Received: 17 May 2020 | Revised: 29 July 2020 | Accepted: 26 August 2020

DOI: 10.1111/medu.14364

MEDICAL EDUCATION IN REVIEW

Synchronous distance education vs traditional education for health science students: A systematic review and meta-analysis

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Funding information
The work was supported in part by the Education and Teaching Reform Project of Peking Union Medical College (2014zlgc0136), National Natural Science Foundation of China (91846106), Non-profit Central Research Institute Fund of Chinese Academy of Medical Sciences Clinical and Translational Medicine Research Fund (2019XK320029), Chinese Academy of Medical Sciences Innovation Fund for Medical Sciences (CIFMS2016-I2M-4-001), Non-profit Central Research Institute Fund of Chinese Academy of Medical Sciences (2017PT32020, 2018PT32001) and Training Program for Excellent Talents in Dongcheng District (TPETDD20180). These organisations had no role in the design and conduct of the study, collection, management, analysis and interpretation of the data, preparation, review or approval of the manuscript, or the decision to submit the manuscript for publication.

Abstract

Context: Synchronous distance education (SDE) has been widely used for health science students in recent years. This study examined the effectiveness and acceptance of SDE compared with traditional education for health science students and explored the potential moderators that could impact the pooled results.

Methods: A systematic review and meta-analysis was conducted of randomised controlled trials (RCTs) from January 2000 to March 2020 searched on nine electronic databases, including Web of Science, PubMed, Cochrane Library, Scopus, EMBASE, CINAHL, ERIC, PsycINFO, and ProQuest Dissertations and Theses. The outcomes measured were knowledge, skills with objective assessments and overall satisfaction with subjective evaluations. The pooled results were calculated using random-model effects, and moderators were explored through meta-regression.

Results: A total of seven RCTs with 594 participants were included. At the post-test level, the pooled effect size of knowledge acquisitions (SMD 0.12, 95% CI −0.07-0.32) showed insignificant difference between the SDE and traditional education groups ($P = .207$), with low heterogeneity ($I^2 = 17.6\%$). Subgroup analyses observed no factors that significantly impacted the pooled results of knowledge acquisition at the post-test levels (P for interaction > 0.05). Knowledge gains from pretest to post-test in SDE groups also did not differ significantly between groups (SMD 0.15, 95% CI −0.22-0.53; $P = .428$). The pooled effect size of skills (SMD 0.02, 95% CI −0.24-0.28; $P = .735$) was similarly insignificant. The pooled effect size of overall satisfaction (SMD 0.60, 95% CI 0.38-0.83; $P < .001$) significantly favoured SDE over traditional education. Incorporating two-group studies without randomisations did not significantly change the overall results of knowledge acquisition at the post-test level (SMD −0.002, 95% CI −0.11-0.10; $P = .994$), with moderate heterogeneity ($I^2 = 61.9\%$).

Conclusions: Synchronous distance education was not significantly different from traditional education in effectiveness and had higher satisfaction ratings. Our

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findings might provide indications for adoptions of online remote education in health science education centres.

1 | INTRODUCTION

Historically, online distance education (ODE) has been delivered favourably to learners geographically separated from education centres or tutors, enabling them to make the best possible use of educational resources.[1] In recent decades, colleges and universities in several countries have increasingly incorporated ODE into their education programmes and offered online education experience to students.[2] ODE can be offered in two main formats: synchronous or asynchronous courses.[3] Asynchronous distance education (ADE), such as recorded learning videos, comprises the common formats of the majority of electronic learning instruments, such as Moodle. Synchronous distance education (SDE), in turn, involves simulation of the communication models of traditional education to a certain extent by synchronising teaching and learning, as in live web conferences and virtual classrooms (Box 1).

The use of SDE has gained increasing attention in recent years, especially in health science fields.[2,4,5] Many schools have tried delivering SDE to health science students who were in satellite campuses, internship hospitals that were far from the main campus[6-8] or international students who were in different countries.[9,10] Hence, studies were required to assess the effectiveness of SDE for health science students compared with traditional education and evaluate the students' acceptance of them. Although previous studies have compared SDE and traditional education at the higher education level in health science, their results have not been unanimous.[6,11-13] Moreover, there was no systematic review and meta-analysis that focused on SDE for health science students, only a meta-analysis in 2004 that pooled previous studies of ODE.[14] It is therefore necessary to perform a meta-analysis incorporating studies published in recent years to explore the effectiveness and acceptance of SDE for health science students.

To address this gap in knowledge, this study aimed to compare the effectiveness of SDE and traditional classroom-based education for health science students and how favourably each was accepted and to explore the potential moderators that could impact the pooled results. To this end, this study conducted a systematic review and meta-analysis of previous randomised controlled trials (RCTs) on comparisons between SDE and traditional education among health science students.

2 | METHODS

This systematic review and meta-analysis was conducted on the basis of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Appendix S1).[15]

2.1 | Study eligibility

Inclusion criteria for eligible studies were pre-formulated based on the PICOS framework (Populations, Interventions, Comparisons, Outcomes and Study designs; Table 1).

Studies in any language were included if they (a) were conducted among health science students (including medical students, dental students, nursing students, pharmacology students and students in other health science fields); (b) used SDE in the experimental group; (c) involved traditional education as the control group; (d) included quantitative outcomes with regard to learning outcomes (knowledge or skills) or subjective evaluations; and (e) were RCTs.

Studies were excluded if they (a) compared SDE with asynchronous online education; (b) compared asynchronous online learning or blended learning with traditional education; (c) were conducted among health professionals or students unrelated to health science (such as computer science students); (d) only described modalities or technology without quantitative outcomes; and (e) were reviews, editorials, commentaries, opinion articles or conference abstracts without original data.

2.2 | Study identification

Peer-reviewed literature and grey literature from January 2000 to March 2020 were searched in the following nine databases: Web of Science, PubMed, Cochrane Library, Scopus, EMBASE, CINAHL, ERIC, PsycINFO, and ProQuest Dissertations and Theses. The primary search terms included intervention characteristics (eg distance education, synchronous, real-time interaction, simultaneous communication, virtual classroom, videoconference, web-conference) and participants' characteristics (eg medic*, nurs*, dent*, pharmac*, health*, students). The asterisk (*) was used as a truncation symbol during the search. The designed search strategy that followed the PICOS framework is presented in detail in the Appendix S2. The search was supplemented by scanning the reference lists of relevant systematic reviews and meta-analyses. Additional studies were searched by manual search of the reference lists of all included studies.

2.3 | Study selection

On the basis of the inclusion and exclusion criteria, two reviewers (HLY and ZHB) screened all titles and abstracts, and reviewed the full text of all potentially eligible abstracts independently. Each reviewer repeated the selection process twice. Conflicts were resolved

TABLE 1 Criteria for inclusion and exclusion of studies in the systematic review and meta-analysis

Criterion	Inclusion	Exclusion
Population	Health science students who are studying in schools, including medical, dental, nurse, pharmacy students and other health science–related students.	Health professionals (such as doctors, nurses or dentists) who are not studying in schools; students who are not related to health science.
Age group	Adults	Not adults
Intervention	SDE that allows live, simultaneous interactions among students and tutors, and provides synchronous courses with or without asynchronous access for the archives, including videoconference or web conference, online classroom or virtual classroom.	Asynchronous distance education that mainly provides recorded education for students without live interactions and communication among students and teachers; blended education that combines online learning and traditional learning.
Comparison	Traditional education in practical classroom.	Asynchronous distance education or no interventions.
Outcome	Quantitative learning outcomes (knowledge or skills) in objective assessments, with or without subjective evaluations (eg satisfaction).	Without quantitative learning outcomes; learning outcomes assessed by subjective rating scales.
Effect sizes	Studies reporting an effect size and the sample size in both the intervention and control groups	Studies not reporting an effect size or sample size information
Study design	Randomised controlled trials	Single-group studies; non-randomised controlled studies
Technology	All technology	—
Language	All languages	—
Publication date	January 2000-March 2020	Published before 2000
Publication type	Original research, including peer-reviewed journal articles or unpublished dissertations	Literature reviews, meta-analyses, editorials, book reviews, letters.

Abbreviation: SDE, synchronous distance education.

through discussions with other team members until consensus was reached.

2.4 | Data coding and extraction

Data coding and extraction were carried out by two reviewers (HLY and YN) independently, on the basis of a predetermined code scheme and a pre-made data extraction form. The following relevant data were collected: first author, country of intervention, year of publication, study design, participants, topics, duration of intervention, SDE formats, modality or technology, learning outcomes and objective assessments, and learning reactions and subjective evaluations. The studies included were mainly coded for country, publication type, formats, modality, learning achievements, subjective evaluations, participants and study design (pre-test/post-test or post-test only design), as shown in eTables 1 and 2. If any information was missing, we contacted the study authors by e-mail. Disagreements were discussed and judged by the third reviewer (ZHJ).

2.5 | Quality assessment

The methodological quality of eligible studies was evaluated using the Medical Education Research Study Quality Instrument (MERSQI).[16] The MERSQI includes 10 items to reflect six domains of study quality: study design, sampling, type of data (subjective or objective), validity of evaluation instruments, data analysis and outcome.

The risk of bias in the studies included was assessed according to the revised Cochrane risk-of-bias tool for randomised trials, recently released in 2019.[17] The framework of the revised Cochrane risk-of-bias tool contains five domains: (a) risk of bias arising from the randomisation process, (b) risk of bias due to deviations from the intended interventions, (c) risk of bias due to missing outcome data, (d) risk of bias in measurement of the outcome, and (e) risk of bias in the selection of the reported result. Based on the supporting information for each study, the judgements for each domain were made as 'low risk of bias', 'some concerns' and 'high risk of bias'.

In addition, the quality of evidence was estimated with the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) instrument by using the GRADE profiler (GRADEpro) software.[18,19]

Three researchers (HLY, ZHB and LYX) conducted the quality assessments independently, and any disagreements were discussed with other team researchers until consensus was reached.

2.6 | Data synthesis

As the overall test scores in the eligible studies were diverse, the standardised mean difference (SMD; Hedges' g effect sizes) and a 95% confidence interval (CI) were used to eliminate the effects of absolute

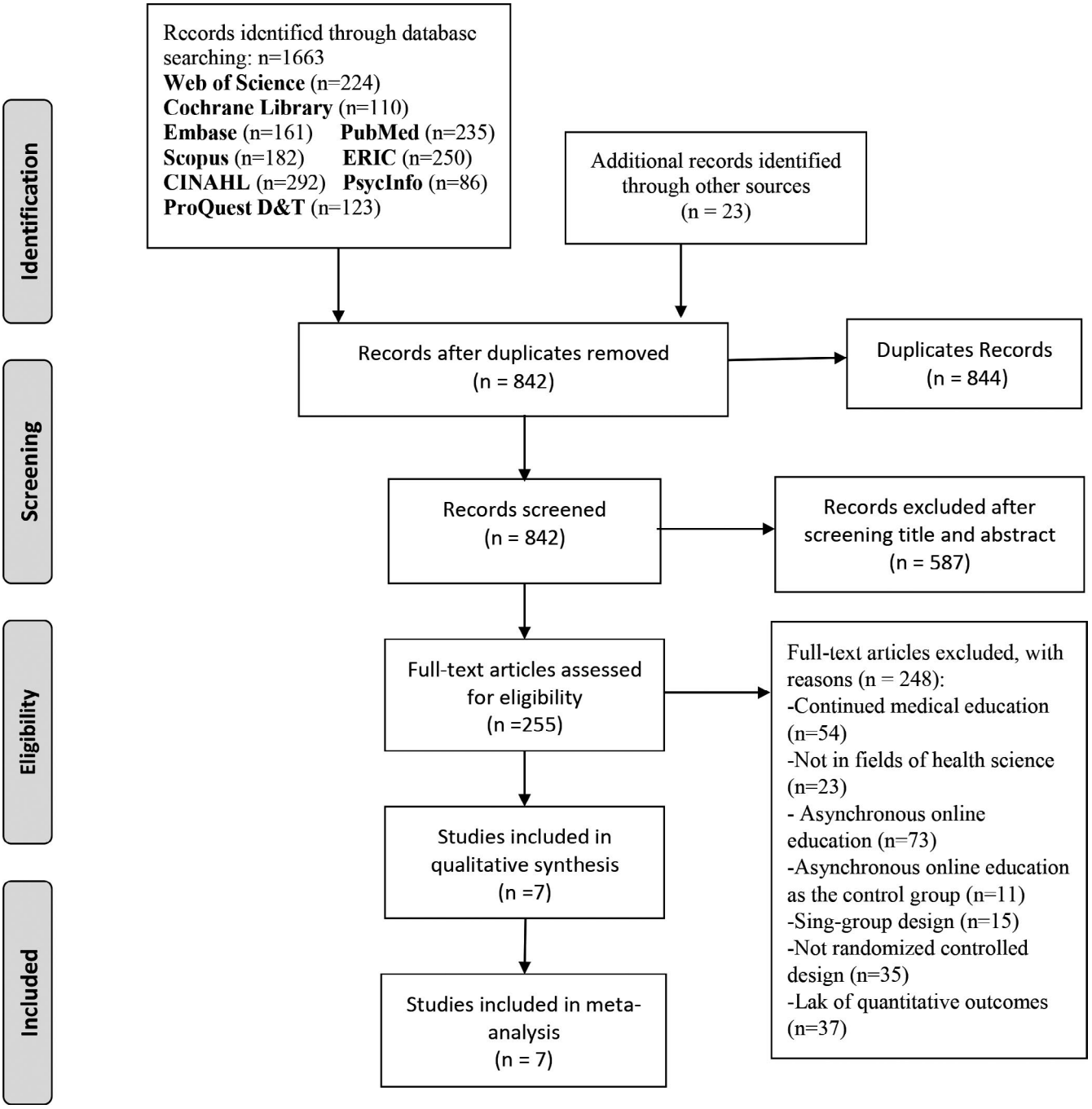

FIGURE 1 Flow chart of search strategy

values.[20] If the mean and standard deviation (SD) were not available, they were estimated from sample size, median, interquartile range and range through mathematical methods.[19,21] Knowledge acquisitions at the post-test level, knowledge gains from pretest to post-test and skills at the post-test level were synthesised to compare the effects between SDE and traditional education. Overall satisfaction was also pooled to evaluate the acceptance of SDE compared to traditional education. Given the diverse education topics, participant types and modalities, random-effects models were used to synthesise weighted effect sizes. The I^2 statistic was used to evaluate heterogeneity across studies quantitatively, with estimated values equal to or greater than 50% indicating large heterogeneity. As the eligible studies involved different participants, technologies and settings, random-effects models were applied to integrate weighted effect sizes. Planned subgroup analyses were carried out on the basis of interested factors that were coded in advance, and the statistical significance of interactions was determined by the *P*-value of the interactions. Publication bias was evaluated by funnel plot visually and Egger's test statistically.

Considering the rising concerns about RCTs in education interventions,[22,23] a further sensitivity analysis on knowledge acquisition at the post-test level was conducted for external validity. We additionally pooled results incorporating two-group studies that

TABLE 2 Characteristics of included studies

Study	Samples		Country	Participants	Topics	Duration	Times of education	Study design	Publication type	MERSQI scores
	Actual	Intended								
Alnabelsi et al (2015)	50	50	UK	Fifth- and fourth-year medical students	Otolaryngological emergencies	NR	Once	Pretest/post-test design	Journal	14.7
Joshi et al (2013)	58	59	India	Nurse students	Essential newborn care	1.5 d	More than once	Pretest/post-test design	Journal	15.0
Lorenzo-Alvarez et al (2019)	156	215	Spain	Third-year medical students	Radiographic education	2-h, 2 mo	More than once	Pretest/post-test design	Journal	13.3
Moazami et al (2014)	35	40	Iran	Fifth-year dental students	Dental teaching	3 wk	More than once	Post-test only design	Journal	14.1
Nelson et al (2010)	224	224	USA	Baccalaureate nursing students	Acid-base balance	0.5-h	Once	Post-test only design	Dissertation	13.2
Nicklen et al (2016)	38	41	Australia	Third-year physiotherapy students	Physiotherapy teaching	0.5-h	Once	Post-test only design	Journal	13.5
Spalla et al (2012)	33	33	USA	Freshman nursing students	General education course	2-h, 3 wk	More than once	Pretest/post-test design	Dissertation	13.7

Study	Formats	Access to archives	Modality (year of use)	Technological feature	Learning achievements		Subjective evaluations	
					Outcomes	Assessments	Outcomes	Assessments
Alnabelsi et al (2015)	Web conference, synchronous communication	Yes	Cisco Webex (NR)	Not specific	Knowledge	Knowledge test	Overall satisfaction Perception	Rating (10-point scale) Rating (10-point scale)
Joshi et al (2013)	Web conference, synchronous communication,	No	NR (2011)	NR	Knowledge Skills	Knowledge test OSCE	Overall satisfaction	Rating (5-point scale)
Lorenzo-Alvarez et al (2019)	Virtual world; synchronous interactions	Yes	Second Life (2014)	Transmitting voice, video, written chat and notecards.	Knowledge Skills	Knowledge test Examination	Satisfaction Experience	Rating (5-point scale) Rating (10-point scale)

(Continues)

TABLE 2 (Continued)

Study	Formats	Access to archives	Modality (year of use)	Technological feature	Learning achievements		Subjective evaluations	
					Outcomes	Assessments	Outcomes	Assessments
Moazami et al (2014)	Virtual classroom; videoconference	Yes	Not specific (NR)	Not specific	Knowledge	Knowledge test	NR	NR
					Knowledge retention	Delayed knowledge test		
Nelson et al (2010)	Web conference, synchronous interactions	No	Cisco Webex (2010)	NR	Knowledge	Knowledge test	NR	NR
Nicklen et al (2016)	Web conference, synchronous communication	No	Cisco Webex (2012)	Transmitting audio, video, written text	Knowledge	Knowledge test	Perception	Rating (5-point scale)
Spalla et al (2012)	Web conference, synchronous communication,	No	Google Chat (2012)	NR	Knowledge	Knowledge test	NR	NR
					Skills	Test		

Abbreviations: NR, not reported; OSCE, objective structured clinical examination.

were not randomised but met the rest of the inclusion criteria of our study. One-group studies that did not involve traditional education as the control group and qualitative studies that did not conduct objective assessments of learning outcomes were not included in the validation analysis. Subgroup analysis stratified by study design frame (RCTs or non-RCTs) was conducted through meta-regression.

All analyses were carried out using Stata version 15.0, and statistical significance was determined as $P < .05$.

3 | RESULTS

3.1 | Study selection

The search strategy initially identified 1686 potentially relevant studies, 1663 from nine databases and 23 from other sources. Literature selection was carried out strictly according to the inclusion and exclusion criteria (Figure 1). Finally, seven randomised controlled trials[11-13,24-27] were included in the meta-analysis.

3.2 | Study characteristics

As shown in Table 2, the main characteristics of the eligible studies included the coding of country, participant types, study design, formats and frequency of courses. The seven eligible studies incorporated a total of 594 participants from different countries. The entire learning duration ranged from several hours to several months, and the frequency of courses ranged from once to more than ten times. All eligible studies provided knowledge acquisition at the post-test level, and four studies reported knowledge gains from pretest to post-test. Concerning skills, only three studies reported quantitative data for synthesis. Four studies conducted subjective evaluations, but only three provided quantitative data.

3.3 | Quality assessments

3.3.1 | Methodological quality

The methodological quality of the studies included is summarised in Table 3, and the scores for each study are displayed in Table 2. The average of the total score (mean ± SD) for the included articles was 13.93 ± 0.67. All eligible studies were randomised controlled trials in single institutions, used objective assessments for learning outcomes and adapted appropriate data analysis methods. Most studies had high response rates (>75%).

3.3.2 | Risk of bias

The summary of risk of bias of eligible studies is displayed in eTable 3. None of the studies included had high risk of bias in any

TABLE 3 MERSQI domain and item scores for seven eligible RCTs

Domain	MERSQI Item	Studies, No. (%)	Score		Mean (SD)	
			Item	Maximum domain	Item	Domain
Study design	1. Study design			3	3.00 (0.00)	3.00 (0.00)
	Single-group cross-sectional or single-group post-test only		1			
	Single-group pretest and post-test		1.5			
	Non-randomised, 2 group		2			
	Randomised controlled trial	7 (100%)	3			
Sampling	2. No. of institutions studied			3	1.00 (0.00)	2.36 (0.23)
	1	7 (100%)	0.5			
	2		1.0			
	>2		1.5			
	3. Response rate, %				1.36 (0.23)	
	Not applicable					
	50 or not reported		0.5			
	50-74	2 (28.57%)	1.0			
	>=75	5 (71.43%)	1.5			
Type of data	4. Type of data			3	3.00 (0.00)	3.00 (0.00)
	Assessment by study participant		1			
	Objective measurement	7 (100%)	3			
Validity of evaluation instrument	5. Internal structure			3		1.29 (0.45)
	Not applicable				0.57 (0.49)	
	Not reported	3 (42.86%)	0			
	Reported	4 (57.14%)	1			
	6. Content				0.71 (0.64)	
	Not applicable					
	Not reported	2 (28.57%)	0			
	Reported	5 (71.43%)	1			
	7. Relationships to other variables				0.00 (0.00)	
	Not applicable					
	Not reported	7 (100%)	0			
	Reported		1			
Data analysis	8. Appropriateness of analysis			3	1.00 (0.00)	3.00 (0.00)
	Data analysis inappropriate for study design or type of data		0			
	Data analysis appropriate for study design and type of data	7 (100%)	1			
	9. Complexity of analysis				2.00 (0.00)	
	Descriptive analysis only		1			
	Beyond descriptive analysis	7 (100%)	2			
Outcome	10. Outcomes			3	1.50 (0.00)	1.50 (0.00)
	Satisfaction, attitudes, perceptions, opinions, general facts		1			
	Knowledge, skills	7 (100%)	1.5			
	Behaviours		2			
	Patient/healthcare outcome		3			
Total Score				18		13.93 (0.67)

Abbreviation: MERSQI, Medical Education Research Study Quality Instrument.

domains of the revised Cochrane risk-of-bias tool for randomised trials. In domain 1 related to selection bias, one study did not report the randomisation process in detail; however, the baseline differences observed between intervention groups appear to be compatible with chance. Concerning domain 2, it was impossible to achieve absolute blindness to tutor and learners; however, this did not impact outcomes and the deviations were balanced between groups as blind assessments were conducted. Three studies were judged as 'some concern' in domain 3 because of the withdrawal of participants.

3.4 | Meta-analysis

Figures 2-4 and Table 3 summarise the results of meta-analysis for outcomes. Given the small number of eligible studies, subgroup analyses were only performed with knowledge acquisition at the post-test levels, as well as sensitive analysis and publication bias.

3.4.1 | Knowledge acquisition at the post-test level

Knowledge acquisition at the post-test level was reported in seven eligible studies, with a total sample size of 594 and average sample size (mean + SD) of 84.86 ± 69.41. The pooled effect size (SMD 0.12, 95% CI −0.07-0.32; $P = .207$) showed insignificant difference in knowledge acquisition between SDE and traditional education with low heterogeneity ($I^2 = 17.6\%$; Figure 2). The quality of evidence with GRADE for knowledge was moderate.

3.4.2 | Knowledge gains at the pretest/post-test levels

Knowledge gains from pretest to post-test were reported in four eligible studies, with a total sample size of 297 and average sample size (mean ± SD) of 74.25 ± 45.76 reported. The pooled effect size (SMD 0.15, 95% CI −0.22-0.53; $P = .428$) exhibited insignificant difference between the experimental and control groups with moderate heterogeneity (I2 = 54.7%; Figure 3). The quality of evidence with GRADE for knowledge was moderate.

3.4.3 | Skills

Skills were reported in three eligible studies, with a total sample size of 247 and average sample size (mean ± SD) of 82.33 ± 53.85 (Table 4). The skills of the SDE group did not differ from those of the traditional education group (SMD 0.02, 95% CI −0.24-0.28; $P = .735$), with nearly zero heterogeneity ($I^2 = 0.0\%$; Figure 4). The quality of evidence with GRADE for skills was low.

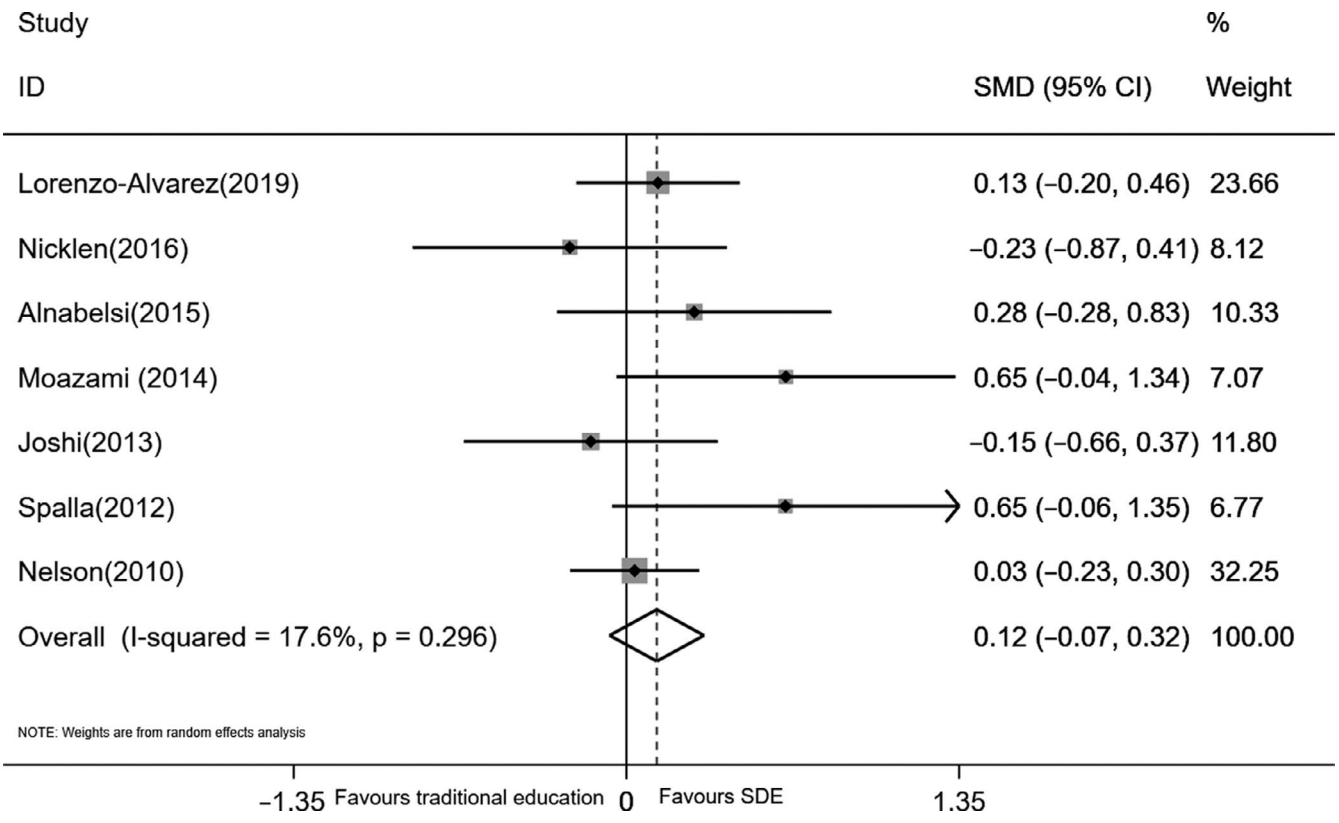

FIGURE 2 Forest plot of knowledge acquisitions at the post-test levels. CI, confidence interval; SDE, synchronous distance education; SMD, standard mean deviance

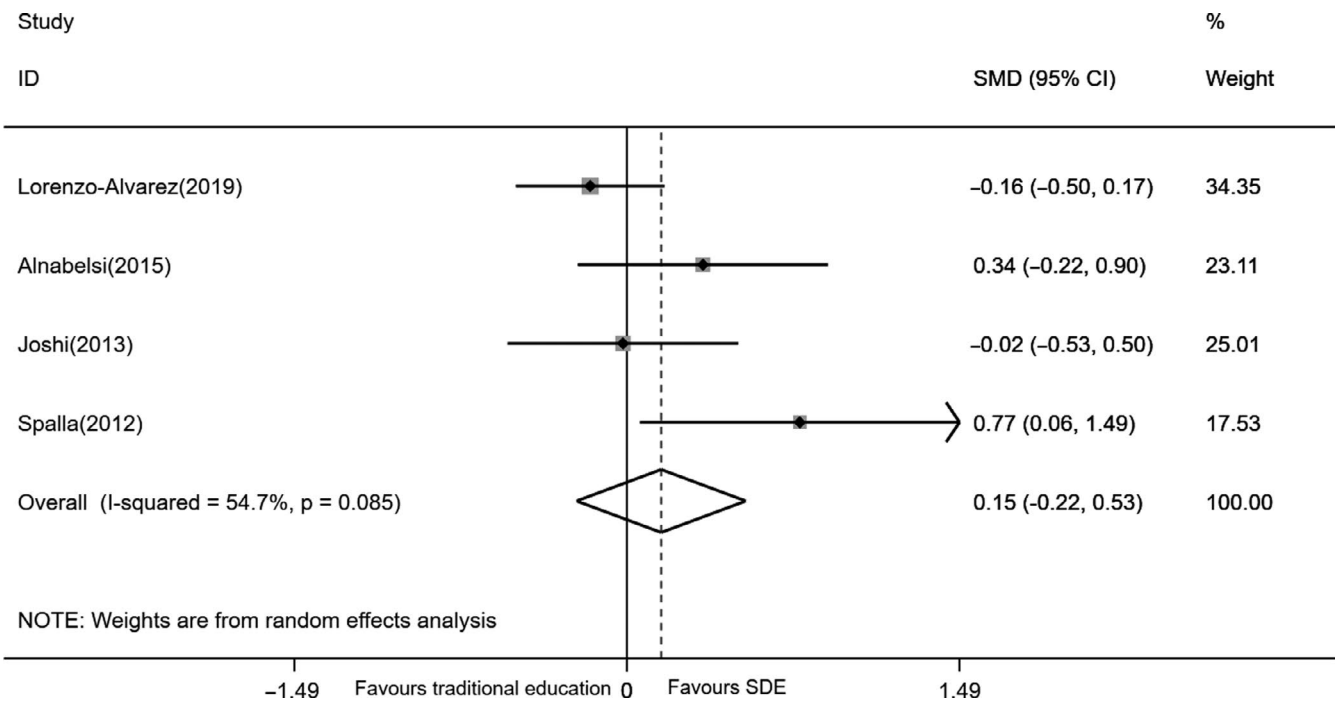

FIGURE 3 Forest plot of knowledge gains at the pretest/post-test levels. Abbreviations: CI, confidence interval; SDE, synchronous distance education; SMD, standard mean deviance

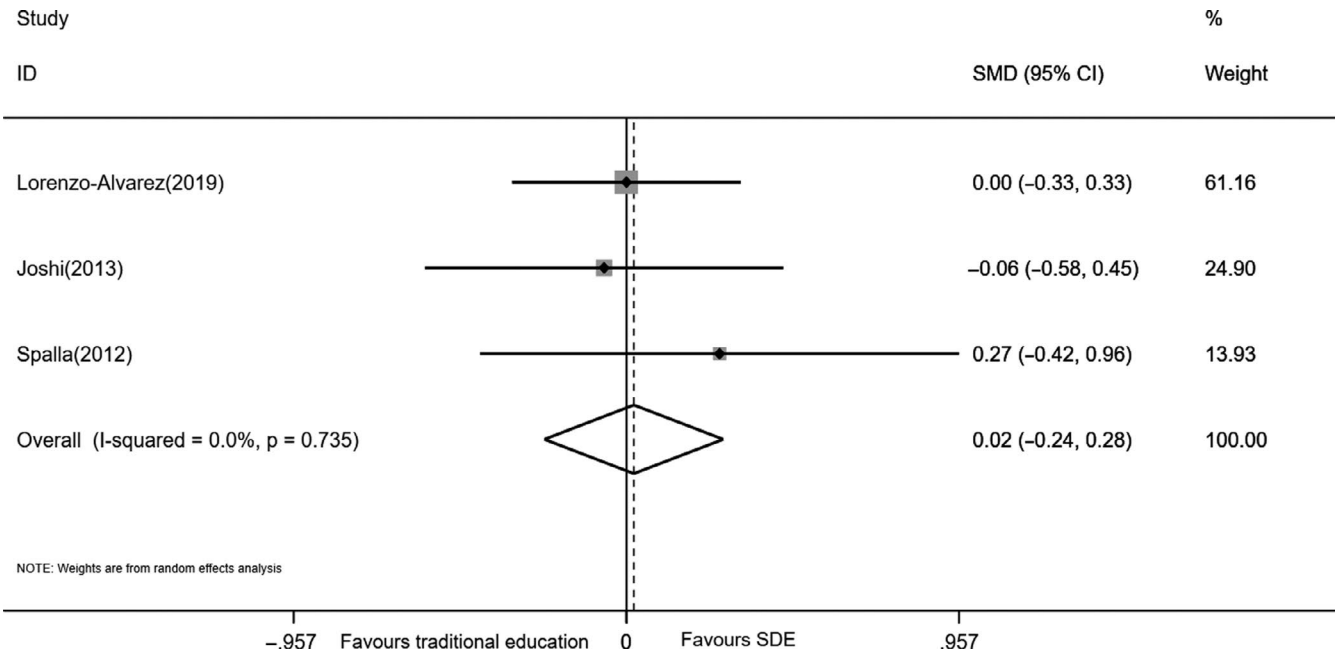

FIGURE 4 Forest plot of skills at the post-test levels. Abbreviations: CI, confidence interval; SDE, synchronous distance education; SMD, standard mean deviance

3.4.4 | Overall satisfaction

Overall satisfaction was reported in three eligible studies, with a total sample size of 264 and average sample size (mean + SD) of 82.33 ± 53.85. Overall satisfaction was higher in the SDE group than in the traditional education group (SMD 0.60, 95% CI 0.38-0.83; $P < .001$) (Figure 5). The quality of evidence with GRADE for overall satisfaction was low.

3.4.5 | Subgroup analyses

Table 5 shows the subgroup analyses on knowledge acquisition at the post-test level. The selected factors included study design, participants, formats, publication type, country and frequency of courses. There was no significant difference between subgroups stratified by selected factors (P for interaction > .05).

TABLE 4 Summary of the outcomes and the results of meta-analysis

Outcomes	*k*	Total N	Average N	Pooled effect size (95% CI)	*P*-value	Heterogeneity I^2	Heterogeneity *P*-value	Quality of evidence (GRADE)
Knowledge (post-test)[b]	7	594	84.86 ± 69.41	0.12 (−0.07,0.32)	.207	17.6%	.296	Moderate
Knowledge gains (pretest/post-test)	4	297	74.25 ± 45.76	0.15 (−0.22,0.53)	.428	54.7%	.085	Low
Skills (post-test)	3	247	82.33 ± 53.85	0.02 (−0.24,0.28)	.871	0.0%	.735	Low
Overall satisfaction	3	264	88.00 ± 48.19	0.60 (0.38,0.83)	<.001	0.0%	.609	Low
Knowledge retention	1	35	35 ± 0	0.59 (−0.10, 1.27)	.093	—[a]	—[a]	Very low
Knowledge in validation analysis (post-test)[c]	28	6437	230.15 ± 229.89	−0.002 (−0.10,0.10)	.963	61.9%	<.001	Moderate

Abbreviations: CI, confidence interval; GRADE, Grading of Recommendations, Assessment, Development and Evaluations; K, number of studies; N, number of participants.

[a]It is not proper to calculate heterogeneity with only one study.

[b]Knowledge acquisition at the post-test level in RCTs.

[c]Knowledge acquisition at the post-test level in the further sensitivity analysis for validity which incorporated RCTs and other two-group studies without randomisations.

3.4.6 | Sensitivity analyses with RCTs

Sensitive analyses were performed by excluding each study one by one to evaluate the influence of each study on the pooled results (Figure S1). Omission of any individual study did not change the overall results significantly.

3.4.7 | Publication bias

No publication bias was identified through visual and statistical evaluations. In the visual evaluations, the funnel plot with seven eligible RCTs was nearly symmetrical (Figure S2). In the statistical evaluations, Egger's test that estimated funnel plot asymmetry with linear regression showed an insignificant funnel plot asymmetry ($P = .336$).

3.5 | Further sensitivity analysis for the external validity

In order to further evaluate the external validity, a total of 28 relevant two-group studies (SDE vs traditional education) were incorporated in the further sensitivity analysis, containing seven RCTs and 21 data sources without randomisations[6-8,28-44] (Figure S3). There were a total

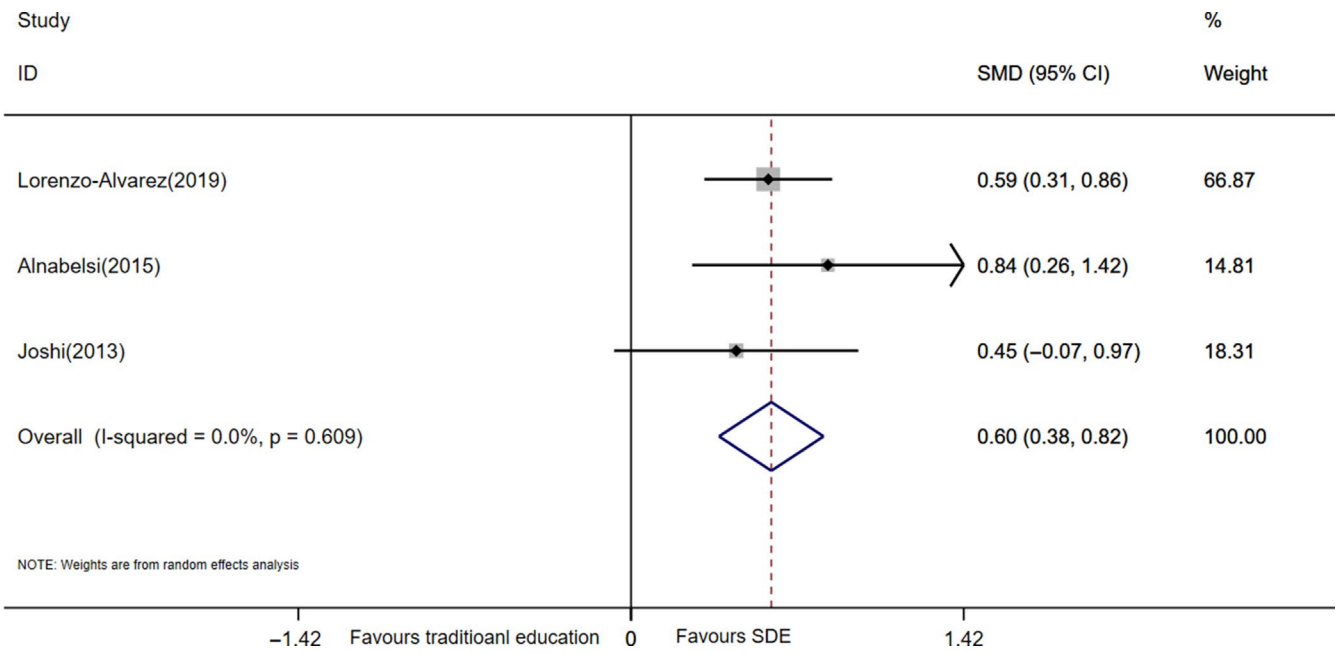

FIGURE 5 Forest *plot of overall satisfaction at the post-test levels. Abbreviation: SDE, synchronous distance education; SMD, standard mean deviance; CI, confidence interval* [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 Subgroup analyses of SDE vs traditional face to face education on knowledge acquisitions at the post-test levels

Subgroup	Interventions, K	N	Pooled effect sizes (95% CI)	Heterogeneity		*P*-value for interaction
				I^2	*P*-value	
All intervention	7	594	0.12 (−0.07,0.32)	17.6%	.296	
Study design						
Post-test only	3	297	0.11 (−0.29,0.51)	47.5%	.149	.677
Pretest/post-test	4	297	0.17 (−0.10,0.43)	14.9%	.317	
Participants						
Medical students	2	206	0.17 (−0.12,0.45)	0.0%	.649	.881
Nurse students	3	315	0.10 (−0.25,0.45)	42.3%	.177	
Others	2	73	0.20 (−0.68,1.08)	71.6%	.061	
Formats						
With special auxiliary functions	2	191	0.30 (−0.18,0.77)	43.7%	.183	.459
Without special auxiliary functions	5	403	0.07 (−0.16,0.29)	44.3%	.322	
Access to archives						
Yes	3	229	0.24 (−0.03,0.50)	0.0%	.407	.313
No	4	365	0.03 (−0.24,0.31)	25.4%	.259	
Publication type						
Dissertation	2	257	0.26 (−0.33,0.85)	62.8%	.295	.831
Empirical Journal	5	337	0.12 (−0.14,0.37)	18.8%	.101	
Country						
Developed	5	501	0.11 (−0.08,0.29)	4.4%	.382	.897
Developing	2	93	0.22 (−0.57,1.02)	70.7%	.065	
Frequency of courses						
More than once	4	262	0.25 (−0.12,0.62)	41.0%	.165	.411
Once	3	332	0.04 (−0.18, 0.25)	0.0%	.554	

Abbreviations: CI, confidence interval; K, number of studies; N, number of participants; SDE, synchronous distance education.
P-value for interaction: The *P* of heterogeneity between groups.

of 6347 participants included. The characteristics of relevant two-group studies without randomisations are displayed in eTable 4 (supplements). Figure 6 exhibits the overall results of knowledge acquisition at the post-test level with 20 two-group studies. There were no significant differences in knowledge acquisition at the post-test level between SDE and traditional education (SMD −0.002, 95% CI −0.11-0.10; $P = .994$) with moderate heterogeneity ($I^2 = 61.9\%$). Subgroup analysis stratified by study design frame (RCTs or non-RCTs) showed no significant differences between subgroups (RCTs: SMD 0.12, 95% CI −0.07-0.32; non-RCTs: SMD −0.04, 95% CI −0.15-0.08; $P = .228$; Figure S4).

No visible publication bias was found through visual (Figure S5) and statistical evaluations (Egger's test: $P = .668$). The omission of any single study did not impact the pooled results significantly (Figure S6).

4 | DISCUSSION

This study showed that SDE was not significantly different from traditional face to face education in learning outcomes and had a higher overall satisfaction rating among health science students. No factors that significantly impacted the overall results were observed. In the further sensitivity analysis for external validity, the final overall results did not change significantly after incorporating two-group studies that were not randomised but met the rest of the inclusion criteria of our study, which indicated our results were stable.

At the post-test level, there were no significant differences in knowledge acquisition between the SDE and traditional education groups with low heterogeneity. With the consideration of prior knowledge levels, knowledge gains from pretest to post-test similarly showed no significant differences between SDE and traditional education with moderate heterogeneity. The skills did not differ significantly either. These results indicate that SDE could be an effective and feasible education method for health science students. In terms of subjective evaluations, most studies reported positive and agreeable evaluations of SDE from participants[6] and the overall satisfaction was rated higher for SDE than for traditional education in our analysis, indicating that SDE was acceptable to students. There are two possible reasons for the positive subjective evaluations of

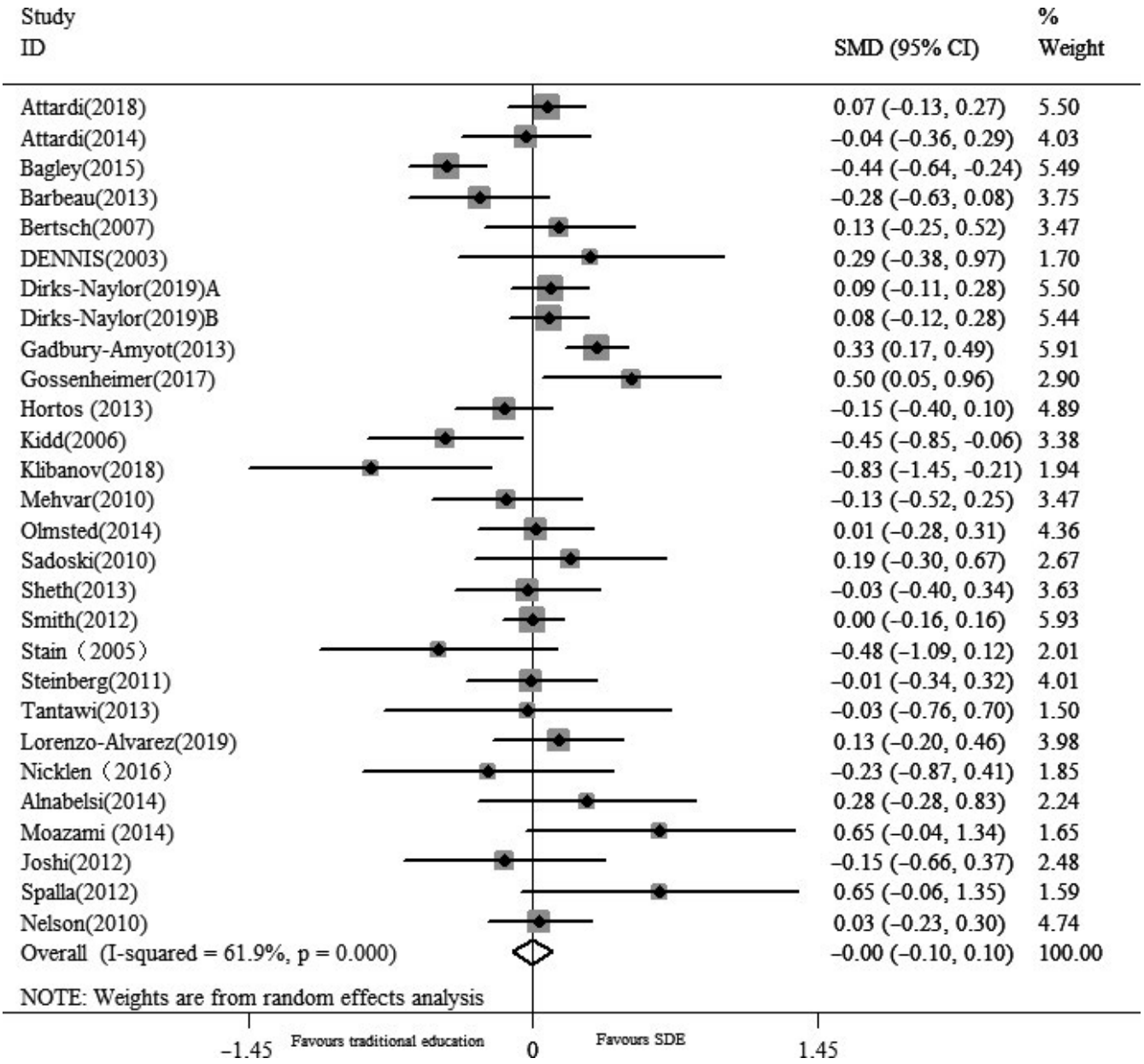

FIGURE 6 Forest plot of knowledge acquisitions at the post-test levels with all two-group studies in validation analysis. Note: Non-RCTs referred relevant two-group studies that were not in randomised design. Abbreviations: CI, confidence interval; RCTs, randomised controlled trials; SDE, synchronous distance education; SMD, standard mean deviance

SDE: first, probably because students who grew up in contact with electronic devices and the Internet showed a preference for ODE over traditional education[2]; second, possibly because SDE better meets the needs of simultaneous communications of health science students and teachers compared to asynchronous education.[45]

By allowing simultaneous communications and real-time interactions between students and teachers, SDE contributes to the improvement of cognitive, social and teaching presences.[46,47] In the synchronous courses, students' questions could be answered by teachers immediately,[48] increasing student engagement and motivation for learning. Enhanced with advanced information and communication technology (ICT), SDE allows for the simulation of live interactions and simultaneous communications of the traditional classroom, with more flexibility and special auxiliary functions.[2,48] Taken to an extreme comparison, SDE can be neither worse nor better than traditional education. Multiple modalities for education might be the best, but the use of multiple modalities for education can be difficult. Several studies included provided asynchronous delivery modules apart from SDE modalities.[11,13,24] Appreciated for the convenience of asynchronous learning,[2,47] the combinations of asynchronous modules and SDE might bring additional benefits,[47] because the access to archives in SDE provides great opportunities for students to review lessons after class without time constraints.[11,24,45] One eligible study combined with asynchronous modules in our study reported favourable effects of knowledge retention.[11] However, no significant favourable effects of SDE groups

BOX 1 Overview of terminology definitions

Term	Definition
Distance education	Provision of access to learning for those who are geographically separated from the instructor. Distance education can be synchronous or asynchronous.
Traditional education	Traditional education comprises the routine teaching methods for students in the physical classroom.
Health science	Health science is the discipline of applied science that deals with human and animal health.
Health science students	Students who study health science in schools (colleges and universities)
Synchronous distance teaching	Synchronous distance teaching involves simultaneous communication and live interaction between students and teachers as well as synchronous communication among students during the courses.
Live interaction	Students can ask questions simultaneously about the education and teachers give corresponding replies immediately.
Videoconference (or web conference)	Videoconference allows the simultaneous transmission of both audio and video information. Video information could comprise a synchronous image of the instructor, or other video media.
Virtual classroom (or online classroom)	A virtual classroom is an online learning environment that allows for live interaction between the tutor and the learners as they participate in learning activities
Knowledge	Factual or conceptual understanding with objective or subjective assessments
Knowledge retention	Knowledge retention is the amount of information people can remember after a period of time as they have first learned something, which is assessed by delayed tests.
Skills	Objective or subjective assessments of students' ability to demonstrate a procedure or technique
Overall satisfaction	Students' satisfaction with the education reported through Likert scales.

were observed compared to traditional groups for immediate knowledge acquisition in our analysis.

Currently, the delivery of SDE is usually conducted through two types of technology: videoconference (or web conference)-related technology and virtual classroom (or virtual learning environment)-related technology.[24,49] Videoconferences or web conferences could provide live interactions and simultaneous communications through videoconference modalities, such as Adobe Connect and Cisco Webex. Besides the characteristics of web conferences, virtual classrooms or virtual learning environments could also be accompanied by auxiliary functions enhanced by advanced technology to facilitate learning, such as Second Life.[24] Two studies used virtual classrooms, whereas five studies mainly used videoconferences.[11,24] Although SDE with auxiliary functions was expected to prove effective, the subgroup analysis did not observe significant differences. Throughout their life span of decades, SDE modalities have gone through evolutions.[2] In early years, most studies only adopted videoconference (Cisco Webex) for SDE[27]; in later years, studies have used advanced modalities equipped with various auxiliary functions to improve the quality of videoconference.[24]

However, technical difficulties such as Internet problems were reported as the main challenges in some eligible studies,[12,13,24] which may have undermined the effects and reduced satisfaction with the SDE modalities utilised in these studies. On the one hand, the technology is developing rapidly; on another, the demands and expectations will increase with the development of technology. Additionally, the unfamiliarity of students and faculty members with the use of SDE tools was reported to possibly aggravate problems with technology.[13] In this sense, pre-training for students and faculty members to improve their familiarity with SDE tools may also help reduce detrimental impacts from technical difficulties.

At present, the global educational centres have been forced to close their classrooms and quickly switch to emergency remote teaching (ERT) due to the unprecedented COVID-19 pandemic.[50-53] The rapid (and mandatory) adoption of ODE has been the only choice to maintain regular teaching and learning.[50,54,55] Health science students, in particular, have faced many unprecedented challenges in ERT during the crisis.[56] Being able to provide live interactions and simultaneous communications between students and teachers, SDE was the choice most adopted for health science students to maximise the online communications and interactions with teachers.[2,50,53,57] This crisis is unlikely to end anytime soon, and the situation may last into 2022,[58] raising concerns about the quality of education.[51] To some extent, the findings in our study might provide indirect implications for education systems in response to the COVID-19 pandemic. In view of there being no significant difference between SDE and traditional education in effectiveness, concerns about the quality of education might mitigate to some extent. Before the COVID-19 pandemic, SDE had already been used in the international education for health science students from all over the world,[46] and in the

cross-campus teaching to ensure the equality in education for health science students from different campuses.[6,7] In this sense, SDE might function well as ERT in the rapid response to the COVID-19 pandemic and other infectious disease outbreaks to provide courses for health science students beyond geographical restrains without foregoing interactions and communications with teachers and other students. Moreover, the current accelerated and forced adoption of SDE during this crisis might generate data to help improve its technologies and modalities.[51,54,59] However, it is crucial to note that the ERT during this crisis is not equal to ODE in normal times.[60] All studies of SDE included in our analysis were attended voluntarily by students and teachers, started with small sample sizes, built up cautiously and were conducted with reasonable support from technical teams and designers. However, the reluctance and anxieties of students and teachers and the inadequate preparation for technological support in some education centres might cripple the acceptance and effectiveness of SDE during the COVID-19 pandemic.

4.1 | Strengths and limitations

This is the first systematic review and meta-analysis that identified the effectiveness of SDE compared to conventional face to face education for health science students. More importantly, this study meets a current critical demand from health science education due to the COVID-19 pandemic: the adoption of ODE strategies to maintain learning quality and routines for health science students. In addition, only RCTs were included in our study to ensure the quality of evidence.

Despite its valuable outcomes, this study had some limitations. First, because of the ethnical problem and the variable compliance of students to the requirements of educational studies, it is hard to carry out experimental studies with randomisation in the scope of education. Hence, only seven RCTs were eligible for our study, most of which were carried out with a small sample size at a single institution. Second, the RCT frame might be problematic in education intervention as Norman and Cook raised their concerns about for educational studies.[22,23] However, we did a further sensitivity analysis for the external validity by additionally incorporating relevant two-group studies without randomisations and the overall results did not change. Third, the eligible RCTs in our analysis were not conducted under the circumstance of the COVID-19 pandemic. There is bias for SDE in teaching contents, because the education in previous educational trials might be more appropriate for SDE rather than courses forced to go distance-only due to COVID-19. Our study might not give direct implications to the COVID-19 response for the education systems in health science.

5 | CONCLUSIONS

In our study, there were no significant differences found between SDE and traditional education in objective assessments, and SDE was acceptable in subjective evaluations with higher satisfaction ratings than traditional education, indicating that SDE was neither better nor worse than traditional education but was preferred to some extent. No significant moderators were observed, and only factors with a trend to impact pooled results were found, which included formats, access to archives and learning times. Our findings might provide indications for the development and adoption of online remote education in health science centres. Moreover, the present study might generate discussions as a possible way for health science education centres to deal with the current COVID-19 pandemic to some extent. Future studies addressing newly developed SDE technologies and large-scale RCTs about SDE are required to further verify the results of this study.

ACKNOWLEDGEMENTS

The authors are grateful to the Staff of the Peking Union Medical College Hospital and all who actively participated in the study.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

ZHB had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. ZHB, HLY and YN conceived and designed the study. HLY, ZHB and XLL involved in relevant database search and study selection. HLY, YN and ZHJ extracted and coded the data. HLY, ZHB and LYX involved in quality assessments of the eligible studies. HLY, ZHB and SQ confirmed the statistical analysis. HLY and ZHB involved in statistical analysis. HLY, ZHB and PF examined the methodology. HLY and ZHB drafted the manuscript. HLY, PF, LW, XLL, ZHB and LYX critically revised the manuscript for important intellectual content. ZHB obtained funding. Zhang involved in administrative, technical and material support. Zhang supervised the study. All authors have approved the final article.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: He L, Yang N, Xu L, et al. Synchronous distance education vs traditional education for health science students: A systematic review and meta-analysis. *Med Educ*. 2021;55:293–308. https://doi.org/10.1111/medu.14364