stress. To improve clinical skills and knowledge of nursing, interactive and intelligent teaching platforms should be developed in the future.

Ethical approval

The study protocol was approved by the Ethics Committee of Zhongshan Hospital Fudan University (B2022-487).

Funding sources

This study was supported by the Nursing Research Fund of the School

Table 5

Written post-learning feedback and themes for nursing students who participated in online training based on the CDIO model.

Categories	Written feedback - quotations (translated from Chinese to English)
Developing assessment skills through training	<p>① ...mastering some good communication skills can effectively help in assessing the patient's situation, which is a prerequisite for a good consultation, such as using open-ended questions when appropriate; listening skills... I believe this can improve my ability to assess patients.</p> <p>② I was surprised by the interactivity of the online course... I need to be well prepared for the case discussions and simulation training. The purpose of the coronary health consultation is not only to impart knowledge, but also to formulate an appropriate plan based on the results of the assessment.</p> <p>③ I was able to determine to what extent the patient would accept my advice and whether he or she would implement the plan I gave him or her in the future.</p>
Increasing awareness of health behavior changes	<p>④ In reality, health education requires a step-by-step approach from assessment to implementation to evaluation, and it takes into account different patients' situations. It makes sense why patients didn't respond well to my education in the past.</p> <p>⑤ Over the past two weeks, I've repeatedly experienced situations that have convinced me that changing a patient's behavior isn't impossible, and that even small changes can promote patient's recovery.</p> <p>⑥ By learning behavior change techniques, we can practice communication and assessment. More importantly, learn to think.</p>
Changes in the perception of clinical decision-making	<p>⑦ Rather than giving fixed knowledge, I'll think about what the patient wants, and not consider whether he'll accept it or how effective it is...</p> <p>⑧ Starting with theory absorption and case preparation is more natural. Going from books to patients has always felt like crossing something to me in the past...</p> <p>⑨ The cases provided in the training are very specific and graphic. Learning this way keeps me thinking and mobilizing my brain.</p>
Future implementations	<p>⑩ It helped me transition between internship and formal work, and I am now confident about handling clinical cases on my own...</p> <p>⑪ It gave me an idea of what health behavior change counseling is like and allowed me to prepare mentally and relax a bit before I actually approached patients.</p> <p>⑫ Having this experience, I am better equipped to help patients change their health behavior and make them feel better.</p>
Insights into nursing's professional responsibility	<p>⑬ It turns out that nurses can promote the health of their patients in this way, and I'm ready to start helping my family.</p> <p>⑭ Nurses who provide proper counseling can make a big difference in patient health, and this inspired me...</p> <p>⑮ It reminded me that the work of nurses is not just administering injections and dispensing medicines, but they can also improve patient's condition without surgery or meds...</p>

of Nursing, Fudan University, China (FNEF201918) and the Nursing Program for Young Medical Talents of Shanghai Medical Academy, China (Shanghai Health Personnel 2021-99).

CRedit authorship contribution statement

Xinyue Dong: Conceptualization, Methodology, Funding acquisition, Investigation, Resources, Data management, Writing-original draft, Writing - review & editing.

Zhen Zhang: Conceptualization, Methodology, Formal analysis, Data management, Writing-review & editing.

Xian Zhang: Data management, Writing-review & editing, Supervision.

Minmin Lu: Conceptualization, Methodology, Writing-review & editing.

Yangyang Zhao: Conceptualization, Methodology, Data management.

Ying Lin: Conceptualization, Methodology, Writing-review & editing, Supervision.

Yuxia Zhang: Conceptualization, Methodology, Writing-review & editing, Supervision, Project management.

Declaration of competing interest

None.

Acknowledgments

We thank the University for approving this study. Special thanks also go to all the staff who helped to create the course content and all students who participated in the project. We would like to thank the project coordinators for their assistance in different phases of the intervention. We also acknowledge the valuable contribution of all participants.

References

AlAteeq, D.A., Aljhani, S., AlEesa, D., 2020. Perceived stress among students in virtual classrooms during the COVID-19 outbreak in KSA. Retrieved from Journal of Taibah University Medical Sciences 15 (5), 398–403. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7395822/pdf/main.pdf>.

Armstrong, P.J., 2007. *The Cdio syllabus: learning outcomes for engineering education*. In: *Rethinking Engineering Education: The CDIO Approach*. Springer US, Boston, MA, pp. 45–76.

Arnett, D.K., Blumenthal, R.S., Albert, M.A., Buroker, A.B., Goldberger, Z.D., Hahn, E.J., Ziaecian, B., 2019. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines. *Circulation* 140 (11), e596–e646. <https://doi.org/10.1161/cir.0000000000000678>.

Chang, C.Y., Chung, M.H., Yang, J.C., 2022. Facilitating nursing students' skill training in distance education via online game-based learning with the watch-summarize-question approach during the COVID-19 pandemic: a quasi-experimental study. *Nurse Educ. Today* 109, 105256. <https://doi.org/10.1016/j.nedt.2021.105256>.

Chen, M., Huang, M., Mu, Y., 2021. Teaching reform and practice of internal medicine nursing course based on CDIO education concept. *J. Nurses Train.* 36 (22), 2103–2108. <https://doi.org/10.16821/j.cnki.hsxx.2021.22.018>.

He, H., Zhou, D., Li, Z., 2021. Innovative practice of workshop training based on the CDIO model for the training of new nurses in the operating room. *Chin. J. Med. Educ. Res.* 20 (4), 489–492. <https://doi.org/10.3760/cma.j.cn116021-20200303-00472>.

He, M., 2008. *The Effects of Experience, Self-efficacy Anmeta-cognition to Nursing Clinical Decision-making*. Southern Medical University (Master).

Henriksen, D., Creely, E., Henderson, M., 2020. Folk pedagogies for teacher transitions: approaches to synchronous online learning in the wake of COVID-19. *J. Technol. Teach. Educ.* 28 (2), 201–209. Retrieved from. <https://www.learnlib.org/primary/p/216179/>.

Huang, R., Liu, D., Tilii, A., 2020. *Guidance on Open Educational Practices during School Closures: Utilizing OER under COVID-19 Pandemic in Line With UNESCO OER Recommendation*. Smart Learning Institute of Beijing Normal University, Beijing.

Jenkins, H.M., 1985. A research tool for measuring perceptions of clinical decision making. *J. Prof. Nurs.* 1 (4), 221–229. [https://doi.org/10.1016/s8755-7223\(85\)80159-9](https://doi.org/10.1016/s8755-7223(85)80159-9).

Kharmats, A.Y., Pilla, S.J., Seveck, M.A., 2020. USPSTF recommendations for behavioral counseling in adults with cardiovascular disease risk factors: are we ready? *JAMA Netw. Open* 3 (11), e2029682. <https://doi.org/10.1001/jamanetworkopen.2020.29682>.

Laddu, D., Ma, J., Kaar, J., Ozemek, C., Durant, R.W., Campbell, T., Turrise, S., 2021. Health behavior change programs in primary care and community practices for cardiovascular disease prevention and risk factor management among midlife and older adults: a scientific statement from the American Heart Association. *Circulation* 144 (24), e533–e549. <https://doi.org/10.1161/cir.0000000000001026>.

Lee, I.R., Kim, H.W., Lee, Y., Koyanagi, A., Jacob, L., An, S., Smith, L., 2021. Changes in undergraduate medical education due to COVID-19: a systematic review. *Eur. Rev. Med. Pharmacol. Sci.* 25 (12), 4426–4434. https://doi.org/10.26355/eurrev_202106_26155.

Liao, J., Sha, L., Yi, J., 2016. The effect of CDIO mode applied in clinical practice of medical nursing among nursing student. *Chin. Nurs. Manag.* 16 (1), 72–76. <https://doi.org/10.3969/j.issn.1672-1756.2016.01.020>.

Noh, G.-O., Kim, D.H., 2019. Effectiveness of a self-directed learning program using blended coaching among nursing students in clinical practice: a quasi-experimental research design. *BMC Med. Educ.* 19 (1), 1–8. <https://doi.org/10.1186/s12909-019-1672-1>.

- Nyka, L., Cudzick, J., Szakajto, K., 2020. The CDIO model in architectural education and research by design. Retrieved from World Trans. Engineering and Technology Education 18, 85–90. [http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.18,%20No.2%20\(2020\)/01-Nyka-L.pdf](http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.18,%20No.2%20(2020)/01-Nyka-L.pdf).
- Oducado, R.M., Estoque, H., 2021. Online learning in nursing education during the COVID-19 pandemic: stress, satisfaction, and academic performance. *J. Nurs. Pract.* 4 (2), 143–153. <https://doi.org/10.30994/jnp.v4i2.128>.
- Polit, D.F., Beck, C.T., 2017. *Nursing Research: Generating and Assessing Evidence for Nursing Practice*, (10 ed.). Wolters Kluwer Health.
- Robinson, K., Friedrich, H., Kirkpatrick, R., Nicholas, C., Rowe, G., 2013. A template for change? De-risking the transition to CDIO. *Australas. J. Eng. Educ.* 19 (1), 39–49. <https://doi.org/10.7158/22054952.2013.11464081>.
- Shehzadi, S., Nisar, Q.A., Hussain, M.S., Basheer, M.F., Hameed, W.U., Chaudhry, N.I., 2021. The role of digital learning toward students' satisfaction and university brand image at educational institutes of Pakistan: a post-effect of COVID-19. *Asian Educ. Dev. S* 10 (2), 276–294. <https://doi.org/10.1108/AEDS-04-2020-0063>.
- Svensson, T., Gunnarsson, S., 2012. A design-build-test course in electronics based on the CDIO framework for engineering education. *Int. J. Electr. Eng. Educ.* 49 (4), 349–364. <https://doi.org/10.7227/IJEEE.49.4.1>.
- Tong, H., Li, X., 2010. Development of the scale of health education competency for nurses. *J. Nurs. Sci.* 25 (23), 17–18. <https://doi.org/10.3870/hlxzz.2010.23.017>.
- Virani, S.S., et al., 2020. American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee, Heart Disease and Stroke Statistics—2020 Update: A Report from the American Heart Association. *Circulation* 141, e139–e596. <https://doi.org/10.1161/CIR.0000000000000757>.
- Wang, X., Zhou, Y., Song, Z., Wang, Y., Chen, X., Zhang, D., 2022. Practical COVID-19 prevention training for obstetrics and gynecology residents based on the conceive-design-implement-operate framework. *Front. Public Health* 10, 808084. <https://doi.org/10.3389/fpubh.2022.808084>.
- Xu, R., Li, X., 2011. Comparative study on nurses' self-appraisal and patients' evaluation of nursing health education competence. *J. Nurs. Sci.* 26 (13), 8–10. <https://doi.org/10.3870/hlxzz.2011.13.008>.
- Yeo, S.C., Lai, C.K.Y., Tan, J., 2021. A targeted e-learning approach for keeping universities open during the COVID-19 pandemic while reducing student physical interactions. *PLoS One* 16 (4), e0249839. <https://doi.org/10.1371/journal.pone.0249839>.
- Zhang, W., Li, J., 2021. Construction of CDIO Integrated Teaching Management System of Software Course Based on Internet of Things. In *Frontier Computing: Proceedings of FC 2020* 1063–1069. Springer Singapore.