

Neurological diseases educational interventions systematic review search strategy. Final day of search 8th September 2023.

Search strategy: OVID- Medline and Embase

#	[MEDLINE AND EMBASE]
1.	exp Neurosurgery/ or exp Neurology/ or exp Neuroscience/
2.	((neuro* adj3 medical adj3 education) or (neuro* adj3 teach*) or simulat* or (virtual adj3 real*) or gamif* or (neuro* adj3 educat* adj3 intervent*) or (neuro* adj3 educat* adj3 innovat*) or neurophobia).mp.
3.	((neuro* adj3 student) or (Health* adj3 student*) or trainee* or resident* or doctor* or (allied adj3 health*) or (health* adj3 profess*)).mp.
4.	1 AND 2 AND 3

CENTRAL: 8th September 2023

#1	MeSH descriptor: [Neurology] explode all trees	MeSH	1018
#2	MeSH descriptor: [Neurosurgery] explode all trees	MeSH	229
#3	MeSH descriptor: [Neurosciences] explode all trees	MeSH	266
#4	([neurophob* OR neurosurg* OR neurolog* OR neuroscienc*]:t,ab,kw	5	Limits 39449
[Word variations have been searched]			
#5	#1 OR #2 OR #3 OR #4	Limits	39648
#6	MeSH descriptor: [Simulation Training] explode all trees	MeSH	1477
#7	MeSH descriptor: [Virtual Reality] explode all trees	MeSH	1039
#8	MeSH descriptor: [Education, Medical] explode all trees	MeSH	4114
#9	MeSH descriptor: [Video Games] explode all trees	MeSH	1062
#10	MeSH descriptor: [Teaching] explode all trees	MeSH	5636
#11	([Neurology NEXT education]:t,ab,kw AND ([innovation OR intervention OR "virtual reality" OR simulation OR gamif*]:t,ab,kw	5	Limits 13
[Word variations have been searched]			
#12	#5 OR #7 OR #8 OR #9 OR #10 OR #11	Limits	10089
#13	MeSH descriptor: [Students, Health Occupations] explode all trees	MeSH	2637
#14	([Neuro* NEXT student]:t,ab,kw OR ([Health NEXT student]:t,ab,kw OR [trainee* OR resident* OR doctor* OR intern*]:t,ab,kw	5	Limits 136364
[Word variations have been searched]			
#15	#13 OR #14	Limits	138402
#16	#5 AND #12 AND #15	Limits	72

Supplementary Figure 1 Search strategy

6	Search 4 for 10-2025000-2025001 [September 01, 2023 to May 31st, 2025]	219	Advanced	Display Results	More
7	remove duplicates from 6	222	Advanced	Display Results	More

1st JUNE 2025- 169 papers

CENTRAL 1st JUNE 2025

-	+	#1	MeSH descriptor: [Neurology] explode all trees	MeSH	112
-	+	#2	MeSH descriptor: [Neurosurgery] explode all trees	MeSH	152
-	+	#3	MeSH descriptor: [Neurosciences] explode all trees	MeSH	143
-	+	#4	((neurophob* OR neurosurg* OR neurolog* OR neuroscienc*)\$).ab,kw	Limits	43596
-	+	#5	#1 OR #2 OR #3 OR #4	Limits	43660
-	+	#6	MeSH descriptor: [Simulation Training] explode all trees	MeSH	1819
-	+	#7	MeSH descriptor: [Virtual Reality] explode all trees	MeSH	1448
-	+	#8	MeSH descriptor: [Education, Medical] explode all trees	MeSH	4800
-	+	#9	MeSH descriptor: [Video Games] explode all trees	MeSH	1315
-	+	#10	MeSH descriptor: [Teaching] explode all trees	MeSH	6167
-	+	#11	((Neurology NEXT education)\$).ab,kw AND (innovation OR intervention OR "virtual reality" OR simulation OR gamif)\$).ab,kw	Limits	15
-	+	#12	#6 OR #7 OR #8 OR #9 OR #10 OR #11	Limits	11568
-	+	#13	MeSH descriptor: [Students, Health Occupations] explode all trees	MeSH	3362
-	+	#14	(Neuro* NEXT student\$).ab,kw OR (Health NEXT student\$).ab,kw OR (trainee* OR resident* OR doctor* OR intern*)\$.ab,kw	Limits	150766
-	+	#15	#13 OR #14	Limits	153396
-	+	#16	#5 AND #12 AND #15	Limits	103

103-

16 studies met criteria

Supplementary Figure 2. Repeat Search results. 1st June 2025.

Supplementary Table 1. Studies exclusively assessing educational interventions by learning reaction (K&K Level 1)

Study (Author/Year)	Disease Area	Intervention	Method (virtual vs non virtual)	Type of study	Objective of intervention	Audience	Main outcome (s)	Findings
Damon Et al. Oper Neurosurg 2023.[31]	Spinal Cord	Simulation vs cadaveric models	Virtual and Non-virtual	Observational	Treatment	Specialist	Learner perception	High satisfaction with simulator.
Ledwos et al Oper Neurosurg 2020.[30], [34]	Spinal Cord	Virtual reality (VR) simulation	Virtual	Observational	Treatment	Specialist	Face, content and construct validity of the simulator	Intervention showed face, content and construct validity.
Milner et al. Eur Arch Otorhinolaryngol 2020. [34]	Brain	Simulation: ovine vs porcine model	Virtual	Observational	Treatment	Specialist	Face, global content and task specific content validity	Ovine model was statistically superior to the porcine model across most validation criteria, excluding realistic appearance of skin, identification and ligation of the trans-oral parotid duct and facial nerve grafting.
Bairamian et al. Neurosurgery	Brain	VR angiogram vs 3D printed	Virtual	Observational	Treatment	Specialist	Face, content and construct	The VR angiogram

2019. [33]		angiogram						validity and practicality	was better for resolution; the 3D model was better for depth perception and manipulation. The synthetic trainer was easier to use. All groups improved their post intervention scores.
Herder et al. Mil Med 2019. [27]	Brain	Swine vs synthetic model for lateral canthotomy	Virtual	Observational	Treatment	Specialist and medical student	Post intervention score		Subjects found the intervention to be beneficial to training. Reduced puncture times and fluoroscopy times were noted.
Yu et al. World Neurosurg 2019. [29]	Spinal Cord	Mixed Reality (MR) for pre-op planning	Virtual	Observational	Treatment	Specialist	Participant Feedback		Reduced puncture times and fluoroscopy times were noted.
Breimer et al. Oper Neurosurg 2017. [32]	Brain	Endoscopic third ventriculostomy (ETV) simulator	Virtual	Observational	Treatment	Specialist	Participant feedback		VR is helpful for learning anatomy and decision-making, while the physical simulator aided manual

Gasco et al. World Neurosurg 2013. [28]	Brain	Haemostasis simulator	Virtual	Observational	Treatment	Specialist and medical student	Participant Feedback	dexterity and technical skills. Participants deemed the intervention suitable for training and important for developing career interest in medical students.
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Supplementary Table 2. Studies exclusively assessing by learning assessment (K&K Level 2).

Study (Author/Year)	Disease Area	Intervention	Method (virtual vs non virtual)	Type of study	Objective of intervention	Audience	Main outcome (s)	Findings
Nasciento et al. Epileptic Disord. 2024;26(4):444-459.	Brain	Epileptiform diagnosis task feedback via web or phone application vs control	Virtual	Randomized controlled trial (RCT)	Diagnosis	Specialists	Knowledge	Intervention groups > control.
Zhang et al. BMC Med Educ. 2024.	All	Flipped classroom vs control	Non-virtual	RCT	Diagnosis	Specialists	Knowledge	Intervention group > control.
Yohannan et al. BMC Med Educ. 2024.	Brain	3 Dimensional (3D) teaching (stereoscopic group / monoscopic group) vs control for neuroanatomy	Virtual	RCT	Diagnosis	Medical students	Knowledge	Both interventions groups > control.
Yilmaz et al. J Surg Educ. 2024.	Brain	Type of feedback (4 types) vs control. .	Virtual	RCT	Treatment	Medical students	Knowledge	Intervention groups > control.
Pitts et al. Am J Speech Lang Pathol. 2023.	All	Cadaver group vs control group	Non-virtual	Observational	Diagnosis	Medical Student	Knowledge	Intervention group > control.
Mohammadi et al. Iran J Pediatr. 2023. [38]	Brain	In person vs. virtual electroencephalogram (EEG) training.	Both	Observational	Diagnosis	Specialists	Knowledge	Both groups improved post intervention with no significant

								difference between groups.
Philbrick et al. World neurosurg 2023. [39]	Brain	Identifying Kocher's point with navigation vs control	Virtual	RCT	Treatment	Medical students	Time and accuracy of identification	Intervention > control
Kiyofuji et al. Oper Neurosurg 2023. [40]	Brain	Slides vs simulator (intervention)	Virtual	RCT	Treatment	Specialists	Objective measure score	No significant difference between groups
Na et al. Anat sci educ 2022.[41]	Brain	Art training vs control	Non-virtual	RCT	Diagnosis	Medical students	Knowledge	Both groups improved
Mei-ling et al. Nurse educ today 2022. [42]	Brain	VR simulator vs lecture (control)	Virtual	Observational	Diagnosis and treatment	Allied professionals	Knowledge	Intervention > control
Shah et al. J Ultrasound Med 2021. [43]	All	Ultrasound participants vs control	Non-virtual	Observational	Examination	Medical students	Knowledge score	No difference in performance
Bornkamm et al. Neurology 2021. [44]	All	Blended teaching vs traditional teaching	Virtual	Observational	Examination	Medical students	Knowledge score	Intervention group > control
Greuter et al. Neurosurg focus 2021. [45]	Brain	3D VR vs control	Virtual	RCT	Diagnosis	Specialists and Medical students	Time to aneurysm detection	Aneurysm detection time better in intervention arm
Wang et al. World Neurosurg 2020.[46]	Brain	Microsurgical space restrictor vs control	Virtual	RCT	Treatment	Specialists	Objective post intervention test	Intervention > control

Ros et al. neurochirurgie 2020. [47]	Brain	Technical note + VR simulation vs control	Virtual	RCT	Treatment	Medical students	Knowledge score	Intervention group > control
Argalious et al. J Cardiothorac Vasc Anesth 2019. [35]	Spinal Cord	Simulation vs problem-based learning (PBL)	Virtual	RCT	Treatment	Specialists	Composite score	No significant difference between groups
Meurer et al. otol neurotol 2019. [48]	Brain	Narrated slides and vignettes vs control	Non-virtual	RCT	Diagnosis	Specialists	Knowledge	Intervention group > control
Shi et al. World Neurosurg 2018. [36]	Spinal Cord	Virtual surgery vs cadaver (control)	Virtual	RCT	Treatment	Specialists	Screw penetration rate	Intervention group > control
Ciechanski et al. World Neurosurg 2017. [49]	Brain	Transcranial direct stimulation vs control	Virtual	RCT	Treatment	Medical students	Change in amount of Tumour resected post intervention	Intervention group > control
Arantes et al. Anat Sci Educ 2017. [18]	All	Course vs control (non-attendance)	Non-virtual	observational	Diagnosis	Non-specialists	Knowledge	Intervention arm > control
Clarke et al. BMC Medical Educ 2016. [50]	Brain	Instrument trainer + simulator vs control	Virtual	RCT	Treatment	Specialists	Total score	Intervention group > control
Belykh et al. J Neurosurg 2016. [51]	Brain	Human placental vessels vs bovine placental vessels	Non-virtual	Observational	Treatment	Specialists and medical students	Anastomosis assessment score	Both beneficial models with face, content, construct validity

Thawani et al. J Clin Neurosci 2016. [52]	Brain	Simulator vs control	Virtual	observational	Treatment	Specialists	Performance score	Intervention > control
Shah et al. Oper Neurosurg 2016.[53]	Brain	3D simulator vs lecture (control)	Virtual	Observational study	Diagnosis	Specialists	Knowledge	Intervention > control
Kockro et al. Ann Anat 2015. [54]	Brain	Lecture + 3D intervention vs control	Virtual	RCT	Diagnosis	Medical students	Knowledge	Intervention non-inferior to control.
Patel et al. Neurol Res 2014. [55]	Brain	Simulator vs control	Virtual	observational	Treatment	Medical students	Knowledge score for identifying structures	Intervention > control
Johnson et al. Med Teach 2013. [56]	Brain	Group learning vs. individual (control)	Non-virtual	RCT	Diagnosis	Medical students	Knowledge	Intervention > control
Park et al. Med Teacher 2011. [57]	All	No feedback vs written only vs written and verbal	Non-virtual	RCT	Examination	Medical students	Knowledge	Written and verbal feedback had the greatest scores.
Schuh et al. J Clin Neurophysiol 2008. [58]	All	Weekly presentations + game vs didactic (control)	Non-virtual	observational	Examination	Medical students	Knowledge score for neurophysiology and overall USMLE	Intervention group > in neurophysiology . No difference in USMLE.
Ochoa et al. Teach Learn Med 2008. [59]	Brain	Web- based teaching vs traditional (control)	Virtual	RCT	Diagnosis	Medical students	Knowledge score	Intervention group > control

Levinson et al. Med Education 2007. [60]	Brain	Learner control vs programme control	Virtual	RCT	Diagnosis	Medical students	Knowledge	Programme control group attained the best score.
Schuh et al. Neurologist 2007. [37]	All	Weekly team oral/ written quiz intervention vs. control	Non- virtual	observational	Examination	Specialists	Knowledge score	Team quizzing improved scores the most.

Supplementary Table 3 Studies assessing educational interventions by behavioural changes (K&K level 3) or a combination of K&K Levels.

Study (Author/Year)	Disease Area	Intervention	Method (virtual vs non virtual)	Type of study	Objective of intervention	Audience	Main outcome(s)	K&K level	Findings
K&K Level 3									
Saposnik et al. MDM Policy Pract 2019[62]	Brain	Simulated reflection-based intervention vs control	Non-virtual	Randomized controlled trial (RCT)	Treatment	Specialist	Reduction in therapeutic inertia	3	Intervention > control.
Sundar et al. J Neurosurg 2016.[61]	Spinal Cord	Simulation with navigation + cadaveric models vs control	Virtual	Observational	Treatment	Specialist	Surgical error	3	Intervention > control
K&K Combination									
Koka et al. J Med Internet Res. 2025.	Brain	E-learning group vs Video group	Virtual	RCT	Diagnosis and Treatment	Medical students and Allied Health Professionals (AHPs)	Knowledge and satisfaction	1 and 2	Both groups improved; however, intervention group > comparator group.
Xuan et al. BMC Med Educ. 2024.	Brain	Database learning vs control.	Virtual	Observational	Diagnosis	Medical Students	Knowledge and satisfaction	1 and 2	Intervention > control.
Li et al. BMC Med Educ. 2024.	All	Online course vs control group.	Virtual	RCT	Diagnosis and Treatment	Medical students	Knowledge and satisfaction	1 and 2	Intervention > control.

Toro J, et al. <i>BMJ Res Notes</i> . 2023;16(1):307. [68]	All	Didactic teaching vs virtual	Virtual and non-virtual	Observational	Examination	Medical students	Knowledge and satisfaction	1 and 2	No clinically significant difference in test results.
Robertson et al. <i>J Neurosurg</i> . 2023. [69]	Brain	Simulation + didactic vs simulation alone (control group)	Virtual	Observational	Treatment	Specialists	Scores on objective assessment of neurosurgical skill	2 and 3	Intervention group had improved technical skills and those early in their career showed a change in behaviour
Tarolli et al. <i>Neurology</i> 2023. [70]	All	Team based learning intervention. Pre- vs Post-intervention scores.	Non-virtual	Observational	Diagnosis	Medical students	Student opinion	1 and 2	Non-inferior results in the post-intervention group
Fazlollahi et al. <i>JAMA network open</i> 2022. [71]	Brain	Feedback from either a Virtual Operator Assistant, VOA (VOA group) or a remote instructor (instructor group) vs no feedback (control)	Virtual	RCT	Treatment	Medical students	Procedural score and blinded Objective Structured Assessment of Technical Skills (OSATS) for VR tumour resection	1 and 2	VOA group > instructor and control group.

Rajan et al. BMC Med Educ 2022. [72]	Brain	Interactive e-module vs Wikipedia page without interaction (control)	Virtual	RCT	Diagnosis and treatment	Medical students	Knowledge, enjoyability, engagement and usefulness	1 and 2	Intervention was more engaging, useful and enjoyable. No difference in quiz scores between the two groups.
Jiang et al. Medicine 2022. [73]	Brain	3D printing + PBL vs traditional teaching (control)	Virtual	Observational	Diagnosis	Medical students	Knowledge and clinical practice skills	1 and 2	Intervention > control, in terms of scores, satisfaction, learning interest and spatial thinking ability.
Shen et al. BMC Med Educ 2022. [74]	All	CBL-PBL vs traditional teaching (control)	Non-virtual	RCT	Diagnosis	Medical students	Satisfaction and knowledge and self-assessed competence	1 and 2 and 3	Intervention > control. Members of the intervention group were more interested and more often recruited to neurosurgery.
Kong et al. Ann Palliat Med. 2021. [75]	All	Microlecture vs control	Virtual	RCT	Diagnosis	Medical students	Teaching effect, theoretical operation, and clinical practice satisfaction	1 and 2	Intervention > control

Perin et al. World Neurosurg 2021. [64]	Brain	Pre-op planning using 3D navigation CT-MADE vs 2D traditional neuro- navigation for surgical planning (control)	Virtual	Observational	Treatment	Specialists	Surgical procedure and patient outcome	1 and 4	No difference between the 2 groups in procedure duration or post-op visual impairment. Simulated craniotomies were significantly smaller than the real ones. The simulator helped residents improve their anatomic and procedural comprehension and was deemed a useful aid to ensure safety.
Rezende et al. Anat Sci Educ 2020. [76]	All	Team based learning vs traditional lectures (control)	Non- virtual	Observational	Diagnosis	Medical students	Knowledge acquisition and perception	1 and 2	Knowledge acquisition was similar between TBL and traditional lectures. TBL was associated with greater acceptance, higher

									motivation and better student perception.
Roth et al. J Grad Med Educ 2020. [77]	All	Written modules vs podcasts	Virtual	RCT	Diagnosis and treatment	Specialists	Knowledge and satisfaction	1 and 2	All groups improved post-intervention Podcast group had higher satisfaction.
Sun et al. World Neurosurg 2018. [66]	Spinal Cord	Problem-based simulation learning vs traditional teaching (control) in performing a lumbar puncture (LP)	Virtual	Observational	Treatment	Specialists	Knowledge scores. Extent that residents are ready to perform LP. Successful LPs.	1 and 2	No difference in knowledge scores. Intervention > control at readiness and success in performing LP.
Stepan et al. Int Forum Allergy Rhinol 2017. [78]	Brain	VR interactive model vs online textbook (control)	Virtual	RCT	Diagnosis	Medical students	Knowledge	1 and 2	No difference in anatomy knowledge between the groups. The VR group found the learning experience to be significantly more engaging, enjoyable and useful.

Boody et al. Global Spine J 2017. [67]	Spinal Cord	40-minute bio-skills training module vs self-directed study (control)	Virtual	Observational	Treatment	Medical students and Specialists	OSATS and self reported score.	1 and 2	Intervention > control.
Rampinelli et al. World Neurosurg 2017. [79]	Brain	2D vs 3D in the endoscopy	Virtual	Observational	Treatment	Specialists	Time needed to complete each task	1 and 2	3D technology conferred an advantage in terms of time of execution and user comfort.
Moisi et al. World Neurosurg 2017.[63]	Spinal Cord	Microscope vs exoscope (extracorporeal video microscope)	Virtual	Observational	Treatment	Specialists	Time of procedure, grading of decompression, complications	1 and 4	No difference in procedure time or complications. Greater comfort with exoscope.
Hsu et al. Nurse Educ today 2016. [80], [81]	All	Outcome based course design vs control	Non-Virtual	RCT	Treatment	Allied professionals	Nursing competency and satisfaction	1 and 2	No statistically significant difference in nursing competency score between groups. Satisfaction higher in intervention group.
Yang et al. BMC Med Educ 2014. [82]	All	Group A: Team based learning (TBL) + Lecture based	Non-Virtual	RCT	Diagnosis and treatment	Medical students	Knowledge test and satisfaction	1 and 2	Groups A and B had similar scores, both of which were significantly

		learning (LBL); Group B: LBL only; Group C: TBL only							higher than group C. Theoretical and total scores for group A were significantly higher than groups B and C. All participants in group A were satisfied with TBL + LBL. No differences in exam scores between groups. AHPs in CBI group spent less time studying. No major preference between students.
Willett et al. J Allied Health 2008. [81]	All	Computer based instruction (CBI) vs lecture-based teaching (control)	Non-Virtual	RCT	Treatment	Allied professionals	Exam scores, study time and student opinions	1 and 2	No differences in exam scores between groups. AHPs in CBI group spent less time studying. No major preference between students.
Heckmann et al. Eur J Neurol 2008. [83]	All	Peer taught vs experienced teachers (control)	Non-Virtual	RCT	Examination	Medical students	Knowledge	1 and 2	No difference between groups. Self-assessed learning success was rated equally.

Holloway et al Ann intern med 1999. [65]	Brain	Combined education strategy in dementia care vs control group	Non- Virtual	RCT	Treatment	Specialists	Adherence to recommendations , based on survey + patient chart review	3 and 4	Intervention group >control group.
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Supplementary Table 4. Newcastle Ottawa Scale risk of bias assessment

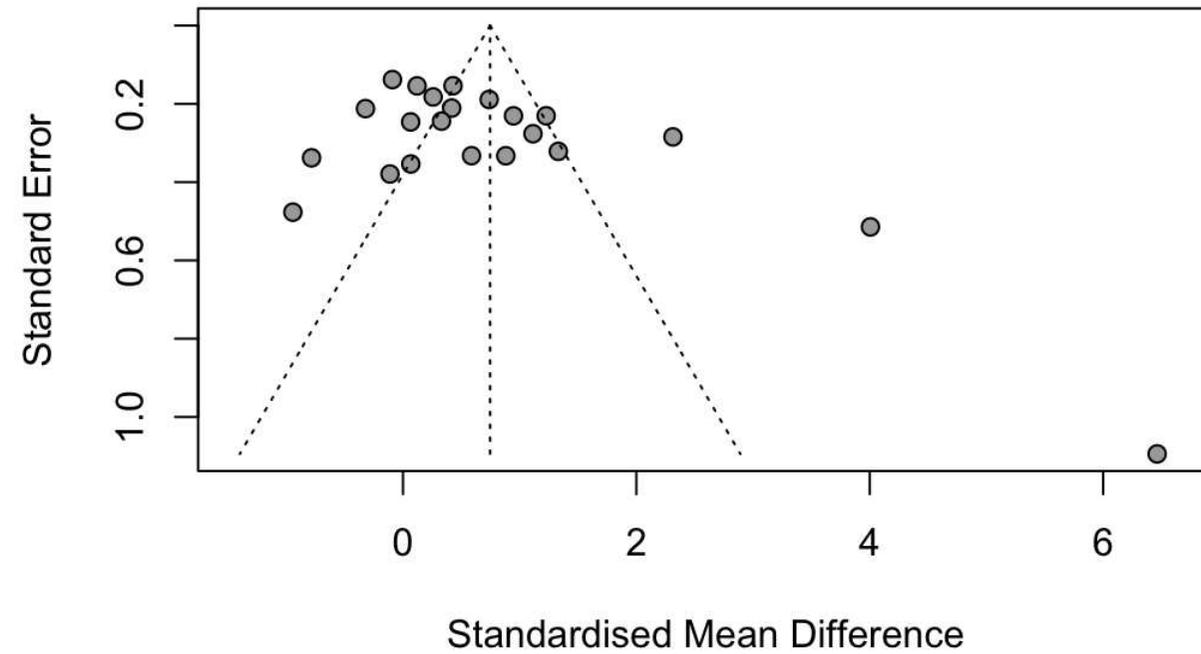
Study ID	Selection			Comparability (2)	Outcome			Total (9)	
	Representativeness of Cohort (1)	Selection of non- exposed cohort (1)	Ascertainment of exposure (1)		Outcome present at start of study (1)	Assessment of outcome (1)	Follow up length (1)		Adequacy of follow up (1)
Damon Et al. Operative Neurosurgery 2023	1	1	1	1	-	-	1	1	6
Toro J, et al. ÊBMC Res Notes. 2023.	1	1	1	1	1	-	1	1	7
Robertson et al. J Neurosurg. 2023	1	1	1	1	-	1	1	1	7
Mohammadi et al. Iran J Pediatr. 2023	1	1	1	1	-	-	1	1	6
Tarolli et al. Neurology 2023	1	1	1	1	-	-	1	-	5
Bornkamm et al. Neurology 2021.	1	1	1	1	-	-	1	1	6
Jiang et al. Medicine 2022.	1	1	1	1	-	1	1	1	7
Mei-ling et al. Nurse educ today 2022.	1	1	1	1	-	-	1	-	5
Shah et al. Oper Neurosurg 2016.	1	1	1	1	-	1	1	-	6
Perin et al. World	1	1	1	-	-	-	-	-	3

Neurosurg 2021. Ledwos et al	1	1	1	1	1	1	1	-	7
Oper Neurosurg 2020. Rezende et al.	1	1	1	1	1	-	1	1	7
Anat Sci Educ 2020. Milner et al. Eur Arch Otorhinolaryngol 2020.	1	1	-	1	-	-	1	1	5
Bairamian et al. Neurosurgery 2019.	1	1	-	1	-	-	1	1	5
Herder et al. Mil Med 2019.	1	1	1	1	-	-	1	-	5
Yu et al. World Neurosurg 2019.	1	1	1	1	-	-	1	-	5
Breimer et al. Oper Neurosurg 2017.	1	1	1	1	-	-	1	-	5
Boody et al. Global Spine J 2017.	1	1	1	1	1	1	1	1	8
Rampinelli et al. World Neurosurg	1	1	1	1	-	-	1	1	6
Moisi et al. World Neurosurg 2017.	1	1	1	1	-	1	1	-	6
Arantes et al. Anat Sci Educ 2017.	1	1	1	1	1	1	1	1	8
Belykh at al. J Neurosurg 2016.	1	1	1	1	-	1	-	-	5
Sundar et al. J Neurosurg 2016	1	1	1	1	1	1	1	1	8

Thawani et al. J Clin Neurosci 2016.	1	1	1	1	-	1	1	1	7
Patel et al. Neurol Res 2014	1	1	1	1	-	1	-	1	6
Schuh et al. J Clin Neurophysiol 2008.	1	1	1	1	1	1	1	-	7
Schuh et al. Neurologist 2007.	1	1	1	1	1	1	1	-	7
Sun et al. World Neurosurg 2018.	1	1	1	1	-	1	1	-	6
Shah et al. J Ultrasound Med 2021.	1	1	1	1	-	1	1	-	6
Gasco et al. World Neurosurg 2013.	1	1	1	1	-	-	1	-	5
Pitts et al. Am J Speech Lang Pathol. 2023.	1	1	1	1	1	1	1	1	8

Intention-to-treat	Unique ID	Study ID	Experimental	Comparator	Outcome	Weight	D1	D2	D3	D4	D5	Overall	D1	D2	D3	D4	D5	Overall	
	16	1	traditional teaching	microlecture teaching	Knowledge	NA	!	!	+	!	!	!							
	20	4	Presentation + vignettes	No intervention	Knowledge on post inter	NA	+	+	+	+	!	!							
	21	5	transcranial direct current	control	Change in amount of tu	NA	+	+	+	+	+	+							
	23	7	Instrument trainer + simu	control (just simulator)	time saved, number of i	NA	+	!	+	+	!	!							
	24	8	Computer based instructi	Control	Exam scores, study tim	NA	!	!	+	+	!	!							
	25	9	Simulation	control	Screw penetration rate	NA	!	!	+	!	!	!							
	27	11	written modules	podcast modules	Knowledge with a pre ar	NA	!	!	+	+	!	!							
	28	12	peer instructors	clinical instructors (control)	Students' practical skills	NA	+	+	+	+	!	!							
	29	13	Team based learning	lecture based learning	Score on Knowledge ter	NA	!	!	+	+	!	!							
	30	14	feedback (VOA/ remote li	no feedback	1) Change in procedura	NA	+	+	+	+	+	+							
	31	15	CBL-PBL	Traditional	Self-perceived compet	NA	+	!	+	+	!	!							
	38	19	2D + audio	3D + audio	Score on Knowledge M	NA	+	!	+	+	!	!							
	39	20	3D VR model	2D	time to aneurysm deter	NA	!	!	+	+	!	!							
	42	22	VR	control	Improvement in achiev	NA	!	+	+	+	!	!							
	44	23	with navigation	without navigation	Time required to identif	NA	+	+	+	+	!	!							
	46	24	Simulator	Control	objective measures (re	NA	!	!	+	+	!	!							
	64	25	space restrictor	control	Smart score	NA	+	!	+	!	!	!							
	100	27	VRNET	Standard patient	NPE score	NA	+	+	+	+	+	+							
	106	29	Database learning	Traditional	Performance on post-i	NA	!	+	+	!	+	!							
	107	30	SPOC+ PBL	LBL	Performance on post-i	NA	!	+	+	!	!	!							
	109	31	ADDIE	Traditional	Assessment score follow	NA	+	+	+	!	+	!							
	110	32	AnaVu (stereo/mono)	Control	Performance on post-i	NA	+	+	+	!	+	!							
	112	34	Feedback (neurosurgical	No Feedback	Performance on post-i	NA	+	!	+	!	!	!							
	115	35	TLS intervention	Control	NA	NA	+	+	+	+	+	+							
	116	36	educationa intervention	control	NA	NA	+	!	+	+	+	!							
Per-protocol	Unique ID	Study ID	Experimental	Comparator	Outcome	Weight	D1	D2	D3	D4	D5	Overall	D1	D2	D3	D4	D5	Overall	
	17	2	Learner controlled e-learn	Programme controlled e le	Knowledge on post inter	NA	!	!	+	+	!	!							
	19	3	Feedback	No feedback	Performance on post int	NA	!	+	+	+	!	!							
	22	6	Outcome based design	control	Nursing competency	NA	+	+	+	+	!	!							
	26	10	technical note + VR	technical note (control)	Score on learning outco	NA	!	+	+	+	!	!							
	32	16	Web based teaching	Control	Score on MCQ on knowl	NA	+	+	+	+	!	!							
	33	17	e-module	wiki page	difference in perception:	NA	+	+	+	+	!	!							
	36	18	art training	control	Mental rotations test t	NA	+	+	+	+	!	!							
	41	21	individual	team	Post simulation knowle	NA	+	+	+	+	!	!							
	69	26	simulation	PBL	ANTS global rating	NA	+	+	+	+	!	!							
	105	28	Video tutorials (web brow	No intervention	EEG test score	NA	!	+	+	+	+	!							
	111	33	e-Learning group	Video group	Knowledge acquisition	NA	!	+	+	+	+	!							

Supplementary Figure 3. Cochrane risk of bias assessment for Randomized Controlled Trials



Supplementary Figure 4. Funnel plot of Randomized Controlled Trials in Forest plot.