BEME Collaboration

REVIEW PROTOCOL

Remediation interventions for undergraduate and postgraduate medical learners with academic difficulties: a BEME systematic review

April 27th 2017

Abstract

Background: Medical school and residency training are demanding programs. Most learners will complete their training without significant difficulties. However, 10-15% will experience some problem during their program. One of the barriers for which clinical teachers often struggle to report unsatisfactory trainee performance is the lack of available remediation options for the trainee. Most remediation interventions do not appear to be based on explicit conceptual frameworks and are focused more on advice than they are evidence-based.

Objective: To identify evidence-based remediation interventions for undergraduate and postgraduate medical learners with academic difficulties and link them to a theory-based conceptual framework.

Methods: This systematic review will search MEDLINE, CINAHL, EMBASE, ERIC, Education Source and PsychINFO based on the following concepts: 1) medical education, 2) professional competence of difficulty and 3) educational support from January 1st 1990 to December 31st 2016. Relevant non-indexed journals will be hand searched and experts in the field will be contacted to ensure a comprehensive search. Studies will be included in the review if they meet the following criteria: primary research studies, innovation reports and reviews describing at least one remediation intervention (individualized additional teaching) for undergraduate or postgraduate medical learners in difficulty. Data will be extracted following Michie's Behaviour Change Techniques (BCT) Taxonomy and program evaluation models from Stufflebeam and Kirkpatrick (modified version). The quality of each included study will be assessed using the Mixed Methods Appraisal Tool. The synthesis of extracted evidence will include descriptive analyses and meta-analyses when possible.

Relevance and translation into practice: Mapping remediation interventions under a taxonomy based on a theoretical domains framework will be helpful 1) to identify the most effective BCT in medical education and build upon them and their associated theories and 2) identify unexplored BCT to inspire developments that might be of interest for medical learners in difficulty. This review will also encourage the use of the most effective evidence-based remediation strategies and will help identification of program evaluation gaps to stimulate further educational scholarship and research in the field. It will provide clinical teachers and educators with a repertoire of evidence-based interventions that could be used for assessment, mentoring and faculty development purposes.

Key words: medical education, professional competence, learning difficulties, remedial teaching, teaching methods

Review team

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Miriam Lacasse is a family physician and assistant professor at the Department of Family Medicine and Emergency Medicine, Université Laval (Quebec City, Canada). She co-chairs the QMA-CMA-MD Educational Leadership Chair in Health Professions Education and is the evaluation director for the family medicine residency program. She is involved in the teaching of undergraduate and postgraduate medical learners, mostly in the clinical setting. She teaches graduate degree courses about medical education principles and practices as well as scholarship in health sciences education. She is involved in faculty development and counselling regarding learners in difficulty. She works part-time clinically in a family medicine teaching unit. This is her first BEME review.

Other reviewers (alphabetical)

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Marie-Claude Audétat is a Clinical Professor in Family and Emergency Medicine at Université de Montréal, where she also served as Faculty Development Director, from 2010 to 2014. Since May 2014, she is in charge of the axis of educational research in the Primary Care Unit at the University of Geneva, Switzerland. She is also involved in innovative projects regarding clinical reasoning and faculty development in the Unit of Development and Research (UDREM).

Élisabeth Boileau, MD MSc CCFP(EM)

Élisabeth Boileau is an Emergency physician and an assistant professor in the Department of Family and Emergency Medicine at the Université de Sherbrooke (Quebec, Canada). She is Program Director for the Family Medicine Enhanced Skills residency program. She has completed a Masters degree in Health Sciences Research, where she explored the use of technology to further engage clinical teachers in the field in the evaluation and remediation of medical learners' clinical reasoning difficulties. She is currently completing a second Masters degree in Health Law and Politics, and examining the normative aspects of medical competencies required to improve – and teach – quality and safety of care. She is very involved in undergraduate and postgraduate medical education, in both clinical and academic contexts, and has given various Faculty development workshops, with a particular focus on giving struggling learners meaningful feedback.

Nathalie Caire Fon, MD CCFP

Nathalie Caire Fon is a family physician and an assistant professor in the Department of Family Medicine and Emergency Medicine at the Université de Montréal. She is the Academic Assistant to the office of the Vice-Dean of Undergraduate Studies. Dr Caire Fon is also the Director of Undergraduate Medical Education for the Department of family medicine. Her work in medical education revolves around

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Alexandre Lafleur is a specialist in internal medicine involved in clinical teaching of postgraduate and undergraduate medical learners. He holds a master's degree in health professions education from Maastricht University in the Netherlands, which he obtained in 2014. One of his research interests is competency assessment. Dr. Lafleur has developed a competency-based assessment program and a simulation-based program as the assistant program director of the internal medicine and general internal medicine residency programs at Université Laval. He co-chairs the QMA-CMA-MD Educational Leadership Chair in Health Professions Education at Université Laval.

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Dr. Shirley Lee completed her medical degree at Western University in 1992, followed by her certification in family and emergency medicine at the University of Ottawa in 1995. She completed her masters in education degree at the University of Toronto in 2000. Previously she was the Education Director for the Schwartz/Reisman Emergency Centre, Mount Sinai Hospital, Sinai Health System. She is an associate professor at the University of Toronto. She has been involved in medical education at the undergraduate, postgraduate and faculty development level, nationally and internationally. Her areas of interest are in curriculum development, e-learning, knowledge translation tools, assessment and

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Mathieu Nendaz is an internist at the Geneva University Hospitals and trained in health professions education at the University of Illinois at Chicago. He is currently Director of the Unit of Development and Research (UDREM) and Professor at the Faculty of Medicine, University of Geneva, Switzerland. His research interests include Internal Medicine and Medical Education. In this field, he is particularly interested in decision-making, clinical reasoning, clinical supervision, and interprofessional issues. He is deeply involved in direct teaching, clinical supervision and training, as well as in the development and organization of teaching concepts and medical curriculum.

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Emmanuelle Paquette-Raynard is a medical librarian and liaison to the Faculty of medicine at Université Laval (Quebec City, Canada). She received her Master of Science in Library and Information Science from Université de Montréal in 2016.

Caroline Simard, PhD(c)

Caroline Simard is a doctorate student in the Measurement and Assessment program at Université Laval. In the context of her thesis, she specialises in the measurement and operationalization of university students' adaptation. She realized two meta-analyses already, hence she provides advice about meta-analysis methodology to the team.

Yvonne Steinert, PhD

Yvonne Steinert is a clinical psychologist and Professor of Family Medicine. She is also the Director of the Centre for Medical Education and the Richard and Sylvia Cruess Chair in Medical Education. Her educational interests relate to teaching and learning in medicine, the impact of faculty development on the individual and the organization, and the continuing professional development of faculty members. She authored/co-authored three BEME systematic reviews.

Johanne Théorêt, MD MA FCFP

Johanne Théorêt is a family physician and professor in the Department of Family Medicine and Emergency Medicine, Université Laval (Quebec City, Canada), where she is Director of Faculty Development and Director of the Promotion Committee for the Family Medicine Program. She has completed a Master Degree in Health Sciences Education. She is involved in challenging learners faculty development workshops. She is involved in the teaching of postgraduate medical learners, especially in the clinical setting.

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Sources of support

Background to the topic

Medical training programs are demanding.Most medical learners will complete their training without significant difficulties. However, 10-15% will experience some problem during their program (Faustinella, Orlando, Colletti, Juneja, & Perkowski, 2004; Reamy & Harman, 2006; Yao & Wright, 2000; Yates & James, 2006). Learner difficulties have a huge impact at various levels in medical education. One of the barriers for which clinical teachers often struggle to report unsatisfactory trainee performance is the lack of available remediation options for the trainee (Yepes-Rios et al., 2016).

Undergraduate students (who are in the process of obtaining a medical degree) or postgraduate trainees (known as *residents*, *interns*, *foundation doctors* – who were formerly known as pre-registration house officers and senior house officers), and *specialty registrars*, depending on each country terminology) in difficulty can be defined as "learners who does not meet the expectations of a training program because of a problem with knowledge, attitudes, or skills" (Steinert, 2008). Underlying causes to such problems might involve personal life (health, spouse/family, financial issues, cultural adaptation and social life), teacher (personal life issues or faculty development issues) or environment (learning climate or learning conditions). However, such underlying problems should not excuse competence issues but help to explain the educational diagnosis and plan remediation accordingly (Lacasse, 2009).

Teachers may become discouraged when facing problem learners, particularly for those with behavioural issues (Hicks et al., 2005). At the institution and society levels, learners in difficulty can also have a serious impact on the quality of patient care and safety (Hicks et al., 2005). It is often hard to identify the learner's educational diagnoses and the associated relevant remediation interventions, since there is no consensus about classification systems of learner difficulties nor guidelines for managing difficulties (Boileau, St-Onge, & Audétat, 2017).

Remediation was defined by Guerrasio et al. as "additional teaching above and beyond the standard curriculum, individualized to the learner who without the additional teaching would not achieve the necessary skills for the profession" (Guerrasio, Furfari, et al., 2014) . From a theoretical perspective, most remediation interventions could be attached to a learning theory. For example:

- feedback and monitoring of behaviour refer to operant conditioning (Skinner, 1974) and social learning theories (Bandura, 1986);
- cognitivist methods such as associative learning strategies and concept mapping are inspired from information processing theory (Miller, 1956) and cognitive load theory (Sweller, 1988);
- learning/remediation plans and reflective practice are inspired from humanist theories such as adult learning (Knowles, 1984) and experiential learning (Kolb, 1984);
- role modeling and problem-based learning follow socio-constructivist principles, such as cognitive apprenticeship (Collins, Brown, & Newman, 1987) and situated learning (Lave & Wenger, 1991).

Most studies describing remediation interventions were published without presenting an explicit conceptual framework (Cleland et al., 2013). However, since health professions education is a form of health professional practice development and health professional practices can be seen as a form of behaviour, therefore educational interventions should take advantage of behavioural change theories and strategies in their design. Michie's Behaviour Change Technique (BCT) Taxonomy (Appendix 1) can facilitate understanding of educational interventions by classifying those under 16 groupings that were linked with a "theoretical domains framework", developed to make theory more accessible to, and usable by, a range of disciplines and theoretical orientations (Michie et al., 2015).

Factors suggestive of academic difficulties during undergraduate or postgraduate medical training and educational diagnoses that might be involved are well described in the medical education literature (Cariaga-Lo, Enarson, Crandall, Zaccaro, & Richards, 1997; Stern, Frohna, & Gruppen, 2005; Yates & James, 2006). However, previous reviews (conducted in 2008 (Hauer et al., 2009) and 2012 (Cleland et al., 2013)) concluded that since most remediation interventions are of expert advice and few appear to have been assessed, evidence is lacking to guide best remediation practices in medical education. Although Cleland searched in multiple databases, some relevant databases for medical education were not explored (eg. Education Source and PsycINFO). Their literature review focused primarily on educational measurement and program evaluation. Furthermore, the two literature reviews we could find about remediation interventions (Cleland et al., 2013; Hauer et al., 2009) have extracted their data following the Kirkpatrick hierarchy (Kirkpatrick, 1994) only, that might set aside other program evaluation issues, such as context, input or process (Stufflebeam, 2003).

In summary, most remediation interventions do not appear to be based on explicit conceptual frameworks and are focused more on advice than they are evidence-based. The goal of this review is to identify educational interventions that provide effective strategies to remediate undergraduate and postgraduate medical trainees in difficulty and link them to a theory-based conceptual framework.

Review topic/question(s), objectives and key words

Primary review question:

- What are the outcomes of remediation interventions for undergraduate and postgraduate medical learners with academic difficulties? (Justification review)

Additional questions:

- What are the behaviour change techniques underlying remediation interventions for undergraduate and postgraduate medical learners? (Description review)
- Which contexts, inputs or processes are effective for remediation interventions (Justification review)

According to M. Gordon (2016), the objectives of this review are therefore to describe remediation interventions and to justify their effectiveness regarding their context, input, process and products (outcomes).

Search sources and strategies

This systematic review will search the MEDLINE, CINAHL, EMBASE, ERIC Education Source and PsychINFO databases based on the following concepts: 1) medical education, 2) professional competence mariedifficulty 3) educational support (the keywords to be used and the detailed search strategy are presented in Appendix 2). The literature search will be conducted from January 1st 1990 to December 31st 2016, since development of competency-based curricula arose during the last decade of 20th century (Carraccio, Wolfsthal, Englander, Ferentz, & Martin, 2002).

Articles retrieved in previous reviews about remediation options in medical learning (Cleland et al., 2013; Hauer et al., 2009) were added to the selection process.

Non indexed journals (Pédagogie Médicale, Journal of Italian Medical Education, International Journal of Health and Education Journal de Escola Bahiana de Medicina e Saúde Pública. Revista Ciencias de la Salud, Educación Médica Superior) will be hand searched. Experts in the field will be contacted by email to share any study results relevant to this review.

Study selection criteria

The focus of this review is on remediation interventions for undergraduate and postgraduate medical learners in difficulty. Therefore, articles will be selected if they meet the following criteria:

- ☐ scientific article (primary research studies, innovation reports and reviews)
- ☐ medical discipline
- ☐ learners in difficulty
    - o undergraduate students (before obtention of medical degree)
    - o postgraduate trainees (known as residents, interns, foundation doctors, formerly known as pre-registration house officers and senior house officers, and specialty registrars)
- ☐ at least one remediation intervention is described
- ☐ at least one form of program evaluation is reported

Articles will be excluded if they are only descriptive without an evaluative methodology, if no intervention is described or if the intervention was designed for learners who were not in difficulty, if they are aimed at other healthcare training programs, or if they are written in languages other than English, French, Spanish, German or Italian.

After removal of duplicates, one reviewer (EL or CS) will screen all titles and abstracts identified by the search strategy and eliminate obviously irrelevant reports. A second author will be added to review the remaining titles and abstracts. If there is any doubt as to their relevance, articles will not be eliminated at that stage. Full text articles will be retrieved for all potentially relevant citations. Two reviewers will independently assess the remaining articles (ML and CS) using full texts and decide if they should be selected for the review based on the inclusion and exclusion criteria. A third reviewer will be consulted if

differences arise in the process. The reference lists of these selected articles will be searched by two reviewers to ensure all key articles were included.

Scoping search

We performed a scoping search to assess the feasibility and practicality of the search sources and strategy as well as to judge the amount of material in the literature. The scoping search identified 19842 articles; 180 were retrieved with a title and abstract screen, and 49 were included in the review after full text assessment, reporting a total of 141 behaviour change techniques, the most common being 1) shaping knowledge, 2) goals and planning and 3) feedback and monitoring. The reported interventions were most commonly categorized under the following BCT: shaping knowledge, goals / planning, feedback / mentoring and repetition / substitution. Program evaluation types reported in the articles rarely assessed context (6% of articles), input (8%) and process (12%), but all assessed at least one product, more commonly learning (Kirkpatrick level 2, 63%) and results (Kirkpatrick level 4, 37%). Examples of remediation interventions that work include: individualized learning plans that incorporate deliberate practice, feedback, and reflection (Guerrasio, Garrity, & Aagaard, 2014); workshops aimed at improving specific skills (Lin, Barley, & Cifuentes, 2001); a course which involved the creation of conceptual maps presenting symptom pathways, activating prior learning and engaging in new learning (Klamen & Williams, 2011); a ten-step clinical reasoning remediation plan (Guerrasio & Aagaard, 2014); a web-based directed reading program (Drake, Qureshi, Morse, & Baker-Genaw, 2015); and a basic surgical skills rural weekend (House & House, 2000).

Data extraction

A standardisation meeting with all reviewers will be conducted to pilot the data extraction sheet using 5 articles identified by the scoping search. Two reviewers will independently extract the data from all full text articles selected and code the relevant information on the data extraction sheet. Data extraction regarding the type of intervention will follow Michie's BCT Taxonomy (Michie et al., 2015) (Appendix 1).

A modified version of Kirkpatrick's classification of training outcomes proposed by (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005) (Freeth, Hammick, Reeves, Koppel, & Barr, 2005) adopted by the BEME collaboration as a grading standard for systematic reviews, (Hammick, Dornan, & Steinert, 2010), will help classify the outcomes during extraction ofprogram evaluation data, without assuming any causality or hierarchy between the different levels. These levels are:

- Level 1: Participation in educational experiences
- Level 2A: Change of attitudes
- Level 2B: Change of knowledge and/or skills
- Level 3: Behavioural change (self-reported / observed, as suggested by Steinert, Naismith, and Mann (2012))
- Level 4A: Changes in professional practice
- Level 4B: Benefits to patients

Kirkpatrick's model has recently been criticised. Issues were reported around its incompleteness (not considering individual or contextual factors), the assumption of causality, and the assumption of

increasing importance of information as the levels of outcomes are ascended (Bates, 2004). Yardley and Dornan (2012) reported that "when evaluating relatively simple training interventions, the outcomes of which emerge rapidly and are easily observed within classical experiment designs, the [Kirkpatrick] levels can direct attention to important beneficiaries other than learners (notably patients) […], however they are […] unsuitable for […] education interventions which are complex, in which the most important outcomes are longer-term, and in which process evaluation is as important as […] outcome evaluation". Therefore, data will also be extracted using Stufflebeam (2003)'s CIPP model (context / input / process / product) which considers program evaluation expanded beyond the scope of outcomes assessment.

Data extraction will be facilitated by an online data extraction form (Appendix 3). Once all the studies are encoded, inter-rater reliability will be assessed by comparing results of study codification between coders, distributed according to control rater effect. Cohen's kappa with be calculated for each behaviour change technique and program evaluation types, while intraclass correlation will be calculated for the MMAT scores. Discrepancies in coding will be submitted to a third reviewer (lead author), who will resolve them through discussion and consensus with the two reviewers. A record of differences of opinion will be kept.

Appraisal of studies

The quality of each included study will be assessed using the Mixed Methods Appraisal Tool (MMAT) (Pluye et al., 2011). This tool was chosen because it is designed for concomitantly appraising and/or describing studies included in systematic mixed studies reviews (reviews including original qualitative, quantitative and mixed methods studies, which is what we are expecting with this search strategy). This tool will be included in the data extraction sheet.

Synthesis of extracted evidence

A descriptive analysis will be conducted to synthesize extracted data. Our scoping search identified numerous remediation interventions for many types of educational diagnoses in both undergraduate and postgraduate learners. It might be possible for groups of similar interventions to conduct meta-analyses for quantitative results using the Cochrane Collaboration's Review Manager. If statistical groupings are impossible, data analyses will be presented in a narrative form which will include tables and figures (for an example, see Appendix 4).

Relevance and translation into practice

This review has both a theoretical and practical relevance. Since most studies reporting remediation interventions were published without presenting an explicit conceptual framework (Cleland et al., 2013), mapping remediation interventions under a taxonomy based on a theoretical domains framework will be helpful from a theoretical perspective to 1) identify the most effective BCT in medical education and build upon them and their associated theories and 2) identify unexplored BCT to inspire developments that might be of interest for medical learners in difficulty. Furthermore, this review will update the knowledge on remediation interventions in medical education since the last two reviews on the subject were conducted in 2008 (Hauer et al., 2009) and 2012 (Cleland et al., 2013). They will also offer a broader perspective on remediation that will include both undergraduate and postgraduate medical trainees, building on a recent BEME review which examined the use of workplace-based assessment in identifying and remediating performance among postgraduate medical trainees (Barrett et al., 2016).

From a practical perspective, this review encourages the use of the most effective evidence-based remediation strategies and will help identification of program evaluation gaps to stimulate further educational scholarship and research in the field. It will provide clinical teachers and educators with a repertoire of evidence-based interventions that could be used for assessment, mentoring and faculty development purposes. The proposed classification under various BCT is intended to help clinical teachers and educators better understand and implement the identified remediation strategies. Finally, it will help them choose the most effective interventions for learners in difficulty that are aligned with current educational frameworks and strategies, with the objective of training physicians to be competent and provide safe patient care.

Project timetable

	6/2016	7/2016	8/2016	9/2016	10/2016	11/2016	12/2016	1/2017	2/2017	3/2017	4/2017	5/2017	6/2017	7/2017	8/2017	9/2017	10/2017	11/2017	12/2017	12/2017	1/2018	2/2018	3/2018	4/2018	5/2018
Development and refinement of the search strategy	▪	▪	▪	▪	▪	▪	▪																		
Scoping search	▪	▪	▪	▪																					
BEME topic registration				▪	▪																				
Protocol redaction								▪	▪	▪															
Protocol acceptance											▪														
Final search strategy												▪													
Study selection												▪													
Data extraction													▪	▪	▪	▪	▪								
Appraisal of studies													▪	▪	▪	▪									
Synthesis of extracted evidence																		▪							
Manuscript redaction																		▪	▪	▪					
Manuscript submission																						▪			
Manuscript revisions and final report submission																							▪	▪	▪

Conflict of interest statement

There was no conflict of interest to declare for any member of the review group.

Plans for updating the review

Five years after publication of this review, the search strategy will be conducted for 2016-2021 to assess the necessity and relevance of an update.

Changes to the protocol

Whilst a well thought out protocol should reduce the need for changes, unanticipated issues may arise and modifications to the review topic/question, coding sheets and/or protocol may become necessary as the review group becomes more familiar with the evidence. Any subsequent changes to the protocol

will be carefully recorded, with the reasons for these changes and the date the changes took place. Significant changes to the protocol will be submitted to BEME for approval.

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Appendix 1 – Taxonomy of behaviour change techniques with medical education examples (adapted from Michie et al. (2015)

Behaviour change technique groupings	Behaviour change techniques		Examples of associated learning/teaching strategies in medical education
1 Goals and planning	1.1	Goal-setting (behaviour)	Remediation plan
	1.2	Problem-solving	Learning plan/contract
	1.3	Goal-setting (outcome)	Clinical case scenarios/problem-based learning
	1.4	Action planning	
	1.5	Review behaviour goal(s)	Written or verbal commitments (or contracts) of the learner regarding goals/outcomes
	1.6	Discrepancy between current behaviour and goal	
	1.7	Review outcome goal(s)	
	1.8	Behavioural contract	
	1.9	Commitment	
2 Feedback and monitoring	2.1	Monitoring of behaviour by others without feedback	Direct or indirect observation and feedback
	2.2	Feedback on behaviour	Portfolio
	2.3	Self-monitoring of behaviour	Video viewing of the student's performance (for self-monitoring or feedback purposes)
	2.4	Self-monitoring of outcome(s) of behaviour	
	2.5	Monitoring of outcome(s) of behaviour without feedback	Practice audit or other Self-assessment activities (related to clinical competence vs #13)
	2.6	Biofeedback	Regular meetings with programme director or dean of students
	2.7	Feedback on outcome(s) of behaviour	
3 Social support	3.1	Social support (unspecified)	Peer support groups
	3.2	Social support (practical)	Mentoring
	3.3	Social support (emotional)	
4 Shaping knowledge	4.1	Instruction on how to perform the behaviour	Teaching sessions
	4.2	Information about antecedents	Lectures
	4.3	Re-attribution	Self-learning modules
	4.4	Behavioural experiments	Directed readings
5 Natural consequences	5.1	Information about health consequences	Feedback about medical errors/ cases of medical law suits
	5.2	Salience of consequences	Feedback about potential consequences of a management plan for the patient
	5.3	Information about social and environmental consequences	
	5.4	Monitoring of emotional consequences	Reassessment of patient due to omission in the history or physical
	5.5	Anticipated regret	
	5.6	Information about emotional consequences	
6 Comparison of behaviour	6.1	Demonstration of the behaviour	Bedside teaching
	6.2	Social comparison	Role modeling (clinical teacher observation, videos, etc.)
	6.3	Information about others' approval	Peer-based learning
			Providing data about the performance of other colleagues, physicians
7 Associations	7.1	Prompts/cues	Prototypes
	7.2	Cue signalling reward	Checklists (used in the workplace) about the steps to follow
	7.3	Reduce prompts/cues	
	7.4	Remove access to the reward	
	7.5	Remove aversive stimulus	

		7.6 Satiation 7.7 Exposure 7.8 Associative learning	Clinical reasoning exercises such as highlighting supporting information/crossing out distracting information, rating relevance of symptoms and signs for each diagnosis, etc.
8	Repetition and substitution	8.1 Behavioural practice/rehearsal 8.2 Behaviour substitution 8.3 Habit formation 8.4 Habit reversal 8.5 Overcorrection 8.6 Generalisation of target behaviour 8.7 Graded tasks	Repeated rotation/year Simulation Practice on models Step-by-step approach Role playing Peer-assisted learning (to practice history or physical examination skills)
9	Comparison of outcomes	9.1 Credible source 9.2 Pros and cons 9.3 Comparative imagining of future outcomes 9.4 Material incentive (behaviour) 9.5 Material reward (behaviour) 9.6 Non-specific reward	Discussion about outcome data from major medical organisations (e.g. WHO recommendations)
10	Reward and threat	10.1 Social reward 10.2 Social incentive 10.3 Non-specific incentive 10.4 Self-incentive 10.5 Incentive (outcome) 10.6 Self-reward 10.7 Reward (outcome) 10.8 Future punishment	Warning letter
11	Regulation	11.1 Pharmacological support 11.2 Reduce negative emotions 11.3 Conserving mental resources 11.4 Paradoxical instructions	Psychotherapy Meditation and stress reduction therapies Pharmacotherapy Leave of absence
12	Antecedents	12.1 Restructuring the physical environment 12.2 Restructuring the social environment 12.3 Avoidance/reducing exposure to cues for the behaviour 12.4 Distraction 12.5 Adding objects to the environment 12.6 Body changes	Accommodations in the workplace or within the work team (e.g. reduced number of patients, reduced distractions, etc.) Accommodations during assessments (e.g. headphones or separated room, more time allowed, etc.)
13	Identity	13.1 Identification of self as role model 13.2 Framing/reframing 13.3 Incompatible beliefs 13.4 Valued self-identify 13.5 Identity associated with changed behaviour	Teaching as a resident Self-assessment of one's values and strengths (in general, not clinical skills which is #2) Meeting with faculty advisor/mentoring to discuss professional identity
14	Scheduled consequences	14.1 Behaviour cost 14.2 Punishment 14.3 Remove reward 14.4 Reward approximation 14.5 Rewarding completion 14.6 Situation-specific reward 14.7 Reward incompatible behaviour	Probation Suspension Delinquent assignment or task

		14.8 Reward alternative behaviour 14.9 Reduce reward frequency 14.10 Remove punishment	
15	Self-belief	15.1 Verbal persuasion about capability 15.2 Mental rehearsal of successful performance 15.3 Focus on past success 15.4 Self-talk	Visualization techniques
16	Covert learning	16.1 Imaginary punishment 16.2 Imaginary reward 16.3 Vicarious consequences	
17	Other		Institutional support
18	Intervention description lacking details to allow classification		

Appendix 2 – Search strategies

This systematic review will search the MEDLINE, CINAHL, EMBASE, ERIC Education Source and PsychINFO databases based on the following concepts:

1) medical education (undergraduate and postgraduate);

2) professional competence difficulty (diagnostic errors, medical errors, professional misconduct, underachievement, learning disorders, etc.);

3) educational support (remediation, teaching methods, etc.).

The literature search will be conducted from January 1st 1990 to December 31st 2016, since development of competency-based curricula arose during the last decade of 20th century (Carraccio et al., 2002).

Search query in MEDLINE (OVID)
Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid* MEDLINE*(R) Daily and Ovid MEDLINE(R)

1. Students, Medical/
2. Education, Medical/
3. Education, Medical, Graduate/
4. Education, Medical, Undergraduate/
5. exp "Internship and Residency"/
6. ((Medicine* or Medical* or premedic* or physician* or doctor* or clinical or dermatolog* or cardiolog* or endocrinolog* or gastroenterolog* or hematolog* or oncolog* or nephrolog* or rheumatolog* or neurolog* or neuropatholog* or psychiatr* or radiolog* or obstetric* or gynecolog* or gynaecolog* or anesthesia* or anaesthesia* or patholog* or pediatric* or paediatric* or urolog* or geriatr* or respirolog* or surgery or surgical or neurosurgery or surgeon or surgeons or ophthalmology or orthopedics or otolaryngology) adj5 (student* or graduate* or undergraduate* or clerk* or fellow* or intern or interns or internship* or residen* or educat* or train* or novice* or supervi* or learner*)).ab,ti.
7. or/1-6
8. exp Professional Competence/
9. Liability, Legal/
10. exp Diagnostic Errors/
11. Medical Errors/
12. exp Learning Disorders/
13. exp Professional Misconduct/
14. Underachievement/
15. Student Dropouts/
16. ((academic or learning or competenc* or personal or professional or education* or behavio?r or study* or "clinical reasoning" or attitud* or knowledge or skills) adj3 (impair* or troubling or trouble

or troubled or disabilit* or disabled or problem? or difficult* or issues or disorder? or challeng* or defici* or "at risk" or struggl* or lapse? or disadvantag* or failure or inadequate)).ab,ti.

17. (error? adj2 (medical or treatment or diagnostic or "health care")).ab,ti.
18. ("special needs" or "cognition disorder?" or incompetence or misdiagnosis or underachieve* or "professional misconduct" or "unprofessional behavio?r" or dropout? or disadvantag* or "performance appraisal" or "educational diagnosis").ab,ti.
19. or/8-18
20. (Remedia* or "assistance program?" or retention or "diagnostic teaching" or "school holding power").ab,ti.
21. (education* adj2 (plan? or planning or therapy or compensatory or supplementary or support)).ab,ti.
22. ((academic or teaching or learning) adj2 (instruction or strategy or strategies or program? or interven* or accommodat* or method? or therapy)).ab,ti.
23. Remedial Teaching/
24. exp Teaching/mt [Methods]
25. or/20-24
26. 7 and 19 and 26

Search query in Embase (Embase.com)

1. medical student'/de OR 'medical education'/de OR 'clinical education'/de OR 'clinical supervision'/de OR 'surgical training'/de OR 'teaching round'/de OR 'residency education'/de
2. ((medicine* OR medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) NEAR/5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*)):ab,ti
3. #1 OR #2
4. professional competence'/de OR 'medical liability'/de OR 'clinical competence'/de OR 'medical error'/exp OR 'learning disorder'/de OR 'concentration loss'/de OR 'dyscalculia'/de OR 'disabled student'/de OR 'professional misconduct'/de OR 'academic achievement'/exp
5. ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavior OR behaviour OR study* OR 'clinical reasoning' OR attitud* OR skills OR knowledge) NEAR/3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem OR problems OR difficult* OR issues OR disorder OR disorders OR challeng* OR defici* OR 'at risk' OR struggl* OR lapse* OR disadvantag* OR failure OR inadequate)):ab,ti
6. (error* NEAR/2 (medical OR treatment OR diagnostic OR 'health care')):ab,ti
7. 'special needs':ab,ti OR 'cognition disorder':ab,ti OR 'cognition disorders':ab,ti OR incompetence:ab,ti OR misdiagnosis:ab,ti OR underachieve*:ab,ti OR 'professional misconduct':ab,ti OR 'unprofessional behaviour':ab,ti OR 'unprofessional behavior':ab,ti OR dropout*:ab,ti OR 'performance appraisal':ab,ti OR 'educational diagnosis':ab,ti

8. #4 OR #5 OR #6 OR #7
9. student assistance program'/de OR 'student retention'/de
10. remedia*:ab,ti OR 'assistance program*':ab,ti OR 'diagnostic teaching':ab,ti OR retention:ab,ti OR 'school holding power':ab,ti
11. (education* NEAR/2 (plan OR plans OR planning OR therapy OR compensatory OR supplementary OR support)):ab,ti
12. ((academic OR teaching OR learning) NEAR/2 (instruction OR strategy OR strategies OR program* OR interven* OR accommodat* OR method OR methods OR therapy)):ab,ti
13. #9 OR #10 OR #11 OR #12
14. #3 AND #8 AND #13

Search query in CINAHL Plus with Full Text (EBSCOHost)

1. (MH "Students, Medical")
2. (MH "Education, Medical")
3. (MH "Education, Clinical+")
4. (MH "Clinical Supervision")
5. (MH "Interns and Residents")
6. TI ((Medicine* OR Medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) N5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))
7. AB ((Medicine* OR Medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) N5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))
8. S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7
9. (MH "Professional Competence")
10. (MH "Health Care Errors+")
11. (MH "Diagnostic Errors+")
12. (MH "Treatment Errors+")
13. (MH "Learning Disorders+")
14. (MH "Clinical Competence")
15. (MH "Cognition Disorders")
16. (MH "Students, Disabled")
17. (MH "Professional Misconduct+")

18. (MH "Student Misconduct")
19. (MH "Academic Performance+")
20. (MH "Student Performance Appraisal+")
21. (MH "Student Dropouts")
22. TI ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio#r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) N3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem# OR difficult* OR issues OR disorder# OR challeng* OR defici* OR "at risk" OR struggl* OR lapse# OR disadvantag* OR failure OR inadequate))
23. AB ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio#r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) N3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem# OR difficult* OR issues OR disorder# OR challeng* OR defici* OR "at risk" OR struggl* OR lapse# OR disadvantag* OR failure OR inadequate))
24. TI (error# N2 (medical OR treatment OR diagnostic OR "health care"))
25. AB (error# N2 (medical OR treatment OR diagnostic OR "health care"))
26. TI ("special needs" OR "cognition disorder#" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio#r" OR dropout# OR "performance appraisal" OR "educational diagnosis")
27. AB ("special needs" OR "cognition disorder#" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio#r" OR dropout# OR "performance appraisal" OR "educational diagnosis")
28. S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27
29. (MH "Teaching Methods+")
30. (MH "Remedial Teaching")
31. (MH "School Accommodation")
32. (MH "Student Assistance Programs")
33. (MH "Student Retention")
34. TI (Remedia* OR "assistance program#" OR retention OR "diagnostic teaching" OR OR "school holding power")
35. AB (Remedia* OR "assistance program#" OR retention OR "diagnostic teaching" OR "school holding power")
36. TI (education* N2 (plan# OR planning OR therapy OR compensatory OR supplementary OR support))
37. AB (education* N2 (plan# OR planning OR therapy OR compensatory OR supplementary OR support))
38. TI ((academic OR teaching OR learning) N2 (instruction OR strategy OR strategies OR program# OR interven* OR accommodat* OR method# OR therapy))
39. AB ((academic OR teaching OR learning) N2 (instruction OR strategy OR strategies OR program# OR interven* OR accommodat* OR method# OR therapy))
40. S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36 OR S37 OR S38 OR S39
41. S8 AND S28 AND S40

Search query in ERIC (EBSCOHost)

1. DE "Medical Education" OR DE "Graduate Medical Education" OR DE "Medical Students"
2. TI ((Medicine* OR Medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) N5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))
3. AB ((Medicine* OR Medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) N5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))
4. S1 OR S2 OR S3
5. DE "Learning Problems" OR DE "Learning Disabilities" OR DE "Cognitive Ability" OR DE "Thinking Skills" OR DE "At Risk Students" OR DE "Special Needs Students" OR DE "Educationally Disadvantaged" OR DE "Educational Diagnosis" OR DE "Academic Failure" OR DE "Reading Failure" OR DE "Academic Achievement" OR DE "Educational Attainment" OR DE "Student Promotion" OR DE "Academic Aptitude" OR DE "Academic Ability" OR DE "Underachievement" OR DE "Dropouts" OR DE "Potential Dropouts"
6. TI ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio#r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) N3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem# OR difficult* OR issues OR disorder# OR challeng* OR defici* OR "at risk" OR struggl* OR lapse# OR disadvantag* OR failure OR inadequate))
7. AB ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio#r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) N3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem# OR difficult* OR issues OR disorder# OR challeng* OR defici* OR "at risk" OR struggl* OR lapse# OR disadvantag* OR failure OR inadequate))
8. TI (error# N2 (medical OR treatment OR diagnostic OR "health care"))
9. AB (error# N2 (medical OR treatment OR diagnostic OR "health care"))
10. TI ("special needs" OR "cognition disorder#" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio#r" OR dropout# OR "performance appraisal" OR "educational diagnosis")
11. AB ("special needs" OR "cognition disorder#" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio#r" OR dropout# OR "performance appraisal" OR "educational diagnosis")
12. S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11
13. DE "Teaching Methods" OR DE "Audiolingual Methods" OR DE "Blended Learning" OR DE "Case Method (Teaching Technique)" OR DE "Clinical Teaching (Health Professions)" OR DE "Community

Based Instruction (Disabilities)" OR DE "Conventional Instruction" OR DE "Creative Teaching" OR DE "Cross Age Teaching" OR DE "Demonstrations (Educational)" OR DE "Diagnostic Teaching" OR DE "Direct Instruction" OR DE "Discussion (Teaching Technique)" OR DE "Drills (Practice)" OR DE "Experimental Teaching" OR DE "Grammar Translation Method" OR DE "Individualized Instruction" OR DE "Kinesthetic Methods" OR DE "Language Experience Approach" OR DE "Learner Controlled Instruction" OR DE "Lecture Method" OR DE "Montessori Method" OR DE "Multimedia Instruction" OR DE "Oral Communication Method" OR DE "Peer Teaching" OR DE "Precision Teaching" OR DE "Reciprocal Teaching" OR DE "Reggio Emilia Approach" OR DE "Scaffolding (Teaching Technique)" OR DE "Sight Method" OR DE "Suggestopedia" OR DE "Team Teaching" OR DE "Telephone Instruction" OR DE "Thematic Approach" OR DE "Training Methods" OR DE "Web Based Instruction" OR DE "Whole Language Approach"

14. DE "Remedial Programs" OR DE "Remedial Instruction" OR DE "Supplementary Education" OR DE "Educational Therapy" OR DE "Educational Methods" OR DE "Academic Accommodations (Disabilities)" OR DE "Educational Strategies" OR DE "Compensatory Education" OR DE "Psychoeducational Methods" OR DE "School Holding Power"
15. TI (Remedia* OR "assistance program#" OR retention OR "diagnostic teaching" OR "school holding power")
16. AB (Remedia* OR "assistance program#" OR retention OR "diagnostic teaching" OR "school holding power")
17. TI (education* N2 (plan# OR planning OR therapy OR compensatory OR supplementary OR support))
18. AB (education* N2 (plan# OR planning OR therapy OR compensatory OR supplementary OR support))
19. TI ((academic OR teaching OR learning) N2 (instruction OR strategy OR strategies OR program# OR interven* OR accommodat* OR method# OR therapy))
20. AB ((academic OR teaching OR learning) N2 (instruction OR strategy OR strategies OR program# OR interven* OR accommodat* OR method# OR therapy))
21. S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR 20
22. S4 AND S12 AND S21

Search query in Education Source (EBSCOHost)

1. DE "Medical students" OR DE "Medical education" OR DE "Clinical medical education" OR DE "Clinical clerkship" OR DE "Medicine -- Study & teaching (Graduate)"OR DE "Residents (Medicine)"
2. TI ((Medicine* OR Medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) N5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))
3. AB ((Medicine* OR Medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR

gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) N5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))

4. S1 OR S2 OR S3
5. DE "Learning problems" OR DE "Cognitive ability" OR DE "Automaticity (Learning process)" OR DE "Cognitive training" OR DE "Clinical competence" OR DE "Learning disabilities" OR DE "Nonverbal learning disabilities" OR DE "Reading disability" OR DE "At-risk students" OR (DE "Special needs students" OR DE "Learning disabled persons -- Education (Higher)" OR DE "Educationally disadvantaged students" OR DE "Educational diagnosis" OR DE "School failure" OR DE "Academic achievement" OR DE "Academic ability" OR DE "Academic underachievement" OR DE "Underachievers" OR DE "School dropouts" OR DE "core competencies"
6. TI ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio#r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) N3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem# OR difficult* OR issues OR disorder# OR challeng* OR defici* OR "at risk" OR struggl* OR lapse# OR disadvantag* OR failure OR inadequate))
7. AB ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio#r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) N3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem# OR difficult* OR issues OR disorder# OR challeng* OR defici* OR "at risk" OR struggl* OR lapse# OR disadvantag* OR failure OR inadequate))
8. TI (error# N2 (medical OR treatment OR diagnostic OR "health care"))
9. AB (error# N2 (medical OR treatment OR diagnostic OR "health care"))
10. TI ("special needs" OR "cognition disorder#" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio#r" OR dropout# OR "performance appraisal" OR "educational diagnosis")
11. AB ("special needs" OR "cognition disorder#" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio#r" OR dropout# OR "performance appraisal" OR "educational diagnosis")
12. S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11
13. DE "Teaching methods" OR DE "Accelerated teaching" OR DE "Adult education -- Teaching methods" OR DE "Agazzi method of teaching" OR DE "Anchored instruction" OR DE "Aptitude-treatment interaction (Education)" OR DE "Asynchronous learning" OR DE "Blended learning" OR DE "Case method (Teaching)" OR DE "Circle time (Classroom activity)" OR DE "Cognitively Guided Instruction (Teaching method)" OR DE "Constant time delay procedure (Education)" OR DE "Contextual learning" OR DE "Conventional instruction" OR DE "Conversation method (Language teaching)" OR DE "Critiques (Art education)" OR DE "Cross-age teaching" OR DE "Deductive teaching"
14. DE "Diagnostic teaching" OR DE "Dialogic teaching" OR DE "Dialogue journals (Education)" OR DE "Didactic method (Teaching method)" OR DE "Direct instruction" OR DE "Discovery method (Teaching)" OR DE "Discussion in education" OR DE "Drills (Education)" OR DE "English language -- Programmed instruction" OR DE "Error analysis in education" OR DE "Expeditionary learning system" OR DE "Global method of teaching" OR DE "Grammar translation method (Language teaching)" OR DE "Group work in education" OR DE "Guided reading" OR DE "Health occupations practicums" OR

DE "Herbartianism" OR DE "Inductive teaching" OR DE "Inquiry method (Teaching)" OR DE "Instrumental enrichment programs" OR DE "Intensive reading" OR DE "Kinesthetic method (Education)" OR DE "Kumon method (Education)" OR DE "Language experience approach in education" OR DE "Learning by teaching" OR DE "Lecture method in teaching" OR DE "Microcounseling" OR DE "Pedantry" OR DE "Peer teaching" OR DE "Pestalozzianism" OR DE "Precision teaching" OR DE "Project method in teaching" OR DE "Reciprocal teaching" OR DE "Reggio Emilia approach (Early childhood education)" OR DE "Scaffolding (Teaching method)" OR DE "Sequential approach (Teaching method)" OR DE "Simulated environment (Teaching method)" OR DE "Socratic method (Education)" OR DE "Spiral curriculum (Teaching method)" OR DE "Thematic approach in education" OR DE "Unit method of teaching"

15. DE "Educational intervention" OR DE "Educational therapy" OR DE "Students with disabilities -- Services for" OR DE "Academic accommodations" OR DE "Educational support" OR DE "Supplementary education" OR DE "Compensatory education" OR DE "School dropouts -- Prevention" OR DE "College dropouts -- Prevention"
16. TI (Remedia* OR "assistance program#" OR retention OR "diagnostic teaching" OR "school holding power")
17. AB (Remedia* OR "assistance program#" OR retention OR "diagnostic teaching" OR "school holding power")
18. TI (education* N2 (plan# OR planning OR therapy OR compensatory OR supplementary OR support))
19. AB (education* N2 (plan# OR planning OR therapy OR compensatory OR supplementary OR support))
20. TI ((academic OR teaching OR learning) N2 (instruction OR strategy OR strategies OR program# OR interven* OR accommodat* OR method# OR therapy))
21. AB ((academic OR teaching OR learning) N2 (instruction OR strategy OR strategies OR program# OR interven* OR accommodat* OR method# OR therapy))
22. S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21
23. S4 AND S12 AND S22

PsycINFO (OVID)
1. exp internship programs/
2. exp medical education/
3. medical students/
4. ((Medicine* or Medical* or premedic* or physician* or doctor* or clinical or dermatolog* or cardiolog* or endocrinolog* or gastroenterolog* or hematolog* or oncolog* or nephrolog* or rheumatolog* or neurolog* or neuropatholog* or psychiatr* or radiolog* or obstetric* or gynecolog* or gynaecolog* or anesthesia* or anaesthesia* or patholog* or pediatric* or paediatric* or urolog* or geriatr* or respirolog* or surgery or surgical or neurosurgery or surgeon or surgeons or ophthalmology or orthopedics or otolaryngology) adj5 (student* or graduate* or undergraduate* or clerk* or fellow* or intern or interns or internship* or residen* or educat* or train* or novice* or supervi* or learner*)).ab,ti.
5. or/1-4
6. academic achievement/
7. academic aptitude/
8. academic failure/

9. academic stress/
10. academic underachievement/
11. exp brain training/
12. exp cognitive ability/
13. educational diagnosis/
14. exp learning disorders/
15. professional competence/
16. professional liability/
17. ((academic or learning or competenc* or personal or professional or education* or behavio?r or study* or "clinical reasoning" or attitud* or knowledge or skills) adj3 (impair* or troubling or trouble or troubled or disabilit* or disabled or problem? or difficult* or issues or disorder? or challeng* or defici* or "at risk" or struggl* or lapse? or disadvantag* or failure or inadequate)).ab,ti.
18. (error? adj2 (medical or treatment or diagnostic or "health care")).ab,ti.
19. ("special needs" or "cognition disorder?" or incompetence or misdiagnosis or underachieve* or "professional misconduct" or "unprofessional behavio?r" or dropout? or disadvantag* or "performance appraisal" or "educational diagnosis").ab,ti.
20. or/6-19
21. exp teaching methods/
22. educational programs/
23. educational therapy/
24. exp remedial education/
25. (Remedia* or "assistance program?" or retention or "diagnostic teaching" or "school holding power").ab,ti.
26. (education* adj2 (plan? or planning or therapy or compensatory or supplementary or support)).ab,ti.
27. ((academic or teaching or learning) adj2 (instruction or strategy or strategies or program? or interven* or accommodat* or method? or therapy)).ab,ti.
28. or/21-27
29. 5 and 20 and 27

Web of science Core Collection

1. TOPIC: ((medicine* OR medical* OR premedic* OR physician* OR doctor* OR clinical OR dermatolog* OR cardiolog* OR endocrinolog* OR gastroenterolog* OR hematolog* OR oncolog* OR nephrolog* OR rheumatolog* OR neurolog* OR neuropatholog* OR psychiatr* OR radiolog* OR obstetric* OR gynecolog* OR gynaecolog* OR anesthesia* OR anaesthesia* OR patholog* OR pediatric* OR paediatric* OR urolog* OR geriatr* OR respirolog* OR surgery OR surgical OR neurosurgery OR surgeon OR surgeons OR ophthalmology OR orthopedics OR otolaryngology) NEAR/5 (student* OR graduate* OR undergraduate* OR clerk* OR fellow* OR intern OR interns OR internship* OR residen* OR educat* OR train* OR novice* OR supervi* OR learner*))
2. TOPIC: ((academic OR learning OR competenc* OR personal OR professional OR education* OR behavio$r OR study* OR "clinical reasoning" OR attitud* OR skills OR knowledge) NEAR/3 (impair* OR troubling OR trouble OR troubled OR disabilit* OR disabled OR problem* OR difficult* OR issues OR disorder* OR challeng* OR defici* OR "at risk" OR struggl* OR lapse* OR disadvantag* OR failure OR inadequate))

3. TOPIC: (error* NEAR/2 (medical OR treatment OR diagnostic OR "health care"))
4. TOPIC: (("special needs" OR "cognition disorder*" OR incompetence OR misdiagnosis OR underachieve* OR "professional misconduct" OR "unprofessional behavio$r" OR dropout* OR "performance appraisal" OR "educational diagnosis"))
5. #2 OR #3 OR #4
6. TOPIC: (Remedia* OR "assistance program*" OR retention OR "diagnostic teaching" OR "school holding power")
7. TOPIC: (education* NEAR/2 (plan* OR planning OR therapy OR compensatory OR supplementary OR support))
8. TOPIC: ((academic OR teaching OR learning) NEAR/2 (instruction OR strategy OR strategies OR program* OR interven* OR accommodat* OR method* OR therapy))
9. #6 OR #7 OR #8
10. #1 AND #5 AND #9

Appendix 3 – Online data extraction form

Identification

Which article do you want to extract data from? (list of all selected articles)

Reviewer's name :

Study

Meeting of inclusion criteria (yes / no / unsure)

- ☐ scientific article
- ☐ medical discipline
- ☐ learners in difficulty
- ☐ intervention(s)
- ☐ intervention evaluation

Study design

- ☐ Qualitative study
- ☐ Quantitative study with random assignment
- ☐ Quantitative study without random assignment
- ☐ Descriptive quantitative study
- ☐ Mixed methods study
- ☐ (Add comments)

Study population (training level and sample size to write in the Comments box)

Educational diagnoses of the studied population

- ☐ Knowledge
- ☐ Skills
- ☐ Attitude
- ☐ Personal
- ☐ Teacher
- ☐ Environment
- ☐ N/A
- ☐ Other

Is the intervention part of a wider remediation plan? (yes / no / comments)

Type of data (self-report / observation [objective scale] / other)

Behaviour change techniques

Associate all interventions described in the article to corresponding Behaviour Change Techniques (check all that apply). (interventions vary according to the article selected in the first question)

1   Goals and planning
    Ex.: Remediation plan, learning plan/contract, clinical case scenarios/problem-based learning, written or verbal commitments (or contracts) of the learner regarding goals/outcomes

2   Feedback and monitoring
    Ex.: Direct or indirect observation and feedback, Portfolio, Video viewing of the student's performance (for self-monitoring or feedback purposes), Practice audit or other Self-assessment activities (related to clinical competence vs #13)

3   Social support
    Ex.: Peer support groups, Mentoring

4   Shaping knowledge
    Ex.: Teaching sessions, Lectures, Self-learning modules, Directed readings

5   Natural consequences
    Ex.: Call back patient if part of management was inappropriate/ incomplete, Rewrite patient's record if not presented properly

6   Comparison of behaviour
    Ex.: Bedside teaching, Role modeling (clinical teacher observation, videos, etc.), Peer-based learning, Providing data about the performance of other colleagues, physicians

7   Associations
    Ex.: Prototypes, Checklists (used in the workplace) about the steps to follow

8   Repetition and substitution
    Ex.: Repeated rotation/year, Simulation, Practice on models Step-by-step approach, Role playing, Peer-assisted learning (to practice history or physical examination skills)

9   Comparison of outcomes
    Ex.: Discussion about outcome data from major medical organisations (e.g. WHO recommendations)

10 Reward and threat
    Ex.: Warning letter

11 Regulation
    Ex.: Psychotherapy, Meditation and stress reduction therapies, Pharmacotherapy

12 Antecedents
    Ex.: Accommodations in the workplace or within the work team (e.g. reduced number of patients, reduced distractions, etc.), Accommodations during assessments (e.g. headphones or separated room, more time allowed, etc.)

13 Identity
    Ex.: Teaching as a resident, Self-assessment of one's values and strengths (in general, not clinical skills which is #2), Meeting with faculty advisor/mentoring to discuss professional identity

14 Scheduled consequences
    Ex.: Suspension, Delinquent assignment or task

15 Self-belief
    Ex.: Visualization techniques

16 Covert learning
    Ex.: Discussions about medical errors/ cases of medical law suits, Discussions about potential consequences of a management plan for the patient

Comments

Program evaluation

Components of program evaluation assessed:

- ☐ Context (needs/resources assessment,)
- ☐ Input (strategies, feasibility, costs)
- ☐ Process (implementation)
- ☐ Products
  - Level 1: Participation in educational experiences
  - Level 2A: Change of attitudes
  - Level 2B: Change of knowledge and/or skills
  - Level 3A: Behavioural change (self-reported)
  - Level 3B: Behavioural change (observed)
  - Level 4A: Changes in professional practice
  - Level 4B: Benefits to patients

Copy-paste the results from the text.

Appraisal of study quality with the Mixed Methods Appraisal Tool (MMAT)[12]

Preliminary questions :

- Are there clear qualitative and quantitative research questions (or objectives*), or a clear mixed methods question (or objective)?
- Do the collected data allow address the research question (objective)? E.g., consider whether the follow-up period is long enough for the outcome to occur (for longitudinal studies or study components).

Qualitative

- Are the sources of qualitative data (archives, documents, informants, observations) relevant to address the research question (objective)?
- Is the process for analyzing qualitative data relevant to address the research question (objective)?
- Is appropriate consideration given to how findings relate to the context, e.g., the setting, in which the data were collected?
- Is appropriate consideration given to how findings relate to researchers' influence, e.g., through their interactions with participants?

Quantitative randomized controlled

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[1] only the first subsection is always visible. The other subsections depend on the 4th question of questionnaire (about the research setting).
[2] the answer scale for each question is yes / no / unsure

- Is there a clear description of the randomization (or an appropriate sequence generation)?
- Is there a clear description of the allocation concealment (or blinding when applicable)?
- Are there complete outcome data (80% or above)?
- Is there low withdrawal/drop-out (below 20%)?

Quantitative non- randomized

- Are participants (organizations) recruited in a way that minimizes selection bias?
- Are measurements appropriate (clear origin, or validity known, or standard instrument; and absence of contamination between groups when appropriate) regarding the exposure/intervention and outcomes?
- In the groups being compared (exposed vs. non-exposed; with intervention vs. without; cases vs. controls), are the participants comparable, or do researchers take into account (control for) the difference between these groups?
- Are there complete outcome data (80% or above), and, when applicable, an acceptable response rate (60% or above), or an acceptable follow-up rate for cohort studies (depending on the duration of follow-up)?

Quantitative descriptive

- Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)?
- Is the sample representative of the population understudy?
- Are measurements appropriate (clear origin, or validity known, or standard instrument)?
- Is there an acceptable response rate (60% or above)?

Mixed methods

- Is the mixed methods research design relevant to address the qualitative and quantitative research questions (or objectives), or the qualitative and quantitative aspects of the mixed methods question (or objective)?
- Is the integration of qualitative and quantitative data (or results*) relevant to address the research question (objective)?
- Is appropriate consideration given to the limitations associated with this integration, e.g., the divergence of qualitative and quantitative data (or results*) in a triangulation design?

Appendix 4 – Proposed table for synthesis of evidence

Authors (date)	Behaviour Change Technique	Intervention	Study design	Program evaluation										Quality appraisal
		…		Context	Input	Process	Reactions	Learning/ Attitudes	Learning/ Knowledge or skills	Products Behaviour (self-reported)	Behaviour (observed)	Results/ Professional practicel	Results/ Patients	