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Research article

Effect of simulation-based zoom learning on clinical decision-making among undergraduate nursing students and experiences of students and instructors: A mixed methods study

Carmen Wing Han Chan, Fiona Wing Ki Tang *, Ho Yu Cheng, Ka Ming Chow, Zoe Ching Man Kwok, Caixia Li, Yuli Zang, Sek Ying Chair

The Nethersole School of Nursing, Faculty of Medicine, The Chinese University of Hong Kong, Shatin, N.T., China

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ABSTRACT

Aim: To determine the effect of simulation-based Zoom learning (SBZL) on perceived capabilities and clinical decision-making skills among undergraduate nursing students and to explore experiences of the instructors and students participating in SBZL.

Background: Nursing is a practice profession and students acquire clinical decision-making skills in clinical settings. However, the COVID-19 pandemic has disrupted conventional clinical learning activities. In this study, the outcomes of implementing SBZL in an undergraduate programme to support students' clinical learning were examined.

Design: A mixed methods design was employed.

Methods: This study recruited 195 final-year students to participate in the SBZL programme, which was developed based on the NLN Jeffries Simulation Theory to guide its design, implementation and evaluation. Case scenarios were developed and simulated through Zoom. Students' perceived capabilities, perceptions of the learning environment and clinical decision-making skills were assessed before and after SBZL. A historical control group of 226 previous final year students who had received a clinical practicum was included for comparison. Semi-structured interviews were conducted with 11 instructors and 19 students to explore their experiences of participating in SBZL.

Results: A total of 102 students completed the post-SBZL questionnaire. An increase in perceived creative thinking (mean difference = 0.24, $p < 0.001$) was observed post-SBZL. After SBZL, the perceptions of the learning environment were significantly improved. However, the SBZL group demonstrated lower perceived problem-solving capability than the control group (mean difference = 0.14, $p = 0.007$). Clinical decision-making was significantly improved in the SBZL group than in the control group ($p < 0.001$). Both the instructors and students reported positive experiences with SBZL, and highlighted challenges and factors for improving its implementation.

Conclusions: SBZL showed improvement in perceived creative thinking, perceptions of the learning environment and clinical decision-making. This innovative teaching and learning method can be valuable for nursing education in various regions to prepare students for real-life roles.

* Corresponding author. The Nethersole School of Nursing, The Chinese University of Hong Kong, 7/F Esther Lee Building, Shatin, N.T., China.
E-mail addresses: whchan@cuhk.edu.hk (C.W.H. Chan), wktang@cuhk.edu.hk (F.W.K. Tang), hycheng@cuhk.edu.hk (H.Y. Cheng), kmchow@cuhk.edu.hk (K.M. Chow), zoekwok@cuhk.edu.hk (Z.C.M. Kwok), caixiali@link.cuhk.edu.hk (C. Li), amyylzang@cuhk.edu.hk (Y. Zang), sychair@cuhk.edu.hk (S.Y. Chair).

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Tweetable abstract: Simulation-based Zoom learning is better than traditional teaching in improving clinical decision-making skills among undergraduate nursing students.

1. Introduction

The acute infectious disease COVID-19, led to a significant global outbreak and subsequent social restrictions. These restrictions substantially affected the delivery of university education [1]. Since mid-February 2020, most universities globally, including those in Hong Kong, rapidly transitioned to online teaching. This change required both teachers and students to adhere to teaching schedules and attend real-time online classes through videoconferencing platforms [2]. This shift posed a challenge to nursing education, which conventionally relies on face-to-face teaching.

Nursing, a practice-oriented profession, requires students to develop clinical decision-making skills and various psychomotor abilities in both laboratory and clinical settings. The COVID-19 pandemic led to the suspension of face-to-face laboratory sessions and clinical practicums in hospitals as part of the emergency response measure implemented by the Hospital Authority of Hong Kong to combat the outbreak. Similar to students in other countries, final-year undergraduate nursing students in Hong Kong are required to demonstrate competency and decision-making ability to graduate and to become licensed as registered nurses. Students' perceived capabilities that are crucial for practice include critical thinking, creative thinking, self-managed learning, adaptability, problem-solving, communication skills, interpersonal skills and group work. Critical thinking involves the intellectual process of analysing, synthesizing and evaluating information to guide belief and action [3]. Creative thinking is a cognitive process that allows individuals to generate novel ideas or products under the influence of their environmental [4]. Self-managed learning refers to the process in which individuals independently plan, implement and evaluate their learning needs, with or without assistance [5]. Adaptability is the ability to adjust one's thoughts, actions and emotions in response to uncertain situations [6]. Problem-solving entails observing and critically thinking to find solutions that lead to the desired outcome [7]. Communication skills encompass the ability to effectively exchange information during interactions [8]. Interpersonal skills and group work involve the ability to navigate dynamics between individuals during interaction [9]. The sense of competence in these areas is vital for achieving academic goals [10]. Furthermore, this perceived competence is also associated with the resilience of students [11]. Yet, the cessation of face-to-face laboratory and clinical teaching emerged as a major challenge in nursing education during the pandemic [12]. Despite advancements in treatment that led to decrease in mortality rates and the incidence of critical illness during the first and second waves of COVID-19 in Hong Kong, hospitals maintained stringent infection control measures, which results in the continued suspension of the full range of clinical practice opportunities for nursing students.

The advantages of digital technology have accelerated the transition from face-to-face teaching to real-time online teaching. Although conventional online teaching methods are effective in disseminating theoretical knowledge and facilitating discussion, they pose challenges in clinical course development and student assessment where in-person sessions are required [13]. Thus, there was an urgent need to explore and adopt an innovative approach to online teaching through videoconferencing platforms, such as Zoom, to fill the void created by the suspension of clinical teaching and learning [14]. Given the success of face-to-face simulation teaching and real-time online teaching in the School of Nursing at our university, the use of simulation-based learning through Zoom for the clinical training of final-year students in the Bachelor of Nursing (BNurs) programme could help to address the abovementioned problem.

With the potential to integrate theoretical knowledge from lectures with practical skills from real-life clinical situations, simulation-based learning presents a practical alternative for students to integrate their classroom learning in an interactive manner while ensuring patient safety [15]. Simulation teaching involves the use of simulation techniques to replicate real-life situations for practice and learning [16]. This method has been implemented in various health professional courses to improve students' knowledge, skills, behaviour and patient outcomes [17]. A study demonstrated the effectiveness of simulation teaching in facilitating knowledge acquisition and psychomotor skill development and improving self-efficacy, confidence and critical thinking among undergraduate nursing students [18]. Following simulation-based learning, students reported feeling more like nurses and were motivated to grow professionally [19]. Simulation teaching in a controlled environment enables students to practice in a safe setting [20]. In light of the COVID-19 pandemic and social distancing measures, some universities have adopted screen-based computer simulation, which allows students to participate in simulation from remote locations, to either supplement or replace traditional face-to-face approaches [21]. For example, previous studies have investigated the effectiveness of a screen-based computer simulation programme for second-year undergraduate nursing students [22] and a combination of face-to-face learning and online simulation-based learning for junior undergraduate nursing students [23] and have found outcomes comparable to those of conventional face-to-face simulation. However, there remains a gap in the literature regarding the effects of exclusively online simulation-based teaching on students' clinical decision-making abilities, their perceptions of the teaching and learning environment and the experiences of both instructors and students. Thus, the effects of these interventions remain unclear.

This study examined the effect of simulation-based Zoom learning (SBZL) for final-year undergraduate nursing students and explored the perspectives of both students and instructors regarding the use of SBZL. The objectives were to i) investigate the effects of SBZL on students' perceived capabilities and perceptions of the teaching and learning environment; ii) evaluate the effects of SBZL on students' knowledge and clinical decision-making ability; and iii) gain insights into the experiences of instructors and students who participated in the SBZL. The study was reported based on the reporting guidelines for health care simulation-based research [24].

2. Methods

2.1. Design

This study adopted a convergent mixed methods design. Triangulation of quantitative and qualitative methods by using a convergent design allows for a more comprehensive understanding of the topic of interest [15]. In this study, data related to students who participated in SBZL were collected and analysed concurrently using both quantitative and qualitative methods. This approach allowed for a comparative analysis enhancing our understanding of how to optimise the effects of SBZL. Moreover, qualitative data obtained from instructors provided insights into their teaching experiences, which are important in enhancing the teaching and learning environment for students.

2.2. Participants

All final-year undergraduate nursing students enrolled in the BNurs programme during the academic year 2018–19 and 2019–20 were eligible to participate in the study. Those who were in the academic year 2018–19 and had completed the clinical practicum as per the pre-pandemic curriculum served as the historical control group for comparison purposes (n = 226). Students from the academic year 2019–20 were recruited through email communication to participate in SBZL during the COVID-19 pandemic (n = 242). The curriculum for both cohorts remained consistent, as mandated by the Nursing Council of Hong Kong. The teaching strategies were similar between the two cohorts of students. The only difference between the two cohorts is that students in the academic year 2019-20 received SBZL, whereas students in the historical control group did not.

Qualitative interviews were conducted with faculty members from the School of Nursing who served as instructors during SBZL sessions. We interviewed 11 instructors and 19 students to gain insights into their experiences with SBZL.

2.3. Setting

This study was conducted in our School of Nursing's simulation ward, which is designed to emulate a real clinical environment and equipped with high-fidelity human simulators. The clinical learning center located in our university's School of Nursing has eight simulated wards with 24 beds in total, which act as venues for students to improve their clinical skills in a protected environment. Each simulation ward is equipped with a high-fidelity device, facilitating both multiple- and single-scenario-based simulation learning. These advanced facilities enable the implementation of real-time simulation providing students with an interactive learning experience that enhances their critical thinking abilities. For this SBZL programme, case scenarios were simulated in this ward setting and delivered online through the Zoom platform. (Fig. 1).

2.4. Intervention

2.4.1. Development of case scenarios

The design of the simulation was guided by the NLN Jeffries Simulation Theory [25] and the findings of previous studies [26,27]. A team of research staff and simulation instructors at the School of Nursing, all of whom received training in simulation scenario writing

Fig. 1. Real-time online simulation.

and facilitation, developed a total of 38 case scenarios covering various aspects of total client care in medical and surgical nursing (Supplementary Material 1) with specific learning objectives to enhance the realism of the simulation experience. These scenarios were reviewed and validated by faculty members who possess expertise in related areas of practice. The scenarios were simulated in the virtual wards of the clinical learning and simulation centre and SimMan 3G, high-fidelity simulators were used.

2.4.2. Implementation of scenario-based simulations

A briefing session was conducted for all instructors to introduce the learning objectives and scenario contents and highlight learning issues prior to the simulation. This session helped to maintain consistency in the learning objectives across groups and thus enhance the fidelity of the intervention. The students were divided into groups of six to eight and participated in two scenario-based simulations led by instructors who had experience in simulation-based teaching. Each simulation session comprised three phases, namely briefing, participation, and debriefing, following the previously reported simulation design [28]. During the briefing, the instructors provided the students with patient information and outlined the tasks for discussion on Zoom. During the participation phase, the students presented their plan of care, involving clinical decision-making through instant communication on Zoom to the instructors, who accordingly operated the simulators to generate simulated feedback for the students. Subsequently, debriefing was conducted by the instructors, who facilitated student discussions on the scenario and encouraged reflection on the simulation experience. The instructors also provided feedback on the students' performance, including their clinical reasoning and decision-making skills. The Zoom platform was used as an interactive tool for online discussion and to give commands in simulation-based learning. The participation sessions were recorded through Zoom. The students could access these recordings through the university system for further revision within a limited timeframe after the session.

2.5. Data collection

2.5.1. Students' perceived capabilities and perceptions of the university teaching and learning environment

The students' perceived capabilities and perceptions of the university teaching and learning environment were examined using the Student Engagement Questionnaire (SEQ) [29]. The SEQ comprises 33 items encompassing two scales: students' perceived capabilities and perceptions of the teaching and learning environment. The students' perceived capabilities were evaluated through seven subscales covering critical thinking, creative thinking, self-managed learning, adaptability, problem-solving, communication skills, interpersonal skills and group work. The teaching and learning environment were assessed via nine subscales covering active learning, teaching for understanding, feedback to assist learning, assessment, relationship between teachers and students, workload, relationship with other students, cooperative learning, and coherence of the curriculum. Each subscale consists of two items, with the exception of the assessment subscale, which includes three items. All items in the SEQ are rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In this study, the Cronbach's alpha coefficients for perceived capabilities and perceptions of the teaching and learning environment were 0.909 and 0.935, respectively, indicating satisfactory reliability. The Cronbach's alpha coefficients for each subscale was reported in Table 1. The SEQ has been shown to exhibit good psychometric properties in a sample of Hong Kong undergraduate students [29,30].

Table 1
Comparison of students' perceived capabilities and perceptions of teaching and learning environment between participants after SBZL and historical control.

SEQ (5 = strongly agree; 1 = strongly disagree)	Cronbach alpha	Mean ± SD			
		After SBZL (n = 102)	Historical control[a] (n = 226)	t	p[b]
Capability	0.909				
Critical thinking	0.667	4.00 ± 0.37	4.05 ± 0.45	1.057	0.292
Creative thinking	0.655	3.94 ± 0.42	3.95 ± 0.56	0.179	0.858
Self-managed learning	0.558	4.03 ± 0.43	4.02 ± 0.56	−0.177	0.860
Adaptability	0.855	4.06 ± 0.45	4.14 ± 0.48	1.459	0.146
Problem solving	0.756	3.99 ± 0.42	4.13 ± 0.45	2.732	0.007
Communication skills	0.799	3.94 ± 0.47	4.03 ± 0.56	1.510	0.132
Interpersonal skills and group work	0.827	3.93 ± 0.54	4.03 ± 0.56	1.535	0.126
Teaching and learning environment	0.935				
Active learning	0.867	4.13 ± 0.47	3.95 ± 0.59	−2.957	0.003
Teaching for understanding	0.844	4.13 ± 0.49	4.07 ± 0.55	−0.987	0.325
Feedback to assist learning	0.777	3.99 ± 0.53	4.01 ± 0.58	0.307	0.759
Assessment	0.838	3.97 ± 0.48	4.04 ± 0.50	1.207	0.229
Relationship between teachers and students	0.870	4.07 ± 0.55	4.04 ± 0.57	−0.452	0.652
Workload	0.736	3.93 ± 0.51	3.50 ± 0.89	−5.526	<0.001
Relationship with other students	0.822	3.80 ± 0.62	3.70 ± 0.73	−1.278	0.203
Cooperative learning	0.683	3.92 ± 0.48	3.90 ± 0.68	−0.305	0.761
Coherence of curriculum	0.822	3.96 ± 0.50	3.93 ± 0.58	−0.478	0.633

SBZL: simulation-based Zoom learning session; SD: standard deviation; SEQ: student engagement questionnaire.
All participants who completed the post-intervention questionnaire were included in the analysis.
[a] The data of historical control was collected by Centre for Learning Enhancement and Research in 2018–2019.
[b] The p-value is obtained from independent *t*-test, comparing test scores between the intervention group and historical control.

The questionnaire was administered online both before and after the SBZL session for the intervention group during the academic year 2019–20. Each student was assigned a unique identifier. Students in the historical control group completed the questionnaire online before their graduation. The students required approximately 15 min to independently complete the questionnaire.

2.5.2. Clinical decision-making

The students' knowledge and clinical decision-making abilities were evaluated on the basis of their course assessment scores, which were assessed by clinical teachers in two clinical assessment courses designed to evaluate students' clinical decision-making abilities and knowledge before their graduation. These assessment scores reflected the students' competencies in both clinical and theoretical areas, making them to be suitable outcome measures for assessing clinical decision-making. The assessment scores of the students who participated in the SBZL programme in the two clinical courses were compared with those of the historical control group. The knowledge and clinical decision-making abilities of all the students were tested individually in the simulation wards.

2.5.3. Experiences of participating in the SBZL

Email invitations to participate in individual interviews were sent to all participating instructors and students from the intervention group after SBZL. A research nurse possessing experience in conducting qualitative interviews arranged the interview schedules with participants who responded positively to the invitations. The interviews were conducted in an interview room at the university. All interviews were semi-structured using an interview guide that focused on capturing the participants' experiences and perceptions regarding the new teaching and learning initiative. Examples of interview questions included "What is the most pleasurable aspect of your experience with SBZL?" and "What is the most difficult or unpleasant aspect of your experience with SBZL?" Data saturation was considered to be achieved during interviews with both instructors and students when the narrative appeared to be redundant and no new information was obtained [31]. Data saturation was achieved after interviewing 9 instructors and 17 students. The research nurse continued to interview two more instructors and students to confirm data saturation. Each interview lasted 20–35 min and was audio-recorded.

2.6. Data analyses

Statistical Package for the Social Sciences version 28.0 (IBM Corp, Armonk, NY, USA) was used to analyse quantitative data. Descriptive statistics were used to summarise demographic data. Independent t-tests were conducted to compare the SEQ and assessment scores between the intervention and historical control groups. A paired *t*-test was used to determine mean differences between the pre- and post-SBZL SEQ scores. The significance level was set at 0.05.

The interviews were transcribed verbatim for analysis. Two researchers, who were faculty members at the university and possessed experience in qualitative inquiry, independently analysed the transcripts. The analysis was guided by an inductive approach using content analysis [32]. The researchers read the transcripts thoroughly to obtain an overall understanding. With the topic of inquiry in mind, they systematically extracted and labelled meaning units with appropriate codes. These codes were then sorted into categories and subcategories, which were refined to reveal meaningful comparisons between the experiences of instructors and those of students. The researchers discussed the findings until consensus was reached, and they remained reflexive throughout the analysis to prevent their personal perspectives from affecting the outcomes.

2.7. Rigor

To enhance the rigor of the study, several measures were implemented during the research process. The fidelity of the intervention was maintained by having instructors with experience in real-time online teaching and simulation training conducted the SBZL learning sessions. The credibility of qualitative findings was maintained through triangulation of data obtained from the students and instructors. The two researchers analysed qualitative data independently and remained reflexive to enhance the dependability and confirmability.

2.8. Ethical considerations

Ethical approval was obtained from the institutional ethics committee (No. SBRE-19-499). Participation in this study was voluntary, and both students and instructors were assured that they could withdraw from the study at any time without any adverse effect on their academic endeavours. An information sheet and a consent form were provided to the students and instructors to obtain their informed written consent before data collection and audio-recording of interviews.

3. Results

3.1. Characteristics of participants

The intervention group comprised of 242 students, with 195 actively participating in SBZL, resulting in a participation rate of 80.58 %. Among these participants, approximately 102 students completed the post-SBZL questionnaires, and 92 of them completed both pre- and post-SBZL questionnaires. The mean age of the students was 22.7 (SD = 0.82) years. The majority of the students were female (82 %). In comparison, the historical control group consisted of 226 final-year students, with 93.04 % completing the SEQ

before their graduation. The mean age of this group was 22 (SD = 0.96) years, and female students dominated the group, comprising 75 % of the participants.

3.2. Students' perceived capabilities and perceptions of the teaching and learning environment

Comparisons of the students' perceived capabilities and perceptions of the teaching and learning environment between the intervention and historical control groups were made based on the SEQ scores. As shown in Table 1, the students' perceived problem-solving abilities were significantly lower in the intervention group than in the historical control groups (SEQ score: 3.99 vs. 4.13, $p < 0.01$). In terms of the teaching and learning environment, compared with the historical control group, the intervention group demonstrated significant improvements in active learning (4.13 vs. 3.95, $p < 0.01$) but reported a lower perceived reasonable workload (3.93 vs. 3.50, $p < 0.001$).

The students' perceived capabilities and perceptions of the teaching and learning environment before and after SBZL were compared. As presented in Table 2, the students' creative thinking ability (SEQ score: 3.68 vs. 3.93, $p < 0.001$) significantly improved after SBZL. In terms of the teaching and learning environment, the post-SBZL scores for the active learning (3.92 vs. 4.12), teaching for understanding (3.94 vs. 4.09), feedback to assist learning (3.65 vs. 3.96), assessment (3.80 vs. 3.96), relationship between teachers and students (3.87 vs. 4.07), workload (3.70 vs. 3.90), cooperative learning (3.81 vs. 3.93) and coherence of the curriculum (3.86 vs. 3.97) were significantly higher than the corresponding pre-SBZL scores (all $p < 0.05$).

3.3. Clinical decision-making

As SBZL was implemented in two courses within the BNurs programme, we compared the average course scores between the intervention and historical control groups, and the findings are presented in Table 3. The assessment scores related to clinical decision-making skills in course 1 were significantly higher in the intervention group than in the historical control group (79.69 vs. 77.69, $p < 0.001$). In course 2, the intervention group scored higher in clinical decision-making, although the comparison results did not reach statistical significance.

3.4. Experiences of participating in the SBZL

The qualitative findings were organized into three categories: novel teaching/enjoyable learning experience, challenges in virtual teaching/learning, and factors for effective virtual teaching/learning. The experiences of both instructors and students were distinct, resulting in various subcategories (Table 4).

3.4.1. Novel teaching/enjoyable learning experience

The instructors expressed their appreciation for the novel teaching experience that SBZL offered them. They indicated that the innovative and well-designed approach enabled them to effectively conduct clinical teaching in a virtual environment.

Table 2
Comparison of students' perceived capabilities and perceptions of teaching and learning environment before and after SBZL (n = 92).

SEQ (5 = strongly agree; 1 = strongly disagree)	Mean ± SD				
	Pre	Post	Mean difference	t	p[a]
Capability					
Critical thinking	3.95 ± 0.36	4.01 ± 0.35	0.06 ± 0.42	1.350	0.180
Creative thinking	3.68 ± 0.52	3.93 ± 0.42	0.24 ± 0.48	4.913	<0.001
Self-managed learning	3.93 ± 0.40	4.02 ± 0.39	0.08 ± 0.45	1.728	0.087
Adaptability	4.05 ± 0.41	4.02 ± 0.42	−0.03 ± 0.46	−0.677	0.500
Problem solving	3.95 ± 0.39	3.96 ± 0.41	0.01 ± 0.47	0.220	0.827
Communication skills	3.93 ± 0.53	3.93 ± 0.48	0.01 ± 0.56	0.093	0.926
Interpersonal skills and group work	3.80 ± 0.61	3.91 ± 0.54	0.10 ± 0.60	1.638	0.105
Teaching and learning environment					
Active learning	3.92 ± 0.46	4.12 ± 0.45	0.20 ± 0.50	3.876	<0.001
Teaching for understanding	3.94 ± 0.40	4.09 ± 0.47	0.15 ± 0.42	3.329	0.001
Feedback to assist learning	3.65 ± 0.65	3.96 ± 0.48	0.31 ± 0.65	4.603	<0.001
Assessment	3.80 ± 0.49	3.96 ± 0.44	0.15 ± 0.44	3.336	0.001
Relationship between teachers and students	3.87 ± 0.53	4.07 ± 0.51	0.20 ± 0.53	3.641	<0.001
Workload	3.70 ± 0.58	3.90 ± 0.51	0.21 ± 0.49	4.022	<0.001
Relationship with other students	3.78 ± 0.66	3.80 ± 0.59	0.03 ± 0.66	0.392	0.696
Cooperative learning	3.81 ± 0.62	3.93 ± 0.47	0.12 ± 0.51	2.248	0.027
Coherence of curriculum	3.86 ± 0.45	3.97 ± 0.45	0.11 ± 0.49	2.149	0.034

SD: standard deviation; SEQ: student engagement questionnaire.
All participants who completed both pre- and post-intervention questionnaires were included in the analysis.
[a] The p-value is obtained from paired sample *t*-test, comparing changes of test scores within intervention group.

Table 3
Comparison of students' assessment scores between participants of SBZL and historical control.

	Mean ± SD			
	After SBZL[a] (n = 87)	Historical control[b] (n = 242)	t	p[†]
Clinical course 1	79.69 ± 3.96	77.69 ± 6.31	−3.406	<0.001
Clinical course 2	77.16 ± 5.12	76.56 ± 7.06	−0.842	0.401

SBZL: simulation-based Zoom learning session; SD: standard deviation.
[a] All participants who completed the pre- and post-intervention questionnaire were included in the analysis.
[b] The historical control involves all students in the cohort of 2018–2019.

> "For me, the combined use of the Zoom platform to conduct the simulation is so creative and innovative … Given the current pandemic, I think it's a very good attempt. We had used the web-based platform for teaching, but this time, using Zoom to carry out the simulation created a virtual learning environment, which is very good. Students gave very positive feedback and considered it's very innovative." (Instructor 08)

Likewise, the students found the SBZL to be an enjoyable experience. They believed that this new initiative enhanced group dynamics because the online platform facilitated communication and the exchange of ideas among peers.

> "I feel that the entire process was enjoyable because we used a chatroom to exchange our ideas, and it seems that students were more active than in the usual sim lab. It was much easier to express oneself via a computer." (Student 19)

Both the instructors and students noted that the high-fidelity interactive learning process aroused students' interest and promoted their engagement in learning.

> "Students saw a manikin that could give responses. Students' experiences were similar to those on-stie, very similar to a real clinical setting … They were so active at giving responses and answering questions. They were very clear on the direction or focus and what to do. The entire process was very good, making me feel that it was very similar to a clinical placement." (Instructor 03)

> "I felt like being in a real clinical environment, I could see a patient instead of doing tutorials based on words and scenarios. I feel that (the Zoom-based simulation) was very interactive and we had many conversations … The entire workflow was very smooth. We took the lead and the nurse took actions accordingly. That was very good." (Student 11)

3.4.2. Challenges in virtual teaching/learning

The instructors identified various challenges related to virtual teaching, with a primary concern being the management of a new teaching platform. They expressed apprehension that technical problems would affect the workflow and teaching plan.

> "The most difficult part was technical matters. I prepared many online documents in advance and spent a lot of time sending the links to students, while worrying that I might have made some mistakes. If someone is unfamiliar with computer technologies, it would take a lot of time." (Instructor 04)

Some students also encountered technical issues that hindered their participation in virtual learning.

> "I think that the most difficult part was the hardware and the Zoom software which we were not familiar with. I spent a lot of time resizing the window." (Student 15)

Furthermore, the instructors encountered difficulties in motivating students who remained passive and kept their cameras off during online sessions.

> "When using the Zoom platform, the quality really depends on the immediate responses that students give. If they don't speak out or decide to mute the microphone, it would be difficult to evaluate their status. They may feel that it's more comfortable not

Table 4
Experience of instructors and students in SBZL.

	Instructors	Students
Categories	Subcategories	Subcategories
Novel teaching/enjoyable learning experience	• Innovative and quality design • High fidelity and interactive learning process	• Enhancing group dynamics • Engagement in high fidelity learning environment
Challenges in virtual teaching/learning	• Managing a new teaching platform • Monitoring passive students	• Tackling technical issues • Varying learning pace
Factors for effective virtual teaching/learning	• Preparation and experience in online teaching • Collaborative effort and technical support • Engagement of students	• Motivation to learning • Enabling learning environment • Hardware and technical support

doing those things (turning on the camera or microphone). Without information about students' status, we would not know whether they had any concerns or anything that they were not clear about." (Instructor 08)

Similarly, some students noted that it was challenging for instructors to monitor the learning progress of each student, especially when students' learning pace varied. Slow learners, in particular, required additional support on the online platform.

"When I had something to say, some students responded so quickly that I didn't have much time to think, while others had already typed out the answers … The answers were always typed by someone in the chatroom … It might be better to give more time or have smaller groups, so that students could work on the questions together and gain more." (Student 02)

3.4.3. Factors for effective virtual teaching/learning

The participants suggested factors for effective SBZL. The instructors mentioned that their prior experience with online teaching was crucial in facilitating their preparation for teaching in a virtual environment.

"Probably, I'm not that experienced in using simulation in Zoom, it's a new trial for me. It took me a lot of time to practice. The transition period from face-to-face to Zoom classes was so short. I'm not yet fully adapted to the online mode nor getting used to using simulation through Zoom." (Instructor 05)

The instructors emphasised that the success of SBZL required collaboration among the instructors, laboratory staff, and technical staff.

"Manpower is so important for an ideal Zoom simulation. Someone needed to control the simulator, whereas another demonstrated the interventions in a professional manner. Meanwhile, a coordinator monitored the chatroom for students' responses, and the actor had to follow the commands given by students … We also prepared equipment, such as the H'stix mentioned by a student, which the actor had to follow immediately." (Instructor 02)

The instructors also perceived that students' active participation and engagement were crucial in a virtual classroom.

"When students are more active, it fosters in-depth discussions and encourages brainstorming of ideas. In addition to care plans, they may discuss topics such as clinical management and the roles of nurses at the bedside. Increased student activity can motivate others (students) to join the discussion." (Instructor 11)

From the students' perspective, self-motivation to learn in such a distance learning approach was crucial, especially when they were not being closely monitored by the instructors.

"I notice that sometimes teachers asked questions with the intention of engaging students in discussions or seeking their comments, but no one would voice their opinions. Zoom teaching is different from face-to-face teaching. In the face-to-face teaching, teachers knew whether we understood or not. In Zoom, because we did not switch on the camera or microphone, teachers couldn't know our feelings or thoughts. They had no idea how much we had gained. So, it's crucial to encourage student participation." (Student 15)

As the students participated in SBZL from their own locations, they consistently mentioned that an enabling learning environment without disruption was necessary for effective SBZL.

"I feel that it [barrier] was the environment because students attend a physical class during usual classes in campus, but for the Zoom class, it was at home or outside. Some (students) have (Zoom) classes outside where it is noisy, affecting the clarity of the

Table 5
Comparison of quantitative and qualitative results.

Quantitative results	Qualitative results		Meta-inference
SEQ after SBZL	Students' perspectives	Instructors' perspectives	
Capability			
Improvement in creative thinking	Engagement in high fidelity learning environment	Innovative and quality design	Confirmation
Non-significant increase in critical thinking, self-managed learning, problem-solving, interpersonal skills and groupwork	Motivation to learning Varying learning pace	Engagement of students Monitoring passive students	Expansion
Non-significant reduction in adaptability	Tackling technical issues Enabling learning environment	Managing a new teaching platform	Expansion
Teaching and learning environment			
Improvement in teaching and learning environment: active learning, teaching for understanding, feedback to assist learning, assessment, relationship between teachers and students, workload, cooperative learning, coherence of curriculum	Enhancing group dynamics Engagement in high fidelity learning environment	High fidelity and interactive learning process	Confirmation

audio and the overall quality of the class … If the environment is noisy, if there's no personal space, or if family members at home are moving around, it could interfere with my concentration during the class." (Student 03)

In addition, some students emphasised that hardware and technical support should be provided to establish an immersive clinical environment to facilitate learning.

"I think that for an ideal zoom-based learning environment, firstly, well-equipped hardware is essential, along with a stable Internet connection. Secondly, the view should be clear, meaning that we need to see what is happening in the sim lab. All these were achieved on the simulation day. Also, some equipment such as the simulator, vital sign charting, monitor setting … and the ability to interact with the simulator are also necessary." (Student 11)

3.5. Integration of mixed methods results

The SEQ results of the intervention group were compared and merged with the perspectives of students and instructors, as presented in Table 5. This integration yielded coherent findings and enhanced the understanding of key elements that contribute to student engagement in SBZL. Regarding the perceived capabilities of students, the innovative use of an online platform to support and engage students in clinical learning potentially stimulated their creativity. Both students' and instructors' responses aligned with positive outcomes in terms of creative thinking. The SEQ results indicated non-significant improvements in most of the subscales related to perceived capabilities. The qualitative results from both students and instructors further expanded the understanding that student motivation and the pace of learning are crucial to engage students in an online learning environment and promote positive learning outcomes. Moreover, the experience of learning through a new platform and the absence of an enabling learning environment for some students, coupled with the challenges of managing technical issues associated with the online platform, potentially had an impact on the adaptability of students. In terms of teaching and learning environment, the positive changes observed in the SEQ results can be attributed to the enhanced group dynamics and engagement in a high-fidelity learning environment. The instructors' perspectives align with this, as the high-fidelity learning environment and interactive learning process complemented the positive outcomes observed in the SEQ.

4. Discussion

This is the first study to use a mixed method approach to examine the effects of a SBZL programme on nursing students' perceived capabilities, perceptions of the teaching and learning environment, clinical decision-making skills, and the experiences of both instructors and students. The programme led to improvements in students' perceived capabilities, perceptions of the teaching and learning environment, and clinical decision-making skills. In addition, it yielded positive teaching and learning experiences for the instructors and students who participated in the programme.

The results revealed that, compared with the historical control group, the intervention group exhibited lower perceived problem-solving capability, as reflected in their SEQ scores. The SEQ comprises two questions aimed at assessing students' perceived problem-solving abilities: one related to their use of knowledge to solve problems within their field of study and the other related to their ability to gather information and different ideas to solve problems. This negative result indicated that the online clinical teaching mode did not enhance students' ability to solve clinical problems, probably due to the limitations of simulating patient situations only through video and online discussions via Zoom. The qualitative findings of this study indicated that the instructors encountered difficulties in monitoring passive students and acquiring their feedback, which hindered their ability to guide students in the process of identifying and solving problems aligned with the learning objectives. A study demonstrated that adopting a problem-based online teaching approach that involved guiding questions for case scenarios to direct students' thinking and learning fostered improved problem-solving abilities and behaviours among nursing students [33]. Based on these findings, a problem-solving approach can be integrated into the SBZL programme to encourage students to take active roles in formulating care plans and engaging in discussions about their simulation experiences. Future studies should be conducted to implement these recommendations and examine the effectiveness of an improved SBZL programme.

In terms of the teaching and learning environment, the intervention group showed improvements in active learning compared with the historical control group. This observation aligns with the qualitative findings of this study. The students expressed their appreciation for how SBZL enhanced group dynamics and provided them with an immersive experience in a high-fidelity learning environment, thereby potentially encouraging participation and active learning. In addition, some students felt more comfortable sharing their opinions online than speaking publicly, and they were given more time to ask questions. In an integrative review, it was reported that online simulation-based education enhanced students' learning motivation and learning experience [34]. Compared with the traditional face-to-face approach, the simulation training method might require students to be better prepared, capable of handling more information and proficient in generating care plans and communicating these plans to the instructor to avoid falling behind their peers in the group. While having more instructors and fewer students in simulation groups would ensure sufficient simulation times, it is essential to compare engagement levels among different group sizes to determine the most appropriate number of students to be included in individual simulation groups. Furthermore, having multiple instructors may increase students' engagement [35].

The current study demonstrated that the students who participated in SBZL exhibited significantly better clinical decision-making abilities than did the historical controls, as reflected by their assessment scores in one of the clinical courses. This result is consistent with that of a previous study that reported significantly higher decision-making skill scores among nursing students in the computer-

based simulation group than among those in the paper-based simulation group [36]. The positive effects of SBZL on clinical decision-making skills might be attributed to the computer-based training that facilitated students' learning of assessment techniques and clinical skills. In particular, formulating individualised care plans requires students to identify nursing diagnoses for clients and to make clinical decisions to prioritise these diagnoses and implement relevant nursing interventions, contributing to the development of their clinical decision-making skills [36]. However, a pilot study found no significant difference in nursing students' perception of clinical decision-making between Hyflex simulation (a combination of face-to-face and online learning) and traditional simulation [23]. These results suggested that Hyflex simulation did not reduce students' perception of improvements in clinical decision-making skills, indicating that this simulation technique could serve as an alternative approach to simulation-based training during the COVID-19 pandemic. Furthermore, another study reported that screen-based computer simulation and skill laboratories, which teach skills similar to those in clinical environments, had beneficial effects on clinical decision-making in preoperative and postoperative care management among second-year undergraduate nursing students [22]. Screen-based computer simulation offers the advantage of providing students with more opportunities to review videos, images, flowcharts, and cases that enhance complex skills, suggesting the benefits of incorporating this approach in regular educational courses [22].

The quantitative and qualitative results of this study provided insights into the effects of SBZL. In general, the instructors and students appreciated the value of SBZL in overcoming the limitations imposed by social distancing measures in clinical teaching. The positive learning experiences shared by the participants supported the improvements observed in the teaching and learning environment and clinical decision-making skills. Livestreaming simulation training provided students with an opportunity to enrich their learning experiences and practice clinical reasoning and decision-making skills. Both results consistently indicated that SBZL effectively engaged students in the learning environment. Furthermore, the qualitative results enhanced our understanding of the critical factors that contributed to strengthening students' capabilities and improving the teaching and learning environment. The opinions of the instructors and students were unanimous. The high-fidelity simulation technology rendered a virtual clinical learning environment in which the interaction between the instructors and students could be adequately maintained. This suggests that the immersive and interactive nature of SBZL contributed to the overall positive changes in the teaching and learning environment. The participants emphasised the pivotal role of student motivation in facilitating learning in the SBZL programme, especially given the inability of instructors to closely monitor all students, unlike in face-to-face teaching. The significance of motivation for online learning platforms has also been highlighted in other studies [26,27]. In addition, both the instructors and students found that technical issues hindered effective virtual learning. Furthermore, the experience of engaging in clinical learning through a new platform and navigating the frequent changes in policies and measures of social distancing in their daily lives potentially impacted the adaptability of students. These factors potentially underpin the development of capabilities and perceptions related to the teaching and learning environment. In addition, qualitative interviews revealed that the instructors highly valued SBZL as a feasible approach to continue clinical teaching during the pandemic. Despite the rapid shift in the teaching mode and the challenges associated with synchronous simulation-based teaching, the collaborative efforts of instructors, coupled with robust information technology support, enhanced the feasibility of this new teaching initiative.

The online platform Zoom was used as the interactive tool for online discussions and commands in this simulation-based learning programme. This programme can be applied to all health-related courses that necessitate the training of clinical decision-making skills to reduce commuting to campus. Nurse educators should be better prepared to ensure that the online teaching mode does not affect the quality of nursing education in the long term. Our study demonstrated that, compared with conventional teaching, simulation-based teaching had equivalent and, in certain aspects, better effects on students' perceptions of active learning and clinical decision-making. SBZL enriched students' experiences as nurses by enabling them to assume the role of a manager and providing opportunities to observe simulated scenarios from a third-person perspective. These effects warrant further investigation. The innovative online teaching approach examined in this study can help to prepare nurses for real-life nursing duties. We recommend that reducing the number of participants in individual simulation groups can enhance students' engagement in educational activities. In addition to online teaching, nurse educators can conduct synchronous meetings through online platforms to address students' questions related to the course content and provide necessary guidance. Furthermore, curriculum content should include information on infectious diseases and their prevention, as well as psychological preparedness to work in a pandemic. These factors can enhance future nurses' willingness to continue their nursing practice during an infectious disease outbreak [37].

Several challenges may impede the application of SBZL in nursing education. First, most of the students may prefer to keep their cameras off during sessions. Thus, some instructors may perceive a reduction in the level of interaction with their students due to the absence of visual contact. This can cause more difficulty for instructors in assessing students' motivation to learn. Second, some instructors may require additional time to familiarise themselves with synchronous educational tools. Third, factors related to Internet connectivity and technical competency in setting up and switching between different devices can also pose a challenge to the implementation of SBZL. Although our study involved adequate staff, including instructors, facilitators (laboratory nurses), and technicians, the sustainability of such a strong team with increased workload should be examined over an extended period.

4.1. Limitations

This study has some limitations. Thus, its findings should be interpreted with caution. First, pre-test and post-test comparisons and comparisons with a historical cohort were performed. The absence of randomisation and concurrent comparisons may compromise the validity of the study results. Second, there were unsatisfactory reliability for two perceived capabilities (self-managed learning and problem solving) and conclusions made about these comparisons should be tentative. Third, because this study was conducted during the COVID-19 pandemic, the societal factors and psychological conditions of the instructors and students may have influenced the

results of this study. Given that the pandemic situation and the associated social restrictions may have affected the students' psychological and financial status, their possible influence on the students' engagement in Zoom-based learning cannot be ruled out.

5. Conclusions

SBZL is an innovative approach to sustain clinical teaching when clinical teaching venues cannot support student learning. This study offers evidence of the effectiveness of SBZL in enhancing nursing students' perceived capabilities, perceptions of the teaching and learning environment, and clinical decision-making. In addition, it sheds light on the instructors and students who participated in this simulation-based learning programme. In general, SBZL is comparable to and in some aspects, even better than conventional teaching in terms of its effectiveness in enhancing the aforementioned outcomes. These results provided valuable insights for enhancing the effects of SBZL and improving the overall learning environment. However, the long-term effects of SBZL on these outcomes remain to be evaluated. With advances in simulation learning in health education, future research should investigate the feasibility and effects of replacing portions of the clinical practicum with simulation-based education.

Declarations

This study received ethical approval from the Survey and Behavioural Research Ethics Committee of The Chinese University of Hong Kong (No. SBRE-19-499).

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Data availability statement

The datasets used and/or analysed in this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Carmen W.H. Chan: Writing – original draft, Supervision, Project administration, Formal analysis, Data curation, Conceptualization. **Fiona W.K. Tang:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis. **Ho Yu Cheng:** Writing – review & editing, Project administration. **Ka Ming Chow:** Writing – review & editing, Project administration. **Zoe C.M. Kwok:** Writing – review & editing, Investigation. **Caixia Li:** Writing – review & editing. **Yuli Zang:** Writing – review & editing, Investigation. **Sek Ying Chair:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e30039.

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