Interventions for undergraduate and postgraduate medical learners with academic difficulties: A BEME systematic review: BEME Guide No. 56

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Miriam Lacasse[a] (iD), Marie-Claude Audétat[b,c,d], Élisabeth Boileau[e] (iD), Nathalie Caire Fon[b], Marie-Hélène Dufour[a], Marie-Claude Laferrière[f], Alexandre Lafleur[g], Ève La Rue[h], Shirley Lee[i,j], Mathieu Nendaz[c,k] (iD), Emmanuelle Paquette Raynard[f], Caroline Simard[a] (iD), Yvonne Steinert[l] and Johanne Théorêt[a]

[a]Department of Family Medicine and Emergency Medicine, Université Laval, Quebec City, Canada; [b]Department of Family Medicine and Emergency Medicine, Université de Montréal, Montreal, Canada; [c]Unit of Development and Research (UDREM), University of Geneva, Geneva, Switzerland; [d]Family Medicine Unit (UIGP), University of Geneva, Geneva, Switzerland; [e]Department of Family and Emergency Medicine, Université de Sherbrooke, Sherbrooke, Canada; [f]Library, Université Laval, Quebec City, Canada; [g]Department of Medicine, Université Laval, Quebec City, Canada; [h]Department of Education, Université Laval, Quebec City, Canada; [i]Department of Family and Community Medicine, University of Toronto, Toronto, Canada; [j]Canadian Medical Protective Association, Ottawa, Canada; [k]Department of Medicine, University Hospitals, Geneva, Switzerland; [l]Institute of Health Sciences Education, Faculty of Medicine, McGill University, Montreal, Canada

ABSTRACT

Background: Clinical teachers often struggle to report unsatisfactory trainee performance, partly because of a lack of evidence-based remediation options.

Objectives: To identify interventions for undergraduate (UG) and postgraduate (PG) medical learners experiencing academic difficulties, link them to a theory-based framework and provide literature-based recommendations around their use.

Methods: This systematic review searched MEDLINE, CINAHL, EMBASE, ERIC, Education Source and PsycINFO (1990–2016) combining these concepts: medical education, professional competence/difficulty and educational support. Original research/innovation reports describing intervention(s) for UG/PG medical learners with academic difficulties were included. Data extraction employed Michie's Behavior Change Techniques (BCT) Taxonomy and program evaluation models from Stufflebeam and Kirkpatrick. Quality appraisal used the Mixed Methods Appraisal Tool (MMAT). The authors synthesized extracted evidence by adapting the GRADE approach to formulate recommendations.

Results: Sixty-eight articles met the inclusion criteria, most commonly addressing knowledge (66.2%), skills (53.9%) and attitudinal problems (26.2%), or learner personal issues (41.5%). The most common BCTs were *Shaping knowledge*, *Feedback/monitoring*, and *Repetition/substitution*. Quality appraisal was variable (MMAT 0–100%). A thematic content analysis identified 109 interventions (UG: $n = 84$, PG: $n = 58$), providing 24 strong, 48 moderate, 26 weak and 11 very weak recommendations.

Conclusion: This review provides a repertoire of literature-based interventions for teaching/learning, faculty development, and research purposes.

Introduction

Medical training programs are demanding. Whereas most medical learners will complete their training without significant difficulties, 10–15% will experience some problem during their program (Yao and Wright 2000; Faustinella et al. 2004; Reamy and Harman 2006; Yates and James 2006). Learner difficulties can have a huge impact at various levels in medical education. Teachers may become discouraged when facing learners experiencing academic difficulties, particularly for those with behavioral issues (Hicks et al. 2005). At the institutional and societal levels, learners in difficulty can also have a serious impact on the quality of patient care and safety (Hicks et al. 2005). Clinical teachers often struggle to report unsatisfactory trainee performance, in part because they are not familiar with evidence-based remediation options (Yepes-Rios et al. 2016).

Practice points

- Academic difficulties (knowledge, skills, attitudes) are often interconnected with other dimension issues (e.g., personal life, teacher, environment); understanding these issues can help determine educational diagnoses and prescriptions.
- This review found 109 literature-based interventions to use for assessment, mentoring and faculty development purposes.
- Since most studied interventions target knowledge, skills and learner personal issues, educators should develop interventions targeting attitudinal, environmental and teacher related issues, while reinforcing the importance of thorough program evaluation.

Box 1 reports the working definitions used in this article for *academic difficulties*, *undergraduate students*, *postgraduate trainees*, and *remediation*.

Box 1. Definitions/Glossary

Learners with academic difficulties
- "Learners who do not meet the expectations of a training program because of a problem with knowledge, attitudes, or skills" (Steinert 2008).

Undergraduate students
- Learners who are in the process of obtaining a medical degree.

Postgraduate trainees
- Learners who already have a medical degree, also 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.

Remediation
- "*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). However, 'academic difficulties' may be caused by a range of individual, educational and environmental factors, and some "interventions for learners with academic difficulties" may go beyond the concept of remediation.

Some textbooks summarize various interventions aimed at remediation in medical education (Guerrasio 2013; Kalet and Chou 2014), but most of the interventions proposed in these works are expert recommendations, not supported by published studies.

Hauer et al. (2009) described published studies on remediation interventions at the undergraduate, graduate, and continuing medical education levels. They identified 13 studies, primarily describing small, single-institution efforts to remediate deficient knowledge or clinical skills of trainees or below-standard-practice performance of practicing physicians. With such paucity of evidence, they encouraged multi-institutional, outcomes-based research on strategies for remediation, with the use of long-term follow-up to determine the impact on future performance. Cleland et al. (2013) synthesized the available evidence to clarify how and why certain remediation interventions worked. They selected 31 studies, mostly targeting medical students, and concluded that most interventions focus on improving performance to pass an examination or assessment and provide no insight into what types of additional support or teaching are critical, in terms of advancing learning. More recent studies were generally of better quality. These reviews stated that most interventions for learners experiencing academic difficulties rely on expert advice and few appear to have been assessed; they also concluded that evidence was lacking to guide best practices to support medical learners with academic difficulties.

Although Cleland searched in multiple databases, some relevant databases for medical education were not explored (e.g. Education Source and PsycINFO). Their literature review focused primarily on educational measurement and program evaluation. Furthermore, both literature reviews extracted their data following the Kirkpatrick hierarchy only (Kirkpatrick 1994), and did not address other aspects of program evaluation, such as context, input or process (Stufflebeam 2003).

Educational diagnosis

Factors suggestive of academic difficulties during undergraduate or postgraduate medical training and educational diagnoses are well described in the medical education literature (Cariaga-Lo et al. 1997; Stern et al. 2005; Yates and James 2006). Most of the frameworks supporting the analysis of challenging learning situations in medical education (Shapiro et al. 1987; Gordon 1993; Vaughn et al. 1998; Kahn 2001; Mitchell et al. 2005) can be summarized by the one proposed by Steinert (2008, 2013), adapted as the Educational Diagnosis Wheel (Lacasse 2009).

This framework refers to a socio-constructivist approach to learning, where the learner interacts with a teacher in a learning environment/system. Learner issues involve academic difficulties (fundamental, clinical, procedural or work setting **knowledge**; cognitive (clinical reasoning skills, study skills and test-taking skills), interpersonal, structural or procedural **skills**; and personal, interpersonal or professional **attitudes**) as well as **personal life issues** (health, spouse/family, financial issues, cultural adaptation and social life). These personal life issues, together with difficulties at the **teacher** level (personal life issues or gaps in faculty development) or **environment/system** level (learning climate or learning conditions) often have an impact on competency development and resulting academic success. However, these dimensions around learning which contribute to academic difficulties should not excuse competence issues but help to explain the educational diagnosis and plan management accordingly (Lacasse 2009).

Conceptual frameworks underlying interventions for learners experiencing academic difficulties

From a theoretical perspective, most interventions for learners experiencing academic difficulties refer to learning theory. For example, feedback and monitoring of behavior refer to operant conditioning (Skinner 1974) and social learning theories (Bandura 1986); cognitivist methods such as associative learning strategies and concept mapping are inspired by information processing theory (Miller 1956) and cognitive load theory (Sweller 1988); learning/remediation plans and reflective practice are inspired by 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 et al. 1987) and situated learning (Lave and Wenger 1991).

However, most studies describing interventions for learners experiencing academic difficulties do not provide an explicit conceptual framework (Cleland et al. 2013). Nevertheless, since health professions education is a form of health professional practice development, and health professional practices can be seen as a form of behavior, educational interventions should take advantage of behavioral change theories and strategies in their design. A reliable method has been developed to specify groups of behavior change techniques (BCTs), which help to identify intervention content with their proposed mechanisms of change. Michie's BCT Taxonomy (Michie et al. 2015), outlined in Supplemental Table 1, is a consensually agreed, reliable taxonomy that could be used across behaviors,

disciplines and areas of interest. This taxonomy is very useful to classify interventions in a process of data extraction and analysis, but it has been rarely used in medical education (Duncan et al. 2012; French et al. 2012). It facilitates understanding of educational interventions by classifying those under 16 groupings, which can be associated with the educational diagnoses depicted previously:

- Interventions using *Shaping knowledge* could address Knowledge deficiencies
- Interventions using *Comparison of behavior*, *Associations*, *Repetition and substitution* or *Comparison of outcomes* seem promising to address Skills issues
- Interventions based on *Natural consequences*, *Scheduled consequences*, *Reward and threat* or *Covert learning* seem relevant for Attitude concerns
- Interventions focusing on *Regulation* (medical/psychological support), *Antecedents* (accommodations), *Identity* or *Self-belief* could help with Learners' personal issues
- Interventions promoting *Social support* would be useful for Teachers' and Environment/System problems
- Interventions grounded on *Goals and planning* or *Feedback and monitoring* may be used to address any educational diagnosis.

Objectives

The goals of this review are to identify interventions for undergraduate (UG) and postgraduate (PG) medical learners experiencing academic difficulties, to link them to a theory-based conceptual framework, and to provide literature-based recommendations around their use.

Methods

This systematic review followed the BEME systematic review framework (http://www.bemecollaboration.org/Publications+Research+Methodology/). The review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Moher et al. 2009) (Supplemental Appendix 1). This review was registered with and approved by the BEME Collaboration. The Review team followed accepted BEME review procedures. The study protocol was peer-reviewed, registered and published on the BEME web site in April 2017 (Lacasse et al. 2017).

Search sources and strategies

This systematic review searched the MEDLINE, CINAHL, EMBASE, ERIC Education Source and PsycINFO databases combining the following concepts: (1) medical education, (2) professional competence or difficulty, and (3) educational support. (The keywords used and the detailed search strategy are presented in Supplemental Appendix 2.) The literature was searched from 1 January 1990 to 31 December 2016 since the development of current competency-based medical education programs arose during the last decade of the twentieth century (Carraccio et al. 2002).

Articles retrieved in previous reviews about remediation options in medical learning (Hauer et al. 2009; Cleland et al. 2013) 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) were hand searched. In addition, three experts in the field were contacted by email to share any study results relevant to this review.

Study selection criteria

The focus of this review is on interventions for undergraduate and postgraduate medical learners experiencing academic difficulties. Therefore, to be included, articles needed to meet these criteria:

- original research studies or innovation reports;
- come from a medical discipline;
- focus on undergraduate students or postgraduate trainees in difficulty;
- describe at least one intervention strategy aimed at supporting learners with academic difficulties;
- include at least one form of program evaluation.

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

After the removal of duplicates, one reviewer (EL or CS) screened all titles and abstracts identified by the search strategy and eliminated obviously irrelevant reports. A second reviewer (ML) reviewed the remaining titles and abstracts. In case of doubt as to their relevance, articles were not eliminated at this stage. Full-text articles were retrieved for all potentially relevant citations. Two reviewers independently assessed the remaining articles (ML and CS) using full texts and decided if they should be selected for the review based on the inclusion and exclusion criteria. A third reviewer (AL) was consulted if differences arose in the process. Bibliographies of selected articles were searched to ensure all key articles were included.

Data extraction

For each article, the reviewers extracted data about each intervention strategy (targeted educational diagnoses and behavior change technique groupings) and program evaluation design, including effectiveness of outcomes and quality appraisal. A standardization meeting allowed to pilot the data extraction sheet using 5 articles identified by a scoping search.

Two random pairs of reviewers independently extracted data from all full-text articles selected and coded the relevant information on the data extraction sheet. Data extraction was facilitated by an online data extraction form (Supplemental Appendix 3). After codification of all included studies, inter-rater reliability was assessed by comparing results of study codification between coders, distributed according to control rater effect. Percentage of agreement on BCT involved in each intervention strategy

was computed since the study setting did not allow for intra-class correlation nor Cohen's kappa. Intra-class correlation was computed for program evaluation types and the MMAT indicators. Three articles were excluded from these analyses as they were part of the reviewers' pilot and were rated by all of them. Discrepancies in coding were submitted to a third reviewer (ML or CS) for final decision.

Behavior change techniques groupings

Data extraction regarding each intervention strategy followed Michie's BCT Taxonomy (Michie et al. 2015). Since this taxonomy might not be intuitive to clinical teachers, a discussion around suggested interventions for each BCT grouping allowed for a common understanding of definitions for each of the 16 groupings (Supplemental Table 1). The reviewers extracted up to three BCTs for each intervention strategy retrieved from every single article.

Program evaluation and importance of outcomes

A modified version of Kirkpatrick's classification of training outcomes proposed by Issenberg et al. (2005) and Freeth (2005), and adopted by the BEME collaboration as a grading standard for systematic reviews (Hammick et al. 2010), helped to classify the outcomes during extraction of program evaluation data, without assuming any causality or hierarchy between the different levels. These levels are:

- Level 1: Reaction;
- Level 2A: Change of attitudes;
- Level 2B: Change of knowledge and/or skills;
- Level 3: Behavioral change (self-reported/observed, as suggested by Steinert et al. (2012));
- Level 4A: Changes in professional practice;
- Level 4B: Benefits to patients.

Data were also extracted using Stufflebeam's (2003) CIPP model (context/input/process/product), which considers program evaluation beyond the scope of outcomes assessment. This model is a decision-focused approach to evaluation, providing systemic information for program managers (Fitzpatrick et al. 2011). Context refers to needs assessments, Input involves costs and feasibility, Process examines how the implementation unfolded, and Products describe the outcomes, presented here according to Kirkpatrick's classification levels.

Effectiveness of outcomes

In order to summarize the effectiveness of outcomes in each article (as stated by the authors), two coders (ML, CS) analyzed the previously identified outcomes (by independent article reviewers) on a 4-point scale: harmful/not reported (0), inconclusive (1), slightly effective (e.g. statistically significant, but not educationally significant) (2) or effective (3). Consensus was established between the two coders for the final score.

Quality appraisal of studies

The quality of each included study was 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 were expected with this search strategy).

The MMAT first screens methodological quality with two questions, and then asks design-specific questions (4 for qualitative or quantitative studies, and 3 for mixed methods studies). A score (out of 100%) is then calculated, corresponding to the number of criteria met (25% for each criterion) for qualitative and quantitative studies, or to the quality of the weakest component in mixed methods studies.

Synthesis of extracted evidence

The lead reviewer conducted a thematic content analysis to group all similar intervention strategies in broader types of interventions. For example, all intervention strategies involving peer-led study groups or student-run instruction or review programs were labeled as "Peer tutoring/support" type of intervention. The codification was conservative, to avoid loss of data while facilitating synthesis and the formulation of recommendations. At the end of the data extraction process, the lead reviewer identified the main BCT for each type of intervention based on the data extracted by each pair of reviewers.

Each type of intervention was mapped to the relevant educational diagnoses (knowledge, skills, attitudes, learner, teacher, and environment). Since most studies involved many diagnoses and interventions, some types of interventions were not always relevant to the primary educational diagnoses addressed in each article. The latter guided a triangulated classification process where three reviewers (MHD, ML, AL) mapped each type of intervention to relevant diagnoses. A descriptive analysis was conducted to synthesize extracted data.

We used an approach inspired from GRADE guidelines (www.gradeworkinggroup.org) to establish a strength of recommendation for each intervention type. This choice was made based on the clinical parallel that can be drawn, to facilitate understanding by clinical teachers. Since the GRADE scores are typically used in the context of healthcare interventions for patients, we adapted the approach to medical education interventions. There are four recommendation levels: strong, moderate, weak and very weak. For each intervention type, the strength of recommendation was established using the approach described in Figure 1. Panel-blinded assessment of the strength of recommendations with three reviewers (MHD, AL and MN) confirmed the pilot version of this logical approach to establishing strengths of recommendation with a good intra-class coefficient ICC(2,1) = 0.72 (<0.001).

Results

Description of the articles

Of the 14,898 screened titles, 68 articles met the inclusion criteria (Figure 2): 45 articles involved undergraduate (UG) learners and 26 involved postgraduate (PG) learners. Three articles included both undergraduate and postgraduate learners, and were therefore included in both groups for subanalyses. The publication dates ranged from 1991 to 2016.
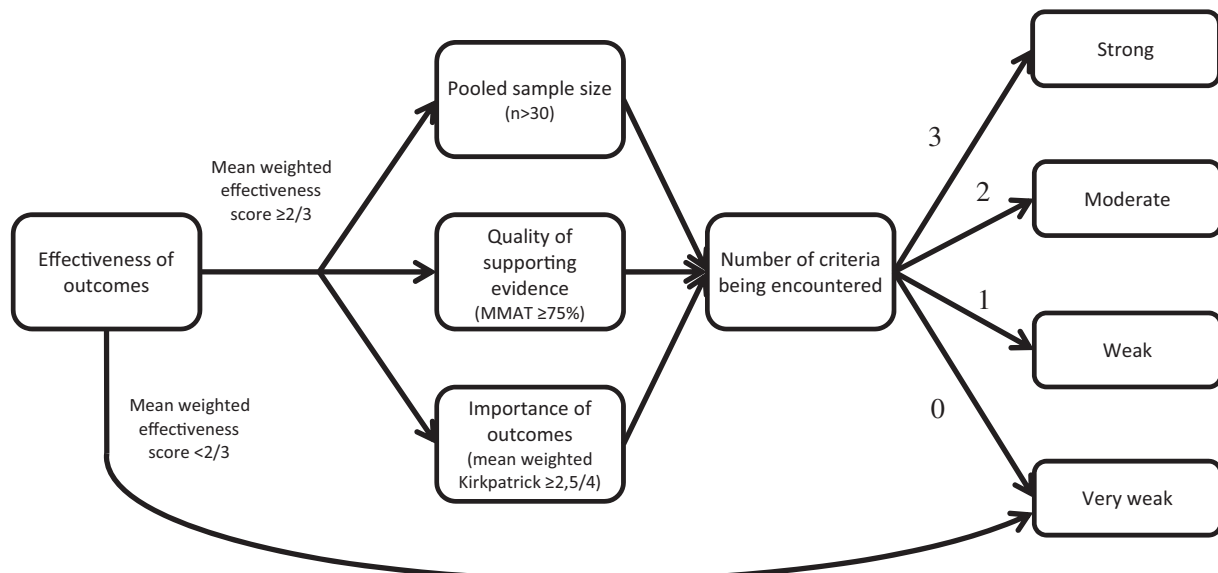
Figure 1. GRADE-like approach to identify the strength of recommendation. A logical sequence determined the strength of recommendation, using the following criteria (adapted from GRADE, www.gradeworkinggroup.org) for each intervention type: - **Effectiveness of the outcomes** or risk/benefit ratio: we coded the evidence for each article by attributing a score between 0 and 3 (from 0: harmful/not reported", 1: inconclusive, 2: slightly effective, 3: effective. Afterwards, we computed a mean score for each intervention type, by weighting each study by its sample size. We coded the criterion as "sufficient" if the weighted mean effectiveness score was equal or over 2. - **Pooled sample size**: we pooled the number of study participants and coded the criterion as "sufficient" if the sum was equal to or over 30. This cutoff represent the well-known but arbitrary minimal sample size for data to distribute normally (Pett 2015). - **Quality of supporting evidence**: we coded the quality of evidence using the MMAT for each article, then we computed a mean score for each intervention type, by weighting each study by its sample size. We coded the criterion as "sufficient" if the weighted mean MMAT score was equal or over 75%. - **Relative importance of outcomes**: for each article, we attributed a score for the most relevant outcomes being reported in terms of Kirpatrick levels (Kirkpatrick 1994). This score varying between 1 and 4 was also computed in a mean weighted by each article's sample size. The criteria was then coded as "sufficient" when the weighted mean score was equal or over 2.5 (therefore involving more studies assessing levels 3 and 4).
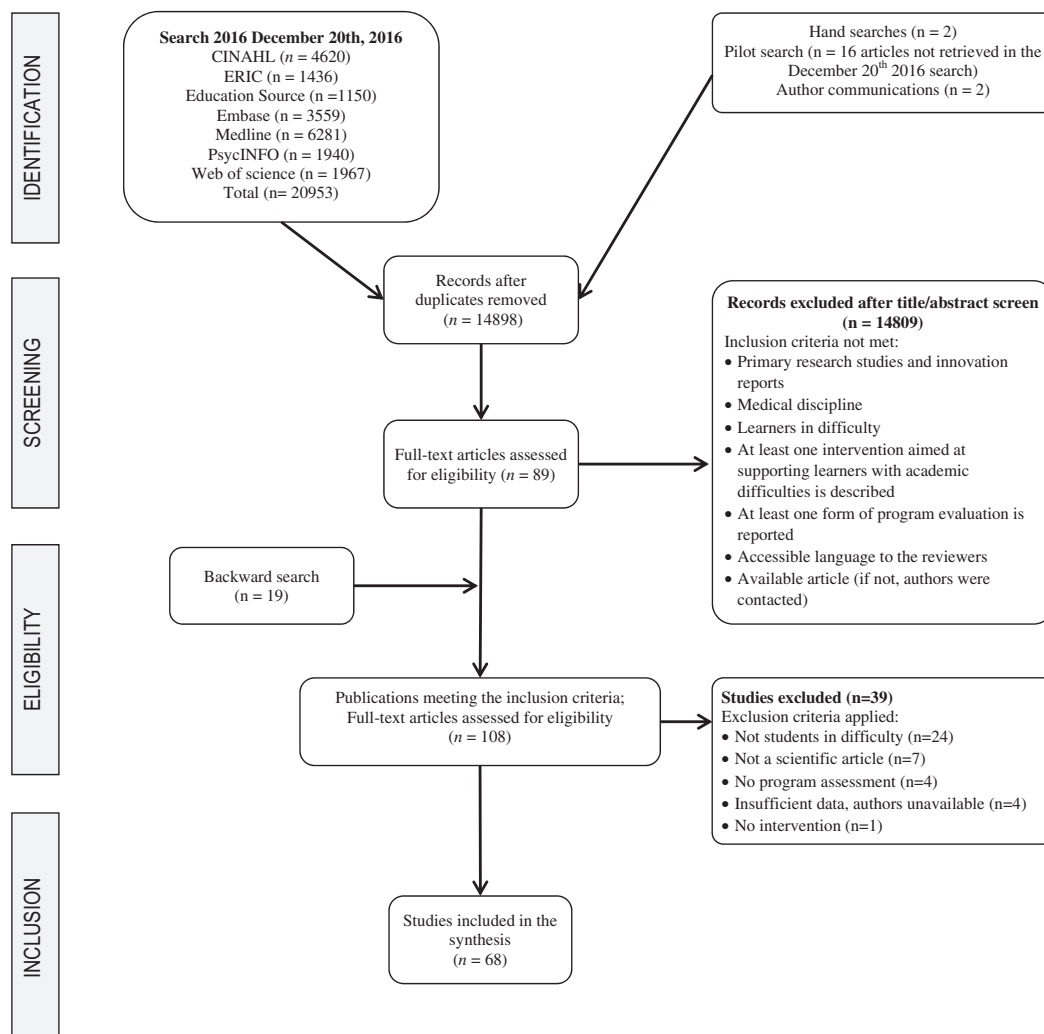

Figure 2. Flow chart.

These articles involved a total of 47,082 learners, most commonly presenting the following educational diagnoses: knowledge deficits (66.2% of the articles, UG: $n = 23$, PG: $n = 22$), unsatisfactory skills (53.9%, UG: $n = 20$, PG: $n = 18$), learner personal issues (41.5%, UG: $n = 21$, PG: $n = 8$) and attitudinal concerns (26.2%, UG: $n = 6$, PG: $n = 13$). Intervention strategies were seldom aimed at correcting teacher issues (3.0%) or environmental/systems issues (1.5%).

Methodological quality of the studies

The methodological quality of the studies was variable. The assessment designs involved 9 qualitative designs, 64 quantitative designs (3 randomized controlled, 46 non-randomized and 15 descriptive), and 5 mixed methods designs (also included in the qualitative or quantitative designs). MMAT scores varied from 0% to 100%. Detailed results for MMAT are provided in Supplemental Table 2. Total MMAT scores were compared for inter-rater reliability. Inter-rater reliability could not be computed for each individual criterion, as it was dependant on the study design, which varied across studies. Intra-class correlation (2,2) between coders was 0.27 ($p = 0.14$), which was poor (Koo and Li 2016).

Five of the nine designs with a qualitative component met the criteria for further appraisal (clear question, which can be addressed by collected data), and were therefore scored (mean $= 41.2\%$, range 0–100%). The sources of qualitative data were relevant to address the research question for the five articles. However, the process for analyzing data was relevant in only three articles, and how findings relate to the context was given appropriate consideration in only three of the articles. There was appropriate consideration given to how findings relate to researchers' influence in four of the five articles.

The three quantitative randomized controlled studies had a score of 100%: clear description of randomization and of the allocation concealment, complete outcome data and low withdrawal/drop-out.

Among the 46 quantitative non-randomized designs, 29 met the criteria allowing to calculate a score (mean $=$ 53.3%, range 0–100%). Most of these reports minimized selection bias in their recruitment ($n = 27$), had appropriate measurements regarding the exposure/intervention and outcomes ($n = 23$), controlled for difference between groups ($n = 19$), and had complete outcome data/acceptable response rate ($n = 26$).

Only seven of the 15 quantitative descriptive designs met the criteria allowing us to calculate a score (41.2%, range 0–100%). All presented a relevant sampling strategy, representative of the population under study, and showed an acceptable response rate. However, only two studies used appropriate (clear origin, valid or standard) measurements.

Finally, among the six mixed methods designs, the MMAT score could be calculated for four articles (66.7%, range 0–100%). They all had a relevant design to address the research questions and demonstrated a relevant integration of qualitative and quantitative data. However, only two articles triangulated the data from the qualitative and quantitative designs and discussed the associated limitations.

Description of the interventions

The selected articles comprised a total number of 261 strategies (UG: $n = 169$, PG: $n = 102$), and many ($n = 77$, 29.5%) involved more than one BCT. The most commonly employed BCTs were *Shaping knowledge* (27.2% of intervention strategies), *Feedback and monitoring* (19.5%), and *Repetition and substitution* (15.3%). None of the retrieved intervention strategies involved *Comparison of outcomes* or *Covert learning*. Very few built on *Identity* (0.4%) *Natural consequences* (0.8%) or *Self-belief* (1.5%). Figure 3 compares the proportions of intervention strategies using each Behavior Change Technique Grouping in undergraduate and postgraduate learners. Since the percentage of agreement was 48.1% between the random pairs of reviewers, a single third reviewer (ML) decided on final codification when facing divergent opinions.

We categorized the 261 intervention strategies in 109 different types of interventions (UG: $n = 84$, PG: $n = 58$). Supplemental Appendix 4 shows how many articles reported each type of intervention with their main BCT, with the training level where they were implemented (undergraduate/postgraduate), and the educational diagnoses for which they are relevant.

Program evaluation and effectiveness of outcomes

Program evaluation data extraction using the four aspects of program evaluation suggested by Stufflebeam (2003) (Figure 4) identified products/outcomes (for at least one of the four levels of Kirkpatrick) in 97% of the articles. Studies providing an assessment of context (22%) mostly presented needs assessment data or described the goals underlying intervention development. The resources (Input) needed for intervention development and implementation were reported in 22% of the articles. Some focused intervention strategies involved short (about 10 minutes) but frequent actions (Drake et al. 2015). Other programs reported mean faculty time commitment of up to 30 hours (Guerrasio and Aagaard 2014; Guerrasio, Garrity, et al. 2014). The costs engaged varied significantly, and were covered mostly by medical schools or student insurance (Segal et al. 1999; Laatsch 2009; Rowland et al. 2012; Guerrasio and Aagard 2018); however, extra tuition was demanded in some schools (Sayer et al. 2002). This review did not identify any funding from commercial sources. Finally, articles reporting on their implementation process (25%) discussed mostly the number of participants in their programs (Dowell et al. 2006; Brokaw et al. 2011; Sanche et al. 2011; Stegers-Jager et al. 2013; Platt et al. 2014), their characteristics (DeVoe et al. 2007; Rowland et al. 2012) and the strategies that were used (Segal et al. 1999; Yaghoubian et al. 2012; Malakoff et al. 2014; Bierer et al. 2015; Bhatti et al. 2016). They also presented some predictors of attendance or program success (Rehm and Rowland 2005; Winston et al. 2014; Brennan and McGrady 2015), as well as suggestions for improvement (Guerrasio and Aagard 2018).

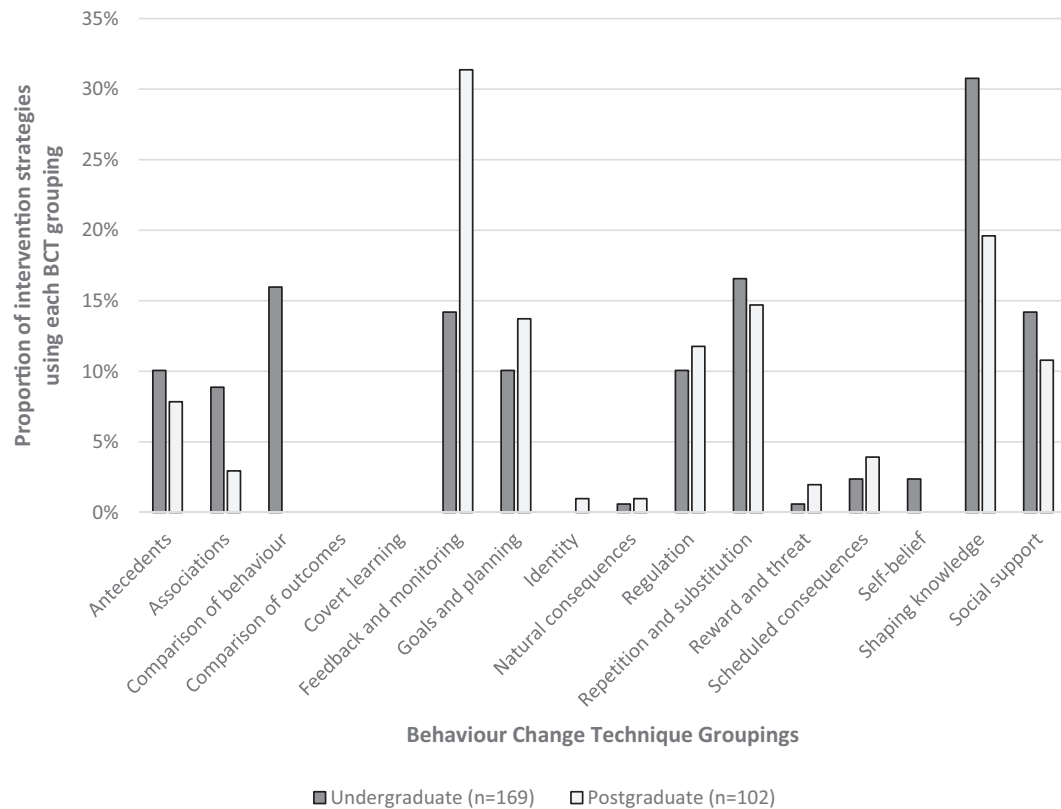Sixty-eight percent of the articles ($n = 46$) assessed more than one intervention in their program evaluation design

Figure 3. Comparative proportion of intervention strategies using each Behavior Change Technique grouping in undergraduate and postgraduate learners.
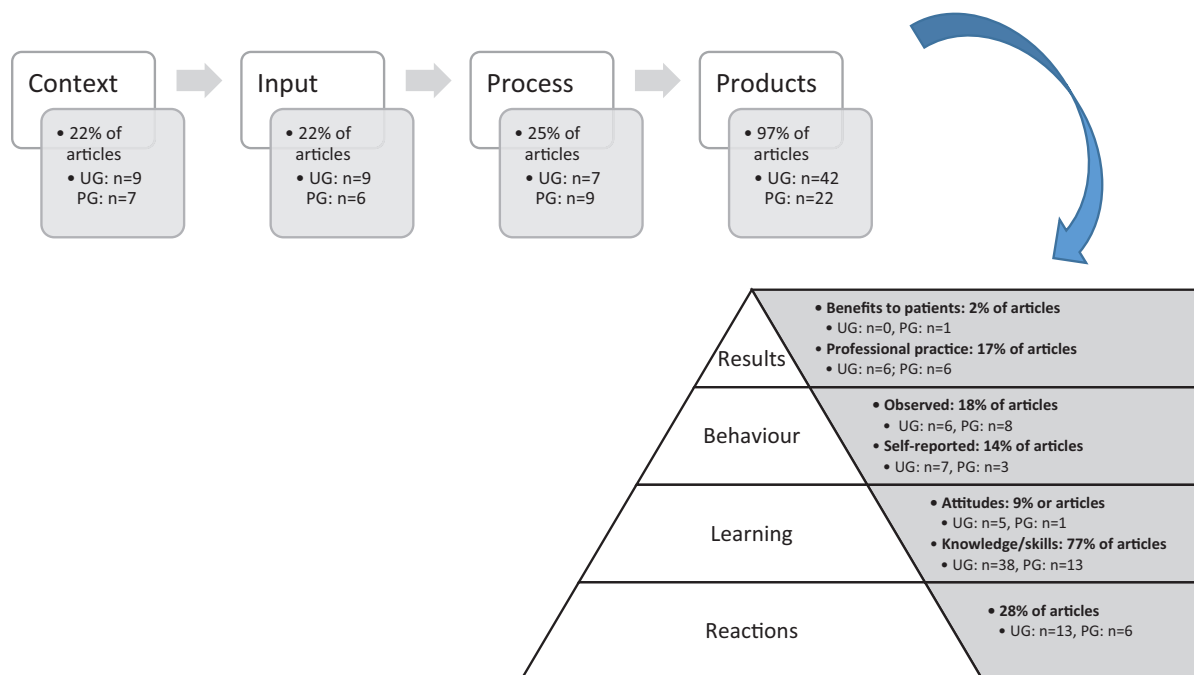

Figure 4 – Distribution of the aspects of program evaluation (Stufflebeam 2003) among undergraduate and postgraduate articles.

(multi-component interventions). Intra-class correlation (two-way random effects model) for program evaluation data varied from −0.18 to 0.71 ($M = 0.29$).

Regardless of the quality of supporting evidence and importance of outcomes, most articles reported effective (64.7%) or slightly effective (20.6%) outcomes, based on the conclusions stated from the authors of each study. Only 10.3% of the articles had inconclusive supporting data. One article found harmful outcomes, demonstrating that a 6–8-week remediation clinical placement led to a performance decline across serial OSCEs (Pell et al. 2012).

Two articles (Dowell et al. 2006; Audetat et al. 2011) did not report any outcomes. Intra-class coefficient revealed an excellent inter-rater reliability (ICC[2,1–4]= .97, $p < .01$).

Interventions with strengths of recommendations

The pooled number of study participants, the mean weighted Kirkpatrick level and the pooled effectiveness that allowed us to compute the strength of each recommendation are described in Supplemental Appendix 4

(supplemental digital content). Eighty-three types of interventions (76%) involved a pooled number of participants over 30, 67 (61%) had a weighted mean Kirkpatrick level outcomes ≥2.5/4, and 50 (46%) had a weighted mean effectiveness score over ≥2/3.

Twenty-four types of interventions met criteria for "Strong" recommendations (available in Table 1), 48 were graded as "Moderate", 26 as "Weak" and 11 as "Very weak".

To validate the computation, we asked three reviewers to appraise the strength of recommendation based solely on their judgement (not being aware of the cutoffs for each criterion). The inter-rater reliability (intraclass correlation) was 0.71 and correlations between reviewer's recommendation levels and our computed level varied from 0.71 to 0.75 ($p < 0.0001$).

The distribution of these recommendations under each BCT grouping is presented in Figure 5. The frequency of the strengths of each recommendation for each educational diagnosis is illustrated in Figure 6.

Supplemental Tables 3 and 4 summarize the types of interventions aimed at relieving contributing factors and those for remediating academic difficulties, for both undergraduate and postgraduate learners. They list the 109 types of interventions classified under their respective main BCT, mapped to the relevant educational diagnoses with their strength of recommendation calculated separately for each training level.

The types of interventions retrieved for each group of BCT are described below (alphabetical order), recalling key elements of their definition (Supplemental Table 1) and specifying for which educational diagnoses they were recommended. The strengths of recommendations presented below result from pooling of interventions for undergraduate and postgraduate learners, and may therefore differ from Supplemental Tables 3 and 4.

Antecedents - restructuring the environment

Most types of interventions in the Antecedent BCT grouping addressed learning environment issues ($n = 9$) or learner personal issues ($n = 7$); two were aimed at remediating knowledge or skills deficits. As defined in Supplemental Table 1, this BCT grouping focuses on restructuring the physical/social environment to avoid/reduce exposure to cues for the behavior or add objects to the environment or other forms of support in order to facilitate performance.

Recommendations to improve the learning environment involved *curriculum content review* ($n = 1$, Strong), *rescheduling a course at a relevant timing* ($n = 1$, Strong) and *reducing contact hours across the first two years* ($n = 1$, Strong) (Slavin et al. 2014). Some types of interventions aimed to reduce workload, such as *curriculum decompression* ($n = 3$, Strong) (McCahan 1991; Kies and Freund 2005; Sikakana 2010), *modified schedule/ease time demands* ($n = 1$, Moderate) (Reamy and Harman 2006) and *reduced patient load* ($n = 1$, Very weak) (Audétat et al. 2011). Others focused on restructuring assessment policies, such as *eliminating norm-referenced exam performance data* ($n = 1$, Strong) and *pass/fail grading system* ($n = 1$, Strong) (Slavin et al. 2014). Only one focused on *environmental changes encouraging health promotion* ($n = 1$, Moderate) (Brennan and McGrady 2015).

This review identified many types of accommodations for learners' personal issues. For example, undergraduate learners with learning disorders or attention-deficit disorders could benefit from *curriculum decompression* ($n = 3$, Strong) (McCahan 1991; Kies and Freund 2005; Sikakana 2010), *extra time on tests* ($n = 2$, Moderate) (Walter and Croen 1993; Segal et al. 1999), *assistance with note taking* ($n = 1$, Moderate) (Segal et al. 1999) and *separate room seating* ($n = 1$, Moderate) (Walter and Croen 1993). At the postgraduate level, types of interventions involved a *quiet area for dictating* ($n = 1$, Moderate) (Katz et al. 2013), *reduced patient load* ($n = 1$, Weak) (Audetat et al. 2011) and *limits on away/elective rotations* ($n = 1$, Moderate) (Reamy and Harman 2006).

Restructuring the environment with interventions such as *course extension* ($n = 2$, Strong) (Burch et al. 2007; Sikakana 2010) or *backup coverage for calls* ($n = 1$, Moderate) (Blumberg et al. 1995) aimed to remediate knowledge and skills difficulties, as studied in undergraduate learners.

Regulation - how to manage underlying conditions contributing to academic difficulties

Regulation involves various pharmacological or non-pharmacological support to reduce negative emotions or minimize demands on mental resources to facilitate behavior change. All retrieved types of interventions for this BCT focused on learners' personal issues. The most commonly retrieved ones under this BCT grouping were *psychological/psychiatric counseling/support* ($n = 10$, Moderate) (Walter and Croen 1993; Segal et al. 1999; Powell 2004; Reamy and Harman 2006; Cleland et al. 2010; Brokaw et al. 2011; Mysorekar 2012; Yaghoubian et al. 2012; Bhatti et al. 2016; Sparks et al. 2016), *medical evaluation and therapy* ($n = 4$, Moderate) (Segal et al. 1999; Cleland et al. 2010; Brokaw et al. 2011; Bhatti et al. 2016) and *stress management/well-being training (interactive sessions)* ($n = 3$, Strong) (McGrady et al. 2012; Brennan and McGrady 2015; Brennan et al. 2016). The other interventions promoting well-being were a *resilience and mindfulness program* ($n = 1$, Strong) (Slavin et al. 2014), *physical exercise* ($n = 1$, Moderate) (Powell 2004), *relaxation* ($n = 1$, Moderate) (Powell 2004) and *meditation* ($n = 1$, Moderate) (Brennan and McGrady 2015), that all assist in the management of personal difficulties. In some cases, learners would benefit from *substance abuse rehabilitation* ($n = 2$, Strong) (Reamy and Harman 2006; Bhatti et al. 2016). Some neuropsychological interventions, such as formal *psychomotor/learning assessment and therapy* ($n = 1$, Strong) (Bhatti et al. 2016) will help those with cognitive skills difficulties including clinical reasoning. Learners with physical problems, such as visual processing deficits, might benefit from *visual training* ($n = 1$, Moderate) (Walter and Croen 1993). *Referral to student support services* ($n = 1$, Moderate) (Cleland et al. 2010) is also an important support strategy. A *leave of absence* ($n = 1$, Strong) (Bhatti et al. 2016) may also benefit many learners and allow them to come back to learning after their personal issues are resolved or controlled.

Table 1. Summary of strong interventions for learners experiencing academic difficulties.

Remediation interventions (references) under each Behaviour Change Technique Groupings	Number of interventions	Level Undergraduate	Level Postgraduate	Knowledge	Skills	Attitude	Learner personal issues	Teacher	Learning environment	Pooled number of participants (n)	Quality of evidence (weighted mean MMAT score) (%)	Importance of results (weighted mean Kirkpatrick) (/4)	Magnitude of results (weighted mean effectiveness) (/3)	Strength of recommendation
Antecedents														
Course extension (Burch et al. 2007; Sikakana 2010)	2	2		●	●					1405	98.7%	3.89	3.06	Strong
Curriculum content review (reduction of unnecessary details) at the program level (Slavin et al. 2014)	1	1							●	741	100.0%	3	4	Strong
Curriculum decompression (McCahan 1991*; Kies and Freund 2005; Sikakana 2010)	3	3							●	1444	99.3%	3.84	3.07	Strong
Eliminating norm-referenced exam performance data (e.g., z scores, ranks) and set a criterion-referenced total score for passing the course (Slavin et al. 2014)	1	1					●			741	100.0%	3	4	Strong
Pass/fail grading system (Slavin et al. 2014)	1	1					●		●	741	100.0%	3	4	Strong
Reduced contact hours across the first two years of the curriculum by approximately 10% (Slavin et al. 2014)	1	1					●		●	741	100.0%	3	4	Strong
Reschedule a course at a relevant timing of curriculum (Slavin et al. 2014)	1	1							●	741	100.0%	3	4	Strong
Associations														
Standardized clinical reasoning remediation plan (Guerrasio and Aagaard 2014*)	1	1	1		●					53	75.0%	4	4	Strong
Goals and planning														
Remedial program/tool (Sayer et al. 2002; Brokaw et al. 2011; Sanche et al. 2011*; Guerrasio et al. (2018)*)	4	2	2	●	●	●	●			373	76.7%	2.79	4	Strong
Regulation														
Formal psychomotor/learning assessment and therapy (Bhatti et al. 2016)	1		1	●			●			207		3	3	Strong
Leave of absence (Bhatti et al. 2016)	1		1				●			207	100.0%	3	3	Strong
Resilience and mindfulness program (Slavin et al. 2014)	1	1					●			741	25.0%	3	4	Strong
Stress management/well-being training (interactive sessions) (McGrady et al. 2012*; Brennan and McGrady 2015; Brennan et al. 2016*)	3	2	1				●			499	100.0%	3	3.9	Strong
Substance abuse rehabilitation (Reamy and Harman 2006; Bhatti et al. 2016)	2		2				●			228	93.7%	3.09	3.09	Strong
Repetition and substitution														
Longitudinal electives (Slavin et al. 2014)	1	1		●	●					741	0.0%	3	4	Strong
Research (Tekian and Hruska 2004; Slavin et al. 2014)	2	2		●●	●●		●●			833	75.0%	2.89	4	Strong
Service opportunities (Slavin et al. 2014)	1	1							●	741	0.0%	3	4	Strong
Shaping knowledge														
Preparation course/program (Tekian and Hruska 2004; Grumbach and Chen 2006*; Sikakana 2010; Burch et al. 2013)	4	4		●	●	●	●			1765	75.0%	3.81	3.25	Strong
Required conferences (Magarian and Campbell 1992; Yaghoubian et al. 2012; Slavin et al. 2014)	3	2	1	●	●		●			1095	60.0%	2.68	4	Strong
Social support														
Learning communities (Slavin et al. 2014)	1	1		●	●	●	●		●	741	29.7%	3	4	Strong
Mentoring (Platt et al. 2014; Slavin et al. 2014; Bhatti et al. 2016)	3	1	2	●●	●●	●●	●			958	100.0%	2.99	3.77	Strong
Social events (Slavin et al. 2014)	1	1			●	●				741	88.3%	3	4	Strong
Tutorials (Walter and Croen 1993; Schwartz and Loten 1998; Sayer et al. 2002; Sikakana 2010)	4	4		●	●	●	●			1542	100.0%	3.73	3.14	Strong
Tutoring and academic assistance (Magarian and Campbell 1992; Walter and Croen 1993; Segal et al. 1999; Enriquez Vilapana et al. 2008; White et al. 2009; Cleland et al. 2010; Sikakana 2010; Brokaw et al. 2011; Yaghoubian et al. 2012; Bhatti et al. 2016; Sparks et al. 2016)	11	8	2	●	●	●	●			3087	86.0%	2.93	3.48	Strong

Studies identified by a * were focused on a single intervention (i.e. not combined with other interventions in the program evaluation design).
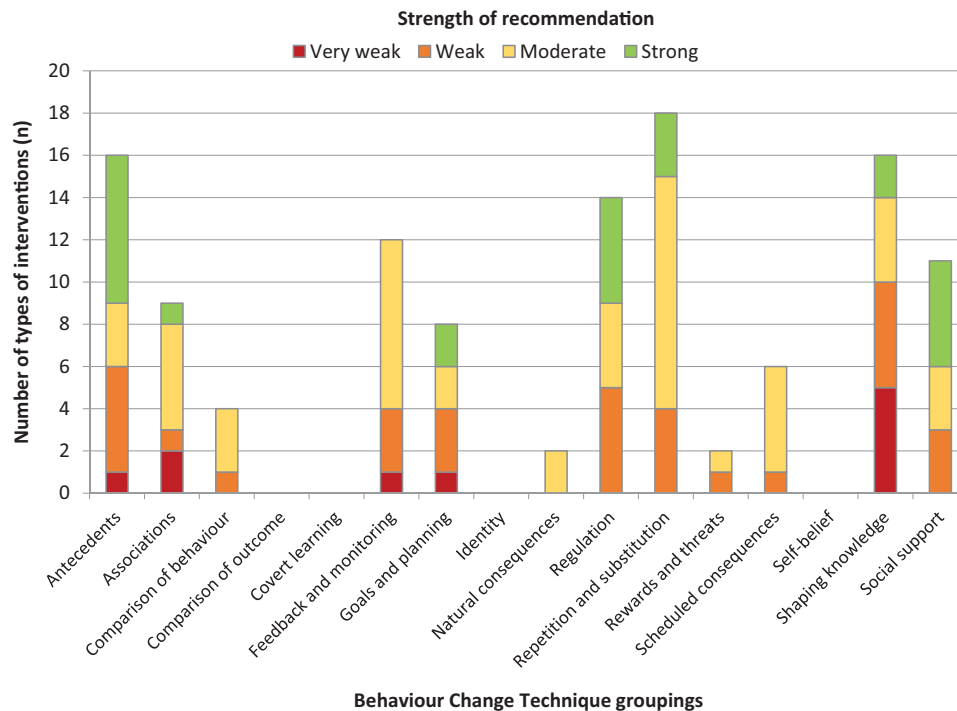
Figure 5. Strength of recommendation of interventions classified by Behavior Change Techniques groupings.

Goals and planning – learning plans and contracts

Most types of interventions using Goals and planning can be applied to any of knowledge, skills or attitude concerns. These are often approached with a *learning/remediation plan* (n = 5, Weak) (Chur-Hansen 1999; Rowland et al. 2012; Katz et al. 2013; Guerrasio, Garrity, et al. 2014; Bierer et al. 2015) or *remediation program/tool* (n = 4, Strong) (Sayer et al. 2002; Brokaw et al. 2011; Sanche et al. 2011; Guerrasio et al. 2018), encouraging learners and teachers to set or agree on a goal and select strategies and resources for learning. *Faculty advisor meeting with learning plan* (n = 4, Moderate) (Harthun et al. 2005; Borman 2006; Reamy and Harman 2006; Enriquez Vilapana et al. 2008) is a key in creating behavioral contracts between learners and faculty. Moreover, *active learning strategies* (n = 2, Weak) (Chur-Hansen 1999; Katz et al. 2013) and *self-regulated learning* (n = 1, Moderate) (Walter and Croen 1993) are often used to encourage learner responsibility and self-esteem. Attitudinal concerns also respond well to *individual remedial training with simulation* (n = 1, Moderate) (Guerrasio and Aagard 2018).

Faculty and peer social support

This review identified *learning communities* (n = 1) and *social events* (n = 1) (Slavin et al. 2014) as strong recommendations supporting interventions to remediate the learning environment involved the Social support BCT.

Many authors studied *tutoring and academic assistance* (n = 11, Strong) (Magarian and Campbell 1992; Walter and Croen 1993; Segal et al. 1999; Enriquez Vilapana et al. 2008; White et al. 2009; Cleland et al. 2010; Sikakana 2010; Brokaw et al. 2011; Yaghoubian et al. 2012; Bhatti et al. 2016; Sparks et al. 2016), *mentoring* (n = 3, Strong) (Platt et al. 2014; Slavin et al. 2014; Bhatti et al. 2016) and *peer tutoring/support* (n = 7, Moderate) (Hesser and Lewis 1992;

Sawyer et al. 1996; Strayhorn 2000; DeVoe et al. 2007; Stegers-Jager et al. 2011; Miller 2014; Suranjana et al. 2015), as a support for learners' personal issues and academic difficulties.

However, the majority of social support interventions retrieved in this review focused on knowledge, skills and/or attitudinal concerns. Learning sessions took place in the form of *tutorials* (n = 4, Strong) (Walter and Croen 1993; Schwartz and Loten 1998; Sayer et al. 2002; Sikakana 2010), *small-group learning* (n = 3, Moderate) (Sayer et al. 2002; Burch et al. 2013; Winston et al. 2014) or *group study* (n = 3, Moderate) (Walter and Croen 1993; Shokar 2003; Rowland et al. 2012). Peer-based learning involving *assignment of high-performance students* (n = 1, Moderate) (Enriquez Vilapana et al. 2008) can also be helpful.

More broadly, an *academic support program* (n = 1, Moderate) such as the one described by Segal et al. (1999) can combine many strategies to guide learners with academic difficulties.

Shaping knowledge … and more

Despite its designation, this grouping supported remediation of more than knowledge issues. All retrieved types of interventions (n = 15) also targeted skills, and seven were also relevant for attitudinal concerns.

Some types of interventions aimed at facilitating learning, such as a *formal orientation program* (n = 1, Moderate) (Blumberg et al. 1995), or *test-taking skills training* (n = 2, Very weak) (Walter and Croen 1993; Shokar 2003).

This review retrieved well-known methods of shaping knowledge such as *required conferences* (n = 3, Strong) (Magarian and Campbell 1992; Yaghoubian et al. 2012; Slavin et al. 2014), *didactic sessions* (n = 5, Weak) (Pickell et al. 1991; Hesser and Lewis 1992; Hardy 1999; Strayhorn 2000; Bhatti et al. 2016) and *workshops* (n = 3, Weak) (Pickell et al. 1991; Chur-Hansen 1999; Winston et al. 2014).
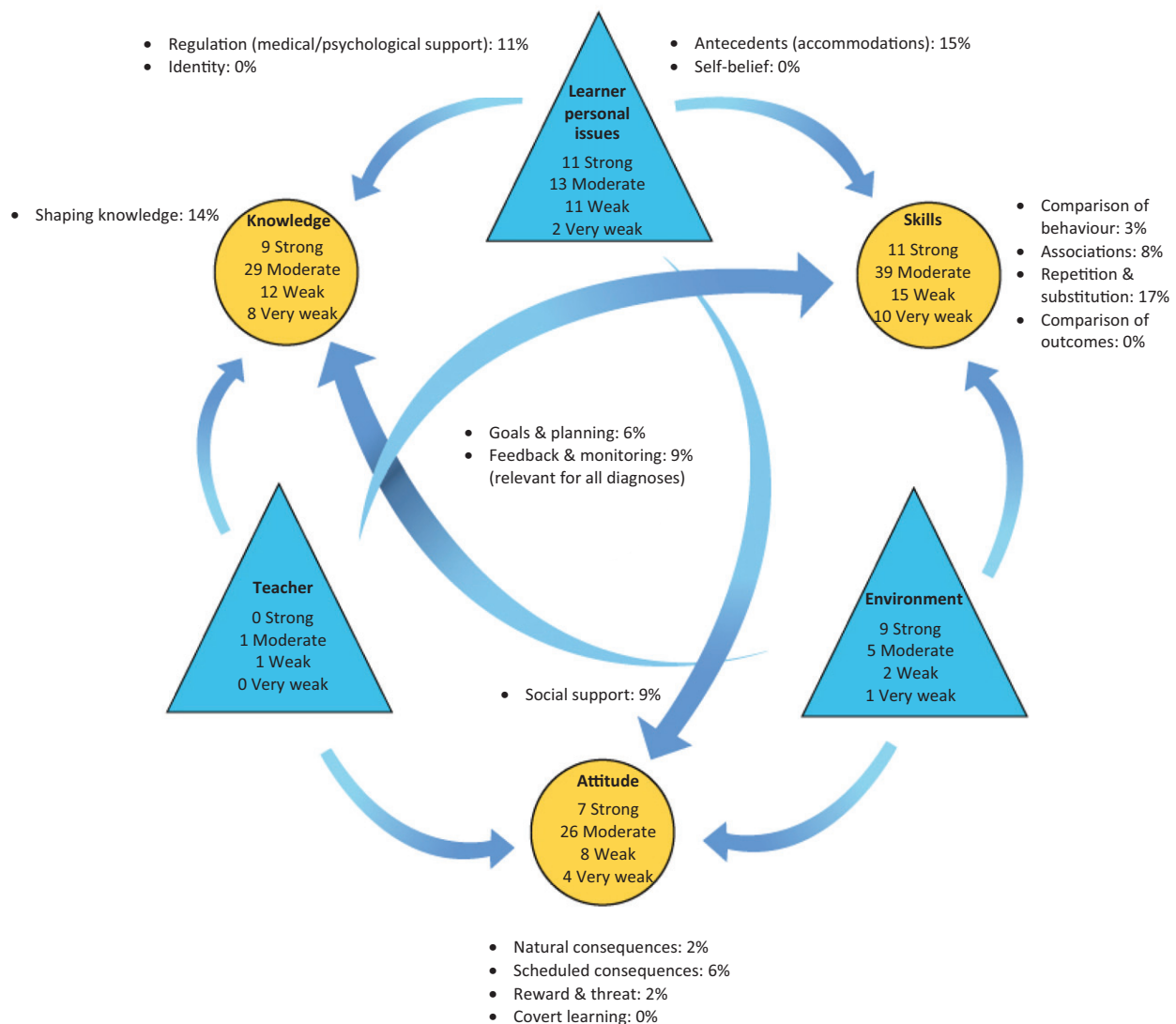
- Regulation (medical/psychological support): 11%
- Identity: 0%

- Antecedents (accommodations): 15%
- Self-belief: 0%

Learner personal issues
11 Strong
13 Moderate
11 Weak
2 Very weak

- Shaping knowledge: 14%

Knowledge
9 Strong
29 Moderate
12 Weak
8 Very weak

Skills
11 Strong
39 Moderate
15 Weak
10 Very weak

- Comparison of behaviour: 3%
- Associations: 8%
- Repetition & substitution: 17%
- Comparison of outcomes: 0%

- Goals & planning: 6%
- Feedback & monitoring: 9% (relevant for all diagnoses)

Teacher
0 Strong
1 Moderate
1 Weak
0 Very weak

Environment
9 Strong
5 Moderate
2 Weak
1 Very weak

- Social support: 9%

Attitude
7 Strong
26 Moderate
8 Weak
4 Very weak

- Natural consequences: 2%
- Scheduled consequences: 6%
- Reward & threat: 2%
- Covert learning: 0%

Figure 6. Educational diagnosis wheel and distribution of the retrieved remediation interventions with their main BCT and strength of recommendation. Educational diagnosis wheel (adapted from (Lacasse 2009) and distribution of the retrieved remediation interventions with their strength of recommendation. This framework refers to a socioconstructivist approach to learning, where the **learner** interacts with a **teacher** in a learning **environment or system**. Learner issues involve academic difficulties (fundamental, clinical, procedural or work setting **knowledge**; cognitive, interpersonal, structural or procedural **skills**; and personal, interpersonal or professional **attitude**) as well as personal life issues (health, spouse/family, financial issues, cultural adaptation and social life). These personal life issues, together with difficulties at the teacher level (personal life issues or lacks in faculty development) or environment/system level (learning climate or learning conditions) often have an impact (blue arrows) on competency development and resulting academic success. However, such underlying problems should not excuse competence issues but help to explain the educational diagnosis and plan remediation accordingly. This figure illustrates the frequency of each Behavior change technique grouping near the educational diagnosis for which they are mostly used. It also lists the number of interventions with their strength of recommendation under the 6 educational diagnoses. Some interventions appear for more than one diagnosis. The study results are presented in an app (https://www.appsheet.com/newshortcut/c3e98044-fd86-4cb2-934f-245e7eff43b4) which lists the studied interventions for each educational diagnosis.

Some authors proposed strategies promoting meaningful learning, such as *discussions* ($n = 1$, Moderate) (Pickell et al. 1991), *clinical forums* ($n = 1$, Very weak) (Hesser and Lewis 1992) and a *review of behaviors after an exam* ($n = 1$, Weak) (Rowland et al. 2012).

Study assistance was investigated in the form of *directed/structured readings/reading assignments* ($n = 10$, Moderate) (Magarian and Campbell 1992; Edeiken 1993; Shokar 2003; Gregg et al. 2008; Aeder et al. 2010; LaRochelle et al. 2012; Yaghoubian et al. 2012; Burch et al. 2013; Platt et al. 2014; Drake et al. 2015), *compared readings* (asking the learner to summarize a few texts on the same subject) ($n = 1$, Very weak) (Audétat et al. 2011), *study skills training* ($n = 8$, Weak) (Hesser and Lewis 1992; Carroll and Lee-Tyson 1994; Hardy 1999; Segal et al. 1999; Powell 2004; Mysorekar 2012; Stegers-Jager et al. 2013; Miller 2014), *study guides/course notes produced by tutors* to support learning sessions ($n = 1$, Weak) (Sayer et al. 2002) or

study sessions with tests ($n = 1$, Moderate) (Reamy and Harman 2006). Many reached a better strength of recommendation than *Private study* ($n = 4$, Very weak) (Hesser and Lewis 1992; Sayer et al. 2002; Shokar 2003; Kosir et al. 2008).

In addition to guiding knowledge, skills and attitudes, *preparation courses/programs* ($n = 4$, Strong) (Tekian and Hruska 2004; Grumbach and Chen 2006; Sikakana 2010; Burch et al. 2013) aimed at also supporting learners with personal risk factors for academic difficulties, such as minority/disadvantaged students and learners from under-resourced educational backgrounds.

Associations – clinical reasoning remediation
Many types of interventions for remediation of clinical reasoning appeared under the Associations group of BCT.

First, if clinical reasoning difficulties result from learners' personal issues such as learning disorders, *cognitive intervention/rehabilitation* (*n* = 5, Moderate) (Walter and Croen 1993; Laatsch 2009; Winston et al. 2010; Klamen and Williams 2011; Katz et al. 2013) can help reinforcing clinical problem solving. Other types of interventions focusing mostly on cognitive skills include *problem-based learning* (*n* = 4, Moderate) (Pickell et al. 1991; Magarian and Campbell 1992; Camp et al. 1994; Burch et al. 2007), *reasoning out loud* (*n* = 2, Very weak) (Walter and Croen 1993; Audetat et al. 2011), *contextual learning* (*n* = 2, Very weak) (Walter and Croen 1993; Chur-Hansen 1999) and *clinical correlations* (*n* = 1, Moderate) (Pickell et al. 1991), to improve hypothesis generation, data collection, diagnosis and/or management of clinical conditions. *Standardized clinical reasoning remediation plan* (*n* = 1, Strong) (Guerrasio and Aagaard 2014) proved to be effective in both undergraduate and postgraduate learners. *Scientific writing* (*n* = 1, Moderate) (Hardy 1999) and *question writing* (*n* = 1, Very weak) (Aeder et al. 2010) also appeared as strategies to develop synthesis skills.

Development of *written clinical protocols* (*n* = 1, Moderate) (Blumberg et al. 1995) for specific high-risk medical conditions highlighted environmental or social stimuli with the purpose of prompting or cueing consistent delivery of high-quality care.

Comparison of behaviors – role modeling

Opportunities to discuss others' performance or perception of behavior to allow comparison with the learner's own performance were provided by role modeling activities, as expected in *demonstration* (*n* = 1, Moderate) (Pickell et al. 1991) and *DVD viewing* (*n* = 1, Moderate) (LaRochelle et al. 2012). Some *motivational activities* (e.g. summer internships allowing to shadow a medical professional) (*n* = 1, Moderate) (Tekian and Hruska 2004) also use role modeling as a preventive strategy for learners at risk of developing academic difficulties.

Repetition and substitution

No intervention seemed to prompt substitution of the unwanted behavior with a wanted/neutral behavior. However, many used repetition, in various contexts.

Supervised practice (*n* = 6, Moderate) [(Pickell et al. 1991; Hardy 1999; Sayer et al. 2002; Cleland et al. 2010; Audetat et al. 2011; Pell et al. 2012), *deliberate practice* (*n* = 1, Moderate) (Guerrasio, Garrity, et al. 2014), *simulation* (*n* = 2, Moderate) (Cleland et al. 2010; Guerrasio and Aagaard 2014) and *standardized patient exercises* (*n* = 1, Moderate) (LaRochelle et al. 2012) provided repeated opportunities to use knowledge, practice various skills and demonstrate appropriate attitudes in varying contexts. Some types of interventions were focused, such as *repetition of previous course content* (*n* = 1, Moderate) (Burch et al. 2013), *laboratories* (*n* = 1, Moderate) (Pickell et al. 1991), *physical examination practice session* (*n* = 1, Moderate) (Pickell et al. 1991), and *communication skills training* (*n* = 2, Weak) (Chur-Hansen 1999; Hardy 1999). Other types of interventions involved more general strategies, like *supplemental training* (*n* = 5, Moderate) (Edeiken 1993; Dowell et al. 2006; Reamy and Harman 2006; Cleland et al. 2010; Brokaw et al. 2011),

which lasted *up to a year* (*n* = 6, Moderate) (Kies and Freund 2005; Rehm and Rowland 2005; Brokaw et al. 2011; Dupras et al. 2012; Pell et al. 2012; Yaghoubian et al. 2012) and sometimes took place at a *new site* (*n* = 1, Moderate) (Reamy and Harman 2006).

Offering *service opportunities* (*n* = 1, Strong) (Slavin et al. 2014), *longitudinal electives* (*n* = 1, Strong) (Slavin et al. 2014) or *research* (Strong) (Tekian and Hruska 2004; Slavin et al. 2014) may increase retention by promoting contextual learning, focusing on consolidation of habits/skills.

Exam preparation appeared in various formats: *MCAT preparation* (*n* = 1, Moderate) (Hardy 1999), *review course/ session* (*n* = 4, Weak) (Reamy and Harman 2006; Gregg et al. 2008; Kosir et al. 2008; Burch et al. 2013), *practice for exams* (*n* = 3, Very weak) (Shokar 2003; Kosir et al. 2008; Aeder et al. 2010). After exam failure, a *second-chance exam without penalty* (*n* = 1, Weak) (Schwartz and Loten 1998) was studied as a possible option.

Feedback and monitoring

Feedback and monitoring techniques were well documented in remediation contexts, with ten types of interventions in this grouping.

Most *feedback* interventions were studied for knowledge, skills or attitude problems in both undergraduate and postgraduate learners (*n* = 11, Moderate) (Blumberg et al. 1995; Chur-Hansen 1999; Sayer et al. 2002; Harthun et al. 2005; Borman 2006; Aeder et al. 2010; Cleland et al. 2010; Rowland et al. 2012; Katz et al. 2013; Guerrasio, Garrity, et al. 2014; Bhatti et al. 2016). *Web-based feedback* (*n* = 1, Moderate) (Drake et al. 2015) was an example of technology-supported feedback to remediate knowledge or skills issues. Strategies such as *pretest/posttest examinations* (*n* = 1, Weak) (Rowland et al. 2012) and *quizes* (*n* = 4, Moderate) (Pickell et al. 1991; Borman 2006; Gregg et al. 2008; Kosir et al. 2008) provided feedback on specific knowledge or skills. *Videotape review* (*n* = 3, Weak) (Borman 2006; Reamy and Harman 2006; Rowland et al. 2012) and *direct observation* (*n* = 1, Very weak) (Audetat et al. 2011) intend to facilitate formative comments on skills or attitudes.

Monitoring interventions retrieved in this review assisted the acquisition of knowledge and/or skills through *quarterly meetings with resident moonlighters led by the service chief* (*n* = 1, Moderate) (Blumberg et al. 1995). Skills and attitudinal concerns were tackled using *informal discussion* (*n* = 1, Moderate) (Dupras et al. 2012) or through a *requirement to check-in at specified intervals and maintain open lines of communication with the Dean of Students and other school officials* (*n* = 1, Moderate) (Brokaw et al. 2011).

The importance of *reflection* (*n* = 1, Moderate) (Guerrasio, Garrity, et al. 2014) seemed a key in ensuring feedback integration for eventual changes in practice.

Reward and threat

Sending a *warning letter* (*n* = 2, Moderate) (Brokaw et al. 2011; Dupras et al. 2012) served to inform that future punishment or removal of reward would be a consequence of the performance of an unwanted behavior. A *point system to document unprofessional behavior* (*n* = 1, Weak) (Malakoff

et al. 2014) was one of the rare types of intervention targeting attitudinal concerns specifically.

Natural consequences

Only two types of interventions appeared under this grouping, both aimed at remediating skills. *Daily management reviews by a quality insurance coordinator* ($n = 1$, Moderate) (Blumberg et al. 1995) improved supervision and performance of moonlighting residents around high-risk medical conditions. *Completion of an independent project* ($n = 1$, Moderate) (Brokaw et al. 2011) to reflect on, or apologize for, unprofessional behavior also appeared relevant for changing attitude.

Scheduled consequences – for severe and persistent difficulties

Learning environment interventions, such as the implementation of an *academic dismissal policy* ($n = 1$, Moderate) (Stegers-Jager et al. 2011), aim to clarify expectations and consequences if progress concerns occur.

Types of interventions under this BCT included *learning contracts* ($n = 5$, Weak) (Sayer et al. 2002; Brokaw et al. 2011; Katz et al. 2013; Sparks et al. 2016; Guerrasio and Aagard 2018), defining learning needs and objectives, strategies to develop competencies, and consequences if there is a failure to meet expectations. Such consequences include *delinquent assignment or task* ($n = 1$, Moderate) (Brokaw et al. 2011), *probation* ($n = 2$, Moderate) (Dupras et al. 2012; Bhatti et al. 2016), *dismissal/voluntary withdrawal* ($n = 2$, Moderate) (Brokaw et al. 2011; Dupras et al. 2012) and, ultimately, *suspension from school* ($n = 1$, Moderate) (Brokaw et al. 2011). These interventions mainly targeted difficulties related to skills and attitudes.

BCT groupings without retrieved interventions

No intervention was retrieved under Comparison of outcomes, Identity, Self-belief and Covert learning.

Operationalizing the results

To operationalize the results from this BEME review, most clinical teachers are likely to search for interventions according to the specific educational diagnoses they are facing with their learners with academic difficulties. Figure 6 illustrates the distribution of the retrieved remediation interventions within each BCT grouping, with their strength of recommendation under each educational diagnosis. Many types of interventions appear for more than one diagnosis. The study results are also presented in MedEd Dx Tx, an app (for iOS and Android) available for free, which lists the studied interventions and their strength of recommendation for each educational diagnosis.

Discussion

This review identified 109 types of interventions for learners experiencing academic difficulties, and established recommendations for each of the retrieved interventions. It updates 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), offering a broader perspective that includes both undergraduate and postgraduate medical trainees. It also builds 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).

Even though Michie's taxonomy was initially designed for healthcare and patient education contexts (Michie et al. 2015), it seems to be a good framework for interventions for learners experiencing academic difficulties in medical education, since most BCT groupings matched at least one intervention. Mapping interventions for learners experiencing academic difficulties under the BCT taxonomy is helpful from a theoretical perspective to identify the content of these interventions. Behavioral interventions were the most common: adjusting the learning environment (*Antecedents*), providing stimuli with opportunities for practice (*Repetition and substitution*) followed by response (*Feedback and monitoring, Reward and threat, Natural/Scheduled consequences*) appear to be good theoretical bases for remediation in the context of competency-based education (Carraccio et al. 2002; Sherbino et al. 2010). Feedback and monitoring was proportionally more commonly used in postgraduate learners' interventions, probably because postgraduate training predominantly involves one-on-one teaching in the clinical environment (Ramani and Leinster 2008). Cognitivist interventions such as those under *Associations* were particularly targeted towards the management of clinical reasoning skills difficulties and in line with a recent AMEE guide on the subject (Audetat et al. 2017). Humanist interventions, identified in this review under the *Regulation* BCT, promoted a learner-centered approach and insisted on self-directed learning, reinforcing the importance of learning plans (*Goals and planning*) in supporting learners with academic difficulties. Finally, socio-constructivist approaches are slightly less common but still moderately recommended as interventions for learners experiencing academic difficulties, under *Social support* and *Comparison of behaviors*. Surprisingly, comparison of behavior was proportionally more frequent as an undergraduate intervention for learners with academic difficulties, maybe because clinical teachers particularly value observation and demonstrations at this level of training. However, role modeling is an important process for the professional development of learners (Passi et al. 2013), at all levels of training.

Very few interventions could not be classified among the 16 BCT. *Comparison of outcomes* never matched as a major BCT for the retrieved interventions. This technique might be limited by patient safety issues, since supervisors should not allow adverse outcomes to occur; nevertheless, some interventions using this BCT are effective in medical education (e.g.: web-based audit and feedback module (Boggan et al. 2017)), but were not tested specifically for learners with academic difficulties. *Covert learning*, understood as a way to imagine performing the wanted/unwanted behavior, followed by imagining a pleasant/unpleasant consequence, or by prompting observation of the consequences for others when they perform the behavior, is in some ways a an approach similar to reflective practice, and could probably be useful for learners with academic difficulties. *Self-belief* was not specifically identified as a major BCT in any intervention in this review;

however, persuasion about capability and visualization techniques might have been used in the *Regulation* interventions involving psychological support. Lastly, despite the fact that the *Identity* BCT did not match any intervention, key elements of professional identify formation including guided reflection, use of personal narratives and role modeling (Wald et al. 2015) might change the lives of some learners who do not feel they "belong" to their discipline. Besides, *Comparison of behavior* was used as the main BCT for interventions in undergraduate but not postgraduate learners. Interventions using role modeling with reflective imitation have been described in medical education (Benbassat 2014) and do use comparison of behavior; it was therefore surprising to find no article using similar interventions specifically aimed at supporting postgraduate learners experiencing academic difficulties.

Boxes 2 and 3 illustrate teaching scenarios with the relevant interventions for each educational diagnosis.

Box 2. Teaching scenario with an undergraduate learner

Brian is a 21 years old, 2nd year medical student. He lives with his parents, and is a member of the university basketball team. You have been his tutor in a problem-based learning course over the last 3 months. You have noticed many issues for this learner:

- Often asks questions about physiopathology or pharmacology concepts you have just explained.
- Commonly lies over his desk during teaching sessions, often wears t-shirts with violent prints as well as holey jeans.
- Tends to interrupt colleagues to ask a question or give his opinion.
- Never teams up with Mohamed or Lee-Chow during physical exam practice sessions. Almost always work with Mary, who patiently teaches him how to perform the various maneuvers as she saw them on the DVD that was to be watched before class.
- Is regularly late, and missed last class without advanced notice.
- Homework: delayed, long continuous text rather than the requested summary, and some sentences contained complex concepts that are not part of the curriculum in second year medical school.

He is not very receptive to feedback, and constantly justifies his difficulties.

Educational diagnoses:
- Learner: health? (attention deficit disorder or other learning disorder? drug abuse?), social? (study time limited by training schedule).
- Structural (study planning) and procedural skills (physical exam maneuvers) issues.
- Interpersonal (racism?) and professional (plagiarism?) attitude issues.

Selection of relevant interventions from this BEME review:
- Formal psychomotor/learning assessment and therapy (strong), medical evaluation and therapy (moderate), referral to student support services (moderate).
- Curriculum decompression (strong) to help with training/study time balance.
- Informal discussion with program director (moderate).
- Learning contract (weak).
- Study skills training (weak).
- Mentoring (strong), assignment of high performance student (weak).
- Point system to document unprofessional behavior (weak), reflection (moderate), completion of an independent project (moderate): eg.: write literature review about impact of unprofessional behavior, warning letter (moderate), delinquent assignment or task (moderate), requirement to check-in at specified intervals and maintain open lines of communication with Dean of Students or other school officials (moderate).

Box 3. Teaching scenario with a postgraduate learner

Elena is a 42 years old international graduate. She immigrated in your country 4 years ago. She practiced as ear, nose and throat specialist for 6 months before immigrating. She just moved in your city less than a month ago. She is single, has no children, but has family in a town 250 km away. She has just started her family medicine residency training, and clinical teachers have noticed some difficulties:

- Difficulty to establish agenda for patient encounter.
- Paternalistic approach.
- Unfocused history of present illness, premature closure for common chief complaints.
- Lack of primary care knowledge for management of common problems.
- Does not always understand the patient; linguistic challenge since English is not her first language.
- Spends lots of time searching through patient records, even when patient is speaking; this causes delays in her schedule.

She is aware that she has some difficulties. She attributes her time management issues to the fact that everything is new to her (health system, work environment and local resources). This is even more obvious when she is on call. She has good insight and welcomes feedback.

Educational diagnoses:
- Learner: cultural adaptation (including language), social network; health? (neuropsychological diagnosis explaining clinical reasoning difficulties?).
- Clinical and work setting knowledge issues;
- Clinical reasoning and interpersonal skills issues.

Selection of relevant interventions from this BEME review:
- Formal orientation program (moderate).
- Referral to student support services (moderate) and leave of absence (strong), for example to take English courses.
- Formal psychomotor/learning assessment and therapy (strong), cognitive intervention/rehabilitation (moderate).
- Faculty advisor meeting with learning plan (moderate), mentoring (strong), tutoring and academic assistance (strong) and peer tutoring and support (moderate).
- Review course/session (weak), directed/structured readings (moderate), private study (very weak).
- Group study (weak), learning communities (strong).
- Feedback (moderate).
- Standardized patient exercises (moderate).
- Supervised practice (moderate), videotape review (weak) or direct observation (very weak), written clinical protocols (moderate), back-up coverage for calls (moderate), supplemental training (moderate) before reintegrating regular program.
- Reasoning out loud (very weak), standardized clinical reasoning remediation plan (strong).
- Communication skills training (weak), demonstration (moderate), for example: how to provide patient-centered care.

Interventions aimed at factors contributing to academic difficulties

Learning environment

As mentioned by Kalet et al. (2017), remediation has typically been considered from the perspective of the individuals (remediator ± remediated). However, it is also intrinsically situated in context. By identifying *Antecedents* as one of the most common group of BCTs for learners experiencing academic difficulties in medical education, this review reinforces the importance of restructuring the learning environment to support these learners. Indeed, Cleland et al. (2018) suggested:

a shift in the culture of medicine from thinking about remediating individual failings to a more holistic and proactive

model, where institutional and structural aspects of a medical programme are aligned and designed to support students from a range of educational and social backgrounds in an educational alliance.

However, most of the types of interventions that focused on the learning environment emerged from a single study (Slavin et al. 2014). In this study, the authors assessed the impact of curriculum modifications and found positive outcomes for undergraduate learners. The literature therefore seems to be scarce about learning environment interventions to support learners in difficulty, particularly for postgraduate learners. Further research should consider interventions at the program or hospital levels to create a favorable environment for remediating medical learners in difficulty, for example by providing multiple means of engagement, of representation and of expression for all learners, as stated in the universal design for learning guidelines (CAST 2018).

Teacher

This review found only two types of interventions focusing on the impact of teacher-specific interventions or faculty development interventions. However, the effectiveness of faculty development in medical education to enhance teaching practices is well documented (Steinert et al. 2006; Steinert et al. 2016), and several authors have proposed competency frameworks for medical teachers and educators (Harris et al. 2007; Srinivasan et al. 2011; Irby 2014; Walsh et al. 2015). Further research should look into specific faculty development efforts and assess their impact on learners with academic difficulties.

Learner

This review found 37 types of interventions to help manage learners' personal issues. Most were under the *Antecedents* or *Regulation* BCT.

The literature on learners' personal issues that may affect academic success describes various sources of difficulties, usually related with health, spouse/family, finances, cultural adaptation and social life (Lacasse 2009). A leave of absence may be essential to allow the learner to resolve personal life issues before concentrating on academic difficulties.

Management of **health issues** rely mostly on the types of interventions under the *Regulation* BCT grouping. This includes medical or psychological consultations and rehabilitation (cognitive, psychomotor, visual training, substance abuse, etc.), accommodations and interventions promoting well-being (physical exercise, stress management, resilience and mindfulness program). This is coherent with recent recommendations at the national, hospital, program, and non-work levels meant to inform stakeholders who have taken up the charge to address trainee well-being (Ripp et al. 2017). Assistance for **spouse/family, finances, and social life** issues can be provided by student support services, who often know available resources very well.

Despite commonly encountered learning difficulties in international medical graduates (Samuelowicz 1987; Zulla et al. 2008; Hashim 2017), this review found few articles assessing interventions to facilitate cultural adaptation. Some prematriculation programs for at-risk learners can be useful for **cultural adaptation**, which is a major challenge

for international graduates (Chen et al. 2011; Lineberry et al. 2015; Kehoe et al. 2016). However, interventions for learners experiencing academic difficulties specifically oriented towards international graduates did not come out in this review.

Remediation of academic difficulties

The majority of the retrieved types of interventions were studied in learners with combined knowledge/skills difficulties; they were also often relevant to attitudinal problems.

The strongest recommendations for interventions designed to target a combination of knowledge, skills and attitudinal concerns appeared under *Social support* and *Goals and planning*. Learning plans and goal-oriented remediation tools or programs build on self-directed learning theory and promote learner engagement and motivation (Knowles et al. 2005). The types of interventions involving social support (peer or faculty tutoring and mentoring, small group learning such as tutorials or group study) are supported by socio-constructivism and the importance of creating communities of practice in medical education.

Knowledge

Shaping knowledge was the BCT grouping with the highest proportion of weak recommendations. None of these types of interventions was targeted at knowledge only, most being used in learners with associated skills or attitude problems. This might be explained by the fact that knowledge deficits are rarely isolated (Guerrasio, Garrity, et al. 2014). Thus, endeavors to shape knowledge may be enhanced by combining them with other interventions aimed at developing more generic skills (Schuwirth 2009).

Types of interventions under the *Shaping knowledge* BCT grouping such as directed readings, private study, didactic sessions/conferences, course extension, and study guides/course notes seem relevant for **fundamental knowledge** consolidation such as anatomy, physiology and pharmacology.

Clinical or procedural knowledge will also benefit from these interventions, but may also be enriched by attendance at morning reports or other meaningful learning activities, as well as supplemental training. Review courses support integration of knowledge at key times during training.

Knowledge of work setting relies mostly on social support, with the advantages of supervised practice and tutoring.

Skills

The types of interventions under the *Associations* BCT grouping were helpful in managing **cognitive skills** deficits such as clinical reasoning deficits. These strategies are consistent with many recommendations from a recent AMEE guide (Audétat et al. 2017); they are also congruent with information processing theory and other cognitivist approaches to learning (Torre et al. 2006). Accommodations such as back-up coverage or other strategies involving role modeling or repetition are also relevant for clinical skills remediation. Finally, **study/test-taking skills** deficits can be

managed using mostly *shaping knowledge* interventions and peer tutoring and support.

Remediation of **interpersonal and procedural skills** is facilitated by feedback obtained through direct observation or videotape review. Surprisingly, these types of interventions appeared only twice in this review, despite the recognized importance of direct observation in clinical teaching (Kogan et al. 2017). Furthermore, the literature is scarce about the impact of direct observation as a remediation intervention. Repetition through laboratories, standardized patient exercises and simulation will also encourage habit formation. Finally, communication skills training focuses on the development of interpersonal abilities.

Structural skills involve practice management and time management. Few interventions relevant to this category of difficulty were retrieved in this review. This might be because the achievement of leadership/management competencies are expected later in training (Lacasse et al. 2014), or are not prioritized during training (Quince et al. 2014; Gonzalo et al. 2016). Initiatives for leadership training are, however, popular for practising physicians (Frich et al. 2015).

Attitude

Personal attitude problems associated with a lack in motivation are sometimes related to doubts about career choice. The impact of interventions involving career advisors do not seem to be known, since no such intervention was retrieved. However, such difficulties can be addressed through appropriate faculty guidance and mentoring (Indyk et al. 2011). Surprisingly, no interventions targeting learner *identity* or professional role (Cruess et al. 2014) was retrieved, which might be good avenues to explore in future studies.

Interpersonal attitude concerns, such as disrespectful behavior or interprofessional collaboration difficulties, might be addressed best through supervised practice, frequent feedback, and *scheduled consequences* documented in a learning contract.

The strategies identified for interpersonal attitude concerns will also be used for **professional issues**; however, some more specific types of interventions such as a point system to document unprofessional behavior (Malakoff et al. 2014) or a requirement to check-in at specified intervals with school officials (Brokaw et al. 2011) can also be implemented.

In summary, supporting medical learners with academic difficulties first involves to identify all possible educational diagnoses. Environment, teacher and learner personal issues explain, but do not excuse academic difficulties involving knowledge, skills or attitudes. This review provides insight about the theoretical bases for a set of interventions mapped to each educational diagnosis, and guidance for their use through strengths of recommendation.

Review limitations

This review has some limitations. It is difficult to report on the effectiveness of individual interventions for learners experiencing academic difficulties since few studies evaluated a single strategy. Many articles assessed multi-component interventions, therefore making it difficult to know which components are individually effective. In such cases, there is a halo effect for some interventions – for example, the BCT involving environment restructuration (*antecedents*) has the highest number of strong recommendations; however, most of the types of interventions in this category come from the same multi-component study. Further studies should try to isolate interventions to get a better understanding of what exactly is effective.

Second, the choice of Kirkpatrick's model as an evaluation framework has been criticized. Issues have been 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.

That is why we also extracted data using Stufflebeam's (2003) CIPP model (context/input/process/product), which considers program evaluation beyond the scope of outcomes assessment. This provided interesting insight about needs, resources and implementation of interventions for learners with academic difficulties.

Inter-rater agreement was poor between reviewer random pairs. The use of multiple random pairs of reviewers was initially thought to reduce clusters of data extraction and therefore control for reviewer's effect (potential bias); however, this might have led to lower inter-rater agreement, probably because the expertise of each reviewer varied and that reaching consensus between high numbers of reviewers is challenging. To overcome this issue for the current review, discrepancies in coding were submitted to a third reviewer (ML or CS) for final decision. Additionally, codification for effectiveness of intervention strategy was performed by a unique pair of reviewers (ML, CS), where the inter-rater agreement was excellent.

Intra-class correlation was poor for methodological quality. Two factors may have hindered inter-rater reliability. First, since the MMAT starts with two screening questions, if one of the two criteria presented is not met, the other questions are dismissed and the score is 0%. In this context, when one reviewer considered the screening criteria met and the other did not or was unsure about it, it may have led to substantial differences in scores attribution. Second, clinician and researcher reviewers had diverse methodological backgrounds. To overcome divergent opinions on some methodological questions, one of the reviewers (CS) with strong methodological background revised the final MMAT scoring.

Conclusion

Implications for practice

This review encourages the use of the most effective literature-based interventions to support undergraduate and postgraduate medical learners with academic difficulties, and helps identification of program evaluation gaps to

stimulate further educational scholarship and research in the field. It provides clinical teachers and educators with a repertoire of literature-based interventions to use for assessment, mentoring and faculty development purposes. The proposed classification under various BCTs is intended to help clinical teachers and educators to better understand the theoretical bases for each intervention, and therefore facilitate their implementation. 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.

Implications for research

Further development of interventions for learners experiencing academic difficulties should build upon effective BCTs to understand better the underlying content of complex behavior change interventions and the associated theories, and test the unexplored BCTs which might be promising for innovative strategies. Scholarship efforts should also reinforce the importance of thorough program evaluation to increase data allowing us to compute the strengths of recommendations. Further research should also look into specific environmental interventions and faculty development efforts and assess their impact on learners with academic difficulties.

Disclosure statement

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper.

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.

Note

1. Cognitive skills include clinical reasoning skills, study skills and test-taking skills.

Notes on contibutors

Miriam Lacasse, MD, MSc, CCFP, FCFP (lead reviewer), is a family physician and associate professor at the Department of Family Medicine and Emergency Medicine, Université Laval (Quebec City, Canada). She co-chairs the QMA-CMA-MDM Educational Leadership Chair in Health Sciences 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 counseling regarding learners in difficulty. She has a clinical practice in a family medicine teaching unit. This is her first BEME review.

Marie-Claude Audétat, MPs, MA (Ed), PhD, is an associate professor at the Family medicine Unit (UIGP) and the Unit of Development and Research (UDREM), both at the University of Geneva, Geneva, Switzerland. She is involved in innovative projects regarding clinical reasoning and faculty development in the Unit of Development and Research (UDREM).

Elisabeth Boileau, MD, MSc CCFP(EM) FCFP, is an emergency physician and an associate professor at Université de Sherbrooke (Quebec,

Canada), where she is the Program Director for the Family Medicine Enhanced Skills residency program.

Nathalie Caire Fon, MD, CCFP (COE), is a family physician and Chair of the Department of Family Medicine and Emergency Medicine at the Université de Montréal (Québec, Canada). Previously she was the Academic Assistant to the Vice-Dean of Undergraduate Studies. Over the years she has been actively involved in providing support for struggling medical students, implementing remediation programs and organizing faculty development workshops on learners with academic difficulties. Her research has led to publications that include a model of clinical reasoning and a guide to help detect clinical reasoning difficulties and provide remediation for students.

Marie-Hélène Dufour, MD, CCFP, is a family physician and assistant professor at the Department of Family Medicine and Emergency Medicine, Université Laval (Quebec City, Canada). She is member of the promotion committee for the family medicine residency program and the Faculty development assistant director. She is involved in the teaching of undergraduate and postgraduate medical learners, especially in the clinical setting, and she has a special interest in mentorship and learners in difficulty.

Marie-Claude Laferrière, MSI, is a health sciences librarian at Université Laval (Quebec City, Canada). She provides reference assistance and curricular information literacy instruction for nursing, dental medicine and physiotherapy students, since 2004.

Alexandre Lafleur, MD, MSc(Ed), FRCPC, is a specialist in internal medicine involved in clinical teaching of postgraduate and undergraduate medical learners. He co-chairs the QMA-CMA-MDM Educational Leadership Chair in Health Sciences Education at Université Laval. 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 (Quebec City, Canada).

Ève La Rue, B.Éd., is a psychoeducator, currently pursuing a master's degree in psychoeducation in the department of Education at Université Laval (Quebec, Canada). She is also involved in a pilot project on mainstreaming education in nursing at Université Laval. She is mostly interested in the mental health of young adults.

Shirley Lee, MD, CCFP(EM), MHSc(Ed), FCFP, is an emergency physician involved in teaching residents and faculty nationally. Previously she was the Education Director for the Schwartz/Reisman Emergency Center, Mount Sinai Hospital, Sinai Health System in Toronto (Canada). She is an associate professor at the University of Toronto. Her areas of interest are in curriculum development, e-learning, knowledge translation tools, assessment and evaluation. In 2016, she became a physician advisor for safe medical care at the Canadian Medical Protective Association.

Mathieu Nendaz, MD, MHPE, 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.

Emmanuelle Paquette Raynard, MSI, 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, is a measurement and evaluation specialist at Université Laval (Quebec City, Canada). In the context of her thesis, she specialized in the measurement and operationalization of university students' adaptation. She is the research professional for the QMA-CMA-MDM Educational Leadership Chair in Health Sciences Education. Her research interests include developing and validating measurement tools and scoring systems.

Yvonne Steinert, PhD, is a clinical psychologist and Professor of Family Medicine and Health Sciences Education. She is also the Director of the Institute of Health Sciences Education and the Richard and Sylvia Cruess Chair in Medical Education in the Faculty of Medicine at McGill University. 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 has authored/co-authored four BEME systematic reviews.

Johanne Théorêt, MD, MA, CCFP, FCFP, 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.

Funding

ORCID

Miriam Lacasse http://orcid.org/0000-0002-2981-0942
Élisabeth Boileau http://orcid.org/0000-0001-8667-8012
Mathieu Nendaz http://orcid.org/0000-0003-3795-3254
Caroline Simard http://orcid.org/0000-0002-3545-8041

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