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Critical Analysis of a Pedagogical Paradigm Shift in Medical Residency in Québec

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Collection
Des points sur les i et des barres sur les t

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There are the rushing waves
mountains of molecules
each stupidly minding its own business
trillions apart
yet forming white surf in unison.

Ages on ages
before any eyes could see
year after year
thunderously pounding the shore as now.
For whom, for what?
On a dead planet
with no life to entertain.

Never at rest
tortured by energy
wasted prodigiously by the Sun
poured into space.
A mite makes the sea roar.

Deep in the sea
all molecules repeat
the patterns of one another
till complex new ones are formed.
They make others like themselves
and a new dance starts.
Growing in size and complexity
living things
masses of atoms
DNA, protein
dancing a pattern ever more intricate.

Out of the cradle
onto dry land
here it is
standing:
atoms with consciousness;
matter with curiosity.

Stands at the sea,
wonders at wondering: I
a universe of atoms
an atom in the Universe.

Poem composed by the physicist Richard P. Feynman, in the summer of 1955

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Credits

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Abstract

Medical progress over the past two centuries essentially took place because medicine became increasingly grounded in scientific research, reflecting reverence for rigour, rationality, scientific method, and evidence. In the early 20th century, the Flexner report (1910) led to this decisive momentum being driven even more rapidly.

Central to this history is the content of learning, but also the pedagogical framework of the training aimed at the learning of that content. In the 21st century, the learning content of medical training is clearly on the side of evidence and rigour. But what of the pedagogical framework of medical training and, in the case at hand, medical residency?

In 2009, the University of Toronto piloted a pedagogical approach in medical residency developed by the Royal College of Physicians and Surgeons of Canada (RCPSC) entitled Competence by Design (CBD).

CBD is a direct descendant of competency-based education (CBE), a pedagogical movement launched in the United States in the wake of the Soviets' Sputnik satellite, which was sent into orbit in 1957. Today, the CBE trend is to be found in general education (elementary, secondary, and postsecondary), vocational education, and medical education.

On what theoretical framework is the RCPSC's CBE (CBD) based? Was this framework scientifically validated, wholly or partially?

The following pages maintain that the RCPSC's CBE did not follow an exemplary, rigorous process and is not based on evidence from scientific research, in either general pedagogy or medical education. More specifically, we assert that the Canadian and Québec medical world, in adopting the RCPSC's CBE, has moved away from the evidence, necessary rigour, and conscientious caution it usually shows with regard to medical innovations.

As we move forward in this text, we also briefly examine the effectiveness of CBE's sometimes co-occurring pedagogical methods that can also provide at least a partial alternative to traditional residency and CBE applied to residency (e.g., technology-enhanced simulation, standardized patients, deliberate practice, mastery learning, and competency-based progression).

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Background

In spring 2021, the *Fédération des médecins résidents du Québec* (FMRQ) asked Normand Baillargeon for his views on the Royal College of Physicians and Surgeons of Canada's new pedagogical paradigm, being employed during residency. Normand Baillargeon then asked Christian Boyer to explore the question with him. Steve Bissonnette and, a little later, Frédéric Morneau-Guérin would also join the team.

It quickly became clear that the review of the situation had to be conducted in total editorial and financial independence, as explicitly expressed in the initial contacts with the FMRQ, and that is what actually took place.

Scientific research in pedagogy at the elementary, secondary, postsecondary, and university levels has long been part of the authors' interests and subjects of study.

Tying one's shoelaces, crossing the street, reading, doing division, solving a math problem, knowing national and world history, writing a novel, designing a robot, producing a silkscreen, creating and performing a choreography, playing the flute, taking notes, reasoning from the frameworks of great philosophers, running a marathon, playing chess, controlling one's anger and impulses, suturing a wound, making a diagnosis, setting a fracture, and repairing a brain aneurysm are all highly intentional actions which involve *teaching* and *learning*.

For the authors of this document, the excursion into the medical world was a novelty. Not so for pedagogy, however, as they have long been immersed in that field.

Medical education and pedagogy are not fundamentally different from general pedagogy, apart from the obvious, paramount obligation to lead the learners to a very high level of performance. General pedagogy, particularly at the elementary and secondary levels, often generates minimum expectations concerning learning that are somewhat incompatible with medical education.

Our foray into medical education leads us to consider that general pedagogy would stand to gain a great deal from taking a look at medical education, and vice versa.

General Information on Methodology

The research underpinning this document focussed on several topics, including the history of medical residency, the birth of competency-based education (CBE), self-regulation, adverse medical events, medical certification, continuing education, impact of the RCPSC's CBE in residency, ePortfolio, and different types of pedagogy (e.g., deliberate practice, mastery learning, etc.) which sometimes operate alongside CBE.

To that end, we used Google Scholar, ERIC and PubMed, and other search engines. As generally happens, the documents and research selected and read led us, through the references cited, to identify other articles and research.

In the case of general pedagogy, since several topics were already familiar to and had been studied by some of the authors of this document, the research was carried out more quickly.

The numerous topics addressed, in general pedagogy and medical education, were not treated equally. The decisions to go into greater detail on certain topics were made on the basis of the importance of the information presented in answering the question of the helpfulness and rigour of the development of the pedagogical approach applied to medical residency in Québec, and to shed light on possible futures. Some choices were also aimed at reverse-engineering certain common pedagogical myths. Finally, in other cases, the sparsity of the research explains why we had so little to say about them.

We identified some 17,000 articles and documents in our research, finally narrowing the field to approximately 275 of them.

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Table of contents

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

 ISBN : 978-2-923805-73-3

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

La page paresseuse

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

1.0 Introduction

Depending on the era, various schools of thought have influenced medical education. The same phenomenon is seen in general pedagogy where at different times certain practices are preferred to others. The medical world is essentially built, in its practice, on a rigorous, rational approach fuelled by evidence from scientific research. One might therefore tend to think that pedagogical changes in medical education should be carried out in a similar manner. But is that what actually happens?

In this study, we provide a brief analysis of a major paradigm shift undertaken in physicians' postgraduate education, known as residency.[1] Embryonic traces of this paradigm shift appeared in the 1970s, without necessarily entering the medical curriculum of the time in the Western world (Bashook, Sandlow and Reinard, 1978; Dunn, Hamilton and Harden, 1985; Carraccio et al., 2002; McGaghie et al., 1978). This paradigm shift—which we call *competency-based education* (CBE)—took place some 10 years earlier in general education.

First, we present a partial background of medical residency training, attempting to expose some of the roots of CBE. Then we briefly describe the underlying rationale, along with a number of the main features of CBE, presenting some empirical data on their effectiveness in general and medical education. In the same breath, we identify the pedagogical groove in which applied CBE in medicine in Canada and Quebec is situated. We go on to present empirical data concerning the impact of CBE applied to medical residency on the quality of patient care, resident doctors'[2] learning, and residents' perceptions and reactions to this new teaching system (CBE).

Throughout this analysis, we highlight a number of our observations and, in the final conclusion, we formulate some questions that may indicate, among other things, certain paths for action to be explored.

Principal acronyms

CBD: Competence by Design (the RCPSC's version of CBE)

CBE: Competency-based education

CBP: Competency-based progression

CMQ: Collège des médecins du Québec (Québec's college of physicians)

EPA: Entrustable professional activity

FMRQ: Fédération des médecins résidents du Québec (Federation representing Québec's resident doctors)

ML: Mastery learning

PBL: Problem-based learning

RCPSC: Royal College of Physicians and Surgeons of Canada

SP: Standardized patients

TES: Technology-enhanced simulation

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2.0
Reminders of the past

In 1889, Dr William Halstead, the first Professor of Surgery at Johns Hopkins Hospital, inaugurated medical *residency*, based on the gradual attribution of responsibility for performing medical acts (Reznick and MacRae, 2006). This final stage of medical education was summed up in the expression "see one, do one, teach one" (Skjold-Ødegaard and Søreide, 2021),[3] meaning that the resident doctor has first to observe an *expert* physician performing a task, then work to carry it out himself under the direct supervision of the expert physician, until he can perform it autonomously; at that time, he is deemed qualified to teach the task to others. In this context, time spent under the supervision of an expert physician, the latter's judgment, and passing formal tests from a medical certification body (e.g., the *Royal College of Physicians and Surgeons of Canada* [RCPSC]) leads to the awarding of the right to practise medicine autonomously. For more than a century, this training model has defined medical residency in the West (Frenk et al., 2010; Kraemer, Alman and Reznick, 2009; Reznick and MacRae, 2006).

The Flexner Report, drafted by educator Abraham Flexner (1910), was released early in the 20th century,[4] and deals with medical education in the United States and Canada. This founding text of modern medicine was influenced by Germany's rigorous medical system (Duffy, 2011; Hodges, 2010). It introduced or strengthened numerous orientations that are still current today, such as the adherence to practices stemming from the scientific approach (RCPSC, 2014; Duffy, 2011; Frenk et al., 2010). In 1925, however, Flexner publicly regretted that the scientific direction proposed by his report had become, in his eyes, *radical*. In his view, impelled by positivism, medicine had become a stranger to culture and philosophy, thus producing physicians who were deficient in those areas which he considered essential for effective, comprehensive action from accomplished expert doctors (Flexner, 1925; see also Whitehead, 2010).[5]

This report, which did not receive unanimous approval owing to its biting tone and harsh attacks on certain medical schools and faculties of the time (Duffin, 2011; Hodges, 2010; Hopkins, 2011; Koch, 2019), is considered to have led to the establishment of a demand for high standards in medical education (Carraccio et al., 2002).[6] This raising of requirements was then accompanied by a substantial tightening of prerequisites for enrolling in medicine and the rejection of the curriculum involving approaches deemed to be incompatible with the scientific process or deriving from downright charlatanism, such as electromagnetic therapy, phototherapy, eclectic medicine (treatment comprising physical manipulations associated with remedies consisting of plants and other substances), physiomedicalism (treatment based on emetic substances, purgatives, stimulants, and steam baths), homeopathy, and osteopathy.[7]

Medicine based on scientific evidence, which had taken root more firmly in the mid-19th century, ended up embedding the conscientious, explicit use of the best available scientific evidence in decisions concerning the care delivered to patients, without rejecting the use of clinical expertise (Evidence-Based Medicine Working Group, 1992; Frenk et al., 2010; Guyatt et al., 1992; Sackett et al., 1996).

From the end of the 19th century to today, scientific research has grown exponentially, fuelling the development of knowledge and medical practices in a substantial and occasionally revolutionary manner, to the point that certain diseases which not so long ago were associated with very negative prognoses offer in the 21st century much more favourable prognoses, and sometimes even cures.

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3.0 Atmosphere of recent years

The use of meta-analyses over the past 50 years has led to the formulation of conclusions which, while not infallible, are more objective (Haidich, 2010; Wang et al., 2021). This characteristic of meta-analysis does not contradict the fact that no single research or review of scientific literature, whether it is a specific study, a meta-analysis or a mega-analysis,[8] *provides definitive understanding and answers to questions about treatments, diagnoses, risk factors influencing the course of a disease or the functioning of the human body.* Science can produce solid knowledge, but it is generally temporary, until a new angle of understanding is discovered, until a new knowledge is updated. Still, in the medical world, the findings of a rigorous meta-analysis are considered high-level evidence in the hierarchy of scientific evidence (Wang et al., 2021).

Brief explanation of meta-analysis

> *A meta-analysis is a statistical process combining the results of a series of independent scientific studies concerning a problem or specific subject. The goal of such a statistical synthesis built on data from several individual studies is to achieve a more objective assessment of the phenomenon being studied. But, just as in logic conclusions based on false premisses can prove inaccurate, it has to be checked that a number of conditions are met before primary data from different studies can be quantitatively pooled, failing which the estimated combined effect will be biased and the resulting conclusions are likely to be incorrect. So meta-analysis, in the right conditions, makes it possible to calculate the mean effect of an independent variable on a dependent variable, and thus to draw some kind of conclusion.*[9]

These days, meta-analyses contribute significantly to the accumulation of evidence in medicine (Haidich, 2010; Wang et al., 2021). The exponential growth of medical information now makes it difficult for practising physicians to examine and evaluate all the available evidence so as to make the best clinical decisions (Haidich, 2010; Wang et al., 2021). Between 1990 and 2009, the number of publications relating to meta-analyses in the medical field increased by 6,600% (Haidich, 2010).

As a result of the proliferation of meta-analyses and scientific research, some medical knowledge may have a much shorter shelf life than 50 years ago; what is true and well-founded today, with respect to specific knowledge or a given practice, may be superseded tomorrow morning by new knowledge, new understanding, a new perspective, or a new practice which tempers or completely invalidates yesterday's truth. The volume of knowledge to be assimilated throughout a medical career, the ability to question one's knowledge and practices in light of new evidence, and continual learning concerning the use of new technologies with increasingly short lives pose a major challenge for medical education today (Campbell et al., 2010) and, concomitantly, for the objectives of residency.

3.1 Residency paradigm challenged

Propelled by a tidal wave of evidence where medical actions aspire to a high degree of rigour, and by an accumulation of shortcomings identified in medical education, the paradigm of residency based on the concept of "see one, do one, teach one" is crumbling away. The paradigm in use for more than a century is exhibiting manifest shortcomings that are publicly acknowledged (RCPSC, 2014; Frenk et al., 2010; Issenberg and McGaghie, 2013; McGaghie, Barsuk and Wayne, 2020; Sales and Schlaff, 2010). In the following paragraphs, we present certain data that fuel the questioning of conventional residency, addressing the link between physicians' certification and their performance, the frequency of adverse clinical events, the effect of doctors' continuing education on their practice, and the low level of ability to self-assess exhibited by the general public and doctors.

 ISBN : 978-2-923805-73-3

3.2 Physician certification

The education of doctors in the Western world consists of a doctorate in medicine (MD), followed by a number of years of residency, depending on the specialty, ending with certification, allowing the doctors to practise without supervision. Some medical stakeholders view this certification system as arbitrary and unscientific, since it is based on the variable judgment of supervisors (known as resident doctors' *staff physicians*), and on traditional paper-and-pencil evaluations (questions and answers) which they say do not measure actual medical competencies in situ (Al-Chalabi et al., 1983; Bandiera et al., 2020; Bashook, Sandlow and Reinhard, 1978; Carraccio et al., 2002; Issenberg and McGaghie, 2013; Holmboe et al., 2017; Kraemer, Alman and Reznick, 2009; Reznick and MacRae, 2006). Some say that traditional written evaluations of pre-MD and postgraduate (residency) education are limited in their capacity to measure (RCPSC, 2014), essentially measuring only knowledge, techniques, and certain types of reasoning, but certainly not, according to several parties, the specific medical competencies involved in daily practice, such as those that have to be deployed in the following situation: *"Conveying to a patient and his family results of analyses leading to a negative prognosis, answering questions, and showing empathy to the patient and his family; planning and coordinating overall future care for this patient (medical and other) from the different professionals involved; etc."* While conventional residency may lead to the development of such medical skills as *suturing a wound* or *cardiac auscultation*, several authors indicate, based on research, that doctors' level of mastery of simple and complex competencies varies considerably (Carraccio et al., 2002; Frank et al., 2017; McGaghie, Barsuk and Wayne, 2020; Vukanovic-Criley et al., 2006).

Numerous authors have been documenting shortcomings in the medical world for many years (Barsuk et al., 2012; Carraccio et al., 2002; Ericsson, 2015; Crosson et al., 2011; Cook, Oh and Pusic, 2020; Issenberg and McGaghie, 2013; Frank et al., 2017; Holmboe, 2004; Holmboe et al., 2017; Lockyer et al., 2017a; McGaghie, Barsuk and Wayne, 2020; Schuster, McGlynn and Brook, 1998; Skjold-Ødegaard and Søreide, 2021; Vukanovic-Criley et al., 2006), and in many countries (Eijkenaar et al., 2013), leading to some rethinking, including questioning of residents' training.

The RCPSC (2014) observed the weak correlation between certification exams and professional performance. Similarly, a weak or even non-existent correlation was also noted between being a recognized *expert* and the quality of professional performance, and this is seen in medicine as in other fields (Ericsson, 2008). Sharp et al. (2002) observed that only just over 50% of published research presents a positive association between certification on completion of residency and positive clinical outcomes.

On the other hand, from 2002 until recently, particularly in the United States, research on the association between certification and level of competency or positive clinical outcomes generally presents data more favourable to certification and recertification (Brennan et al., 2004; Hawkins et al., 2013; Lipner, Hess and Phillips, 2013; Turchin et al., 2008) than the data from Sharp et al. (2002). Nonetheless, the value of the medical certification system in the United States is criticized by Kempen (2020), who points out that it is primarily the bodies responsible for medical certification and recertification that have subsidized and directly produced the studies released in the past few years. Moreover, he states that these bodies derive considerable income from the certification system—as much as 30% of their total revenues—casting doubt on the reliability of the published research.

3.3 Adverse events

From another angle, Schuster, McGlynn and Brook (1998) in the USA and Grol (2001) in the Netherlands point out that patients do not receive care consistent with scientific data in a proportion varying on average from 35% to 50%, that up to 25% of care delivered to patients is not necessary, and is even sometimes potentially dangerous. The review by Schuster, McGlynn and Brook (2005) on the quality of medical care in the United States confirms the observations made in 1998 by McGlynn and Brook. Campbell et al. (2010) also consider that there is a considerable gap between what evidence indicates as being the best medical practices and their actual implementation to enhance the quality of patient care. Donaldson, Corrigan and Kohn (2000; see Norman et al., 2018) published a provocative book (*To Err is Human: Building a Safer Health System*) that still resonates, in which the authors provide figures

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to support their assertion that *avoidable* medical errors lead to significant morbidity and mortality in the United States.

Along the same lines, research by Vukanovic-Criley et al. (2006) looked at the cardiac auscultation skills of 860 volunteers and knowledge associated with cardiac physical examination. These volunteers consisted of medical students, resident doctors, physicians teaching in medical faculties, certified family physicians, cardiologists, and others. These researchers observed that skills and knowledge concerning auscultation and cardiac physical examinations barely improved after the third year of pre-MD training, achieving a low score of 59%, a performance that tends to decrease over time. Moreover, surprisingly, doctors teaching in medical schools were barely better (60%) than their graduating medical students (59%).

The recent meta-analysis by Cook, Oh and Pusic (2020) concerning electrocardiogram (ECG) interpretation calculates accuracy rates of 42.0% for medical students, 55.8% for resident doctors, 68.5% for practising physicians, and 74.9% for cardiologists, all of which leaves nevertheless considerable room for incorrect interpretation. The authors of this meta-analysis also stated that the average improvement between *before* and *after* ECG interpretation training was far from brilliant, moving up only from 54% to 67%.

Squires et al. (2019) mentioned that it is recognized, in Canada and globally, that a certain proportion of healthcare is delivered inappropriately, using harmful or ineffective practices and not clinical practices recognized as effective. Baker et al. (2004) calculated that 7.5% of patients from a sampling of Canadian hospitals would experience one or more *adverse events*[10] ending, for those patients, in 20.8% of cases with their death. Of the 7.5% of patients faced with adverse events, 36.8% would be considered avoidable or highly avoidable. Panagioti et al. (2019), in their meta-analysis involving a sample of 337,025 American patients, reported that 1 patient in 20 (5%) was affected by an avoidable adverse event during their stay in hospital, and that 12% of those patients had permanent after-effects, up to and including death. The study by Matlow et al. (2012) showed that 9.2% of children admitted to Canadian hospitals would experience an adverse event.

3.4 Continuing medical education

Can the mandatory *continuing education* prescribed for physicians throughout their careers, in the form of workshops, lectures, reading, research, and screening of professional videos, offset the shortcomings which doctors could present on completing their residency or later in their practice? There is no unanimous objective answer to this question (Cervero and Gaines, 2014; Davis et al., 2006; Lockyer et al., 2017a).

3.5 Ability to self-assess

First of all, it may be assumed that the effectiveness of continuing education is theoretically based, among other things, on the ability to self-assess in order to recognize one's strengths and weaknesses (Lockyer et al., 2017a). But research demonstrates that medical students do not regularly and significantly increase their self-assessment (and self-monitoring) skills during their training (Kämmer, Hautz and März, 2020). This element may greatly limit the possibility of their benefiting fully from the self-training involved in continuing education.

Physicians, just like the population as a whole (Kämmer, Hautz and März, 2020; Kruger and Dunning, 1999; Lu, Takahashi and Kerr, 2021; Zell and Krizan, 2014), have a limited ability to see their skills correctly, to self-assess accurately, not always being able to determine their strengths and weaknesses realistically (Davis et al., 2006; Colthart et al., 2008; Eva and Regehr, 2008; Lockyer et al., 2017a), unless they are given explicit performance milestones (Lu, Takahashi and Kerr, 2021). Also, comparisons between physicians' self-assessment and external assessments show a low, and sometimes a zero or even a negative correlation (Davis et al., 2006; Colthart et al., 2008). Studies tend to show, as well, that physicians whose self-assessment is the least accurate are the least competent (Davis and al., 2006), and also the least self-critical, but, astonishingly, the most confident—although fundamentally this should not come as much of a surprise (Kruger and Dunning, 1999).[11]

3.6 Impact of continuing medical education

The impact of continuing education varies, depending on the scientific research. Some research indicates a stronger impact on physicians' knowledge, a smaller

 ISBN : 978-2-923805-73-3

impact on their practice, and a slight impact on clinical outcomes (Cervero and Gaines, 2014; Lockyer et al., 2017a; Mansouri and Lockyer, 2007; Marinopoulos et al., 2007). On the other hand, it appears that one method is more effective than others with respect to physicians' continuing education, for modifying both medical practice and patients' clinical outcomes, but it does not appear to be the method most often given precedence (Bloom, 2005; Cervero and Gaines, 2014). This more effective method uses interactive techniques, including detailed functional feedback following on-site observations in the action along with the use of recall lists—see for instance Haynes et al., 2009—or assessment grids, such as Objective Structured Assessment of Technical Skills (OSATS) used in operating rooms—see Niitsu et al., 2013. Continuing education based on general clinical practice guidelines and the advice of experts in the field are not at all effective methods. Similarly, didactic presentations and the distribution of informational documents generally have very few beneficial effects on medical practice (Bloom, 2005).

The overall criticisms and shortcomings mentioned in this section have led several stakeholders to attribute the responsibility for them, among other things, to the inadequacies of the hundred-year-old pedagogical paradigm of residency. In that vein, the conventional time-based framework of residency, usually lasting from two to five years depending on the specialty, is considered to be an element which, in itself, does not ensure the high-level mastery of medical competencies expected of all doctors (Issenberg and McGaghie, 2013; Holmboe et al., 2017; Kraemer, Alman and Reznick, 2009; McGaghie, Barsuk and Wayne, 2020).[12]

As the traditional paradigm of residency no longer appeared to be suitable for meeting contemporary expectations, the *competency-based education* (CBE) trend then began to become more prominent worldwide as one of the possible solutions early in the 21st century (Campbell et al., 2010; Carraccio et al., 2002; RCPSC, 2014; Frenk et al., 2010; Holmboe et al., 2017).

4.0 Competency-based education (CBE)

The first references to the possibility of applying CBE to medical education occurred in the late 1970s (McGaghie et al., 1978; Bashook, Sandlow and Reinard, 1978). CBE applied to the medical field—competency-based medical education—stemmed, among other things from the CBE developed in general pedagogy (thus aimed primarily at children) and from certain applications dedicated to vocational education (RCPSC, 2014; Frank et al., 2010b; Frank et al., 2017; Hodge, 2007; McGuire and Lay, 2020).

It clearly appears that the germinal base for CBE emerged from an unexpected social trauma experienced by our neighbours to the south.

4.1 Historical crucible of CBE

According to Harris et al. (1995) and Hodge (2007), it was the launch of Sputnik by the Soviets in 1957 that led to the development of CBE. The Sputnik event shook U.S. society, which abruptly realized that the Soviet Union had overtaken the USA in space exploration. The American school system and teaching training were immediately accused of being largely responsible for this embarrassing setback. It was said that teaching staff were not very competent, and therefore not well-equipped to foster pupils' learning, particularly in mathematics and science, leading to delays in these subjects and, as a corollary, in the U.S. space sector.

The concept of *competency-based education* (CBE) thus began to develop in the very early 1960s (Houston, 1974—see Hodge, 2007; Hodge, Mavin and Kearns, 2020; Weinert, 1999), but the idea originally sprouted in the late 19th century in agricultural education (Duemer, 2007). Between the 1960s and the 1990s, several terms would emerge to describe CBE, each one involving distinctions, from slight to significant, also varying according to the clientele to which they were targeted, e.g., *Competency-based Education*, *Performance-based Teacher Education*, *Competency-based Education and Training*, *Competency-based Vocational Education*, *Outcomes-based Approach*, and *Outcomes-driven Developmental Model*).[13] In this study, we will simply use the term *Competency-based Education (CBE)*.

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5.0
Brief description of CBE in general pedagogy

CBE took shape around certain key aspects in general pedagogy and vocational education in the school system and industry (Hodge, 2007; Norton, 1987). This approach drew on the behaviourist trend and systems theory (Hodge, 2007; Morcke, Dornan and Eika, 2013; Norman, Norcini and Bordage, 2014). Some authors more or less directly bemoaned this affiliation with behaviourism (Brooks, 2009; Grant, 1999) or considered those roots to be quite simply obsolete for our time (Morcke, Dornan and Eika, 2013).

Overall, CBE in general pedagogy is characterized by: (1) development of competencies comprising a set of knowledge, skills, and attitudes culminating in cognitive and other actions in a given area; (2) a competency learning framework that is not constrained by a specific time frame, but by the observed manifestation of the clear mastery of previously defined competencies—in other words, completion of training and access to a diploma vary in line with the time taken by individuals to demonstrate the expected mastery of prescribed competencies, and not with a pre-set duration of study; (3) formative assessments and frequent feedback, based on criteria observable *in situ* requiring the learner to have achieved high performance thresholds in order to move from one learning unit to another, are the cornerstone for assessment in this pedagogy.[14]

The previous schematic description represents a type of structured, rational pedagogy compatible with certain trends, such as behaviourism and explicit teaching. The behaviourist and explicit teaching trends are not very popular, both in the back rooms of Québec's Ministry of Education and in the dens of Québec's education faculties, as both those environments have for many years vigorously espoused constructivism and its different iterations. In fact, this monochrome reality mirrors what is happening generally in education and universities in Canada, Europe, the United States, and around the world. In that context, then, it is not surprising that CBE should have undergone attempts to reframe it in a constructivist perspective.

Definition of explicit teaching

Essentially, "explicit teaching" describes a form of educational framework aimed at making visible and explicit to learners what is expected of them, what they have to do to perform a task or practise a skill (Boyer, 1993). This general definition applies both to teaching young children to read and to vocational training for adults.

*Explicit teaching can be used to develop skills or complex competencies. This pedagogy generally involves analysis of the task (skill/competency) identifying the underlying components. A component is then taught explicitly through modeling, using scaffolding (*for a definition of scaffolding, see note 72, p. 80*) usually consisting of direct support in the action from a master with guidelines, descriptive procedures, and checklists of the elements of the component or task. The component is then practised by the learner with scaffolding gradually adapted in line with the performance observed. Specific feedback accompanies the learning, aimed at highlighting the gap between the learner's performance and the objective, while specifying what the learner has to do to bridge the gap.*

The acquired components are then gradually associated with each other until the task is fully recombined. Throughout the process, the scaffolding and support are progressively decreased. Explicit teaching, directive support, isolated and recombined practice of the components of a task, and feedback are specific characteristics of explicit teaching so that the learning takes place speedily and effectively (types of learning: knowledge, task, cognitive, motor or socio-behavioural ability, etc.). Explicit teaching has much in common with the behaviourist trend—something often roundly criticized by the fiercest opponents of explicit teaching, to put it mildly.

 ISBN : 978-2-923805-73-3

6.0
Constructivist reframing of CBE in general pedagogy

In general pedagogy, much reframing with a constructivist flavour was carried out over the years, leading to the emergence of iterations of CBE far removed from its behavioural origin and often justified, at the outset, by ideological choices and not by evidence (see the article by Levine and Patrick, 2019, for a description and defence of constructivist CBE). These CBE variants inspired by the constructivist trend generally elicit a highly favourable response from Québec's education ministry, and education faculties as a whole.

Constructivism favours pedagogical "*learner-centered*" as opposed to "*teaching and learning-centered*" approaches. The materialization of constructivism is seen, among other things, in the structure of school activities and the evaluation framework. The pedagogical activities preferred then include discovery learning, investigation, and self-management of pedagogical projects chosen by the learner or learners. In these pedagogical variants, responsibility for learning and its organization falls much more directly to the learner, whether aged 5 or 30, than to the teaching staff. As to the learning evaluation framework, constructivism tends to reject categorically all standardized tests[15] and generally looks askance at any comparison of the learner's performance with fixed criteria not determined by the learner. Self-assessment, informal observation of the learner by teaching staff, and creation of a portfolio for each learner are the assessment approaches most often favoured by constructivism.[16] The limits of the possible effectiveness of constructivist approaches in pedagogy are discussed from a theoretical and empirical point of view (Bernstein, 1975; Clark, Kirschner and Sweller, 2012; Kirschner, Sweller and Clark, 2006; Tobias and Duffy, 2009). Correlational studies based on international comparisons—PISA, TIMMS[17]— (Cairns and Areepattamannil, 2017; Chi et al., 2018; Grabau and Ma, 2017) observe a negative correlation between the use of inquiry-based pedagogy and performance in science.[18] Finally, research and meta-analyses in general pedagogy present evidence prompting the fostering of direct, explicit teaching (Chall, 2000; Gersten et al., 2009; Gersten et al., 2020; Kaldenberg, Watt and Therrien, 2015; Rosenshine, 2009; Stevens, Rodgers and Powell, 2018; Stockard et al., 2018; Watkins, 1997) or, at the very least, greatly limiting the use of constructivist pedagogies.

Constructivism and its pedagogical approaches have some observable influence in medical education. Some research and literature in medical education explicitly defends the constructivist trend, and some authors refer to it as a legitimate, effective philosophy or paradigm for medical education (Baker et al., 2021; Neville, 2009; Schmidt et al., 2009; Tallentire et al., 2011). The prompt introduction in the 1980s and 1990s of *problem-based learning* (PBL) in medical education (ten Cate, 2005) may be seen as one example among others of a certain, at least partial application of constructivism in the teaching of medicine[19] (see Appendix A—Problem-solving applied to medical education, p. 62—for a brief critical presentation of PBL in medicine).

The development of constructivism in general pedagogy was associated with the emergence of *postmodernism* over the past few years. That trend, which could be called *constructivism-postmodernism*, leads to a relativism that contests the concept of *universal knowledge*, considering that personal, cultural, and religious beliefs can be as valid as knowledge stemming from experimental research (Boyer, 2021; Chevrier, 2021; Matthews, 2003).

Does RCPSC CBE have a *constructivist-postmodernist* thrust? The following sections answer that question.

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

7.0
Brief description of RCPSC CBE applied to residency[20]

The RCPSC, responsible for, among other things, the certification of resident doctors, has developed and overseen the application of competency-based education (CBE) in the different medical specialties (67 specialties in Canada, of which 60 are practised in Québec). To the CBE it implements, the RCPSC has given the name of *Competence by Design* (CBD).

Royal College International (www.royalcollege.ca/rcsite/international-e), an entity associated with the RCPSC, makes the expertise developed by the RCPSC accessible internationally, with respect to medical education, assessment, and medical accreditation.

CBD is defined overall by an organization of all educational activities and assessments to develop a number of complex professional competencies that each resident doctor has to master objectively at a high level of performance. In that spirit, it is no longer summative testing or certification for autonomous practice that are the ultimate markers of professional competency, but the observable manifestation, assessed in situ, of each of the professional competencies identified in each medical specialty. Similarly, as in CBE in general pedagogy, priority is given, in principle, to mastery of competencies rather than to the framework of a residency whose duration varies from two to five years[21] in conventional residency.

Consequently, it is not the time spent in residency (nor the paper-and-pen exams passed) that would give access to certification, but the observable manifestation of high-level mastery of the targeted professional competencies. So, in theory, a resident doctor can achieve certification more quickly than under the traditional residency framework insofar as he demonstrates mastery of the competencies identified for his medical specialty through direct observations of his performance in action. Similarly, a resident physician can also be delayed in his progression toward certification if he shows weaknesses in mastering the competencies to be acquired, then taking longer than in conventional residency. On the other hand, in practice, starting in 2013 the RCPSC opted for a hybrid approach where mastery of competencies, which plays a central role, is combined with the traditional time-based milestones.

7.1 RCPSC CBE competencies (CanMEDS)

The RCPSC adopted seven competencies in its CBD program, found in CanMEDS[22] (RCPSC, 2015). In 1998, the *Educating Future Physicians for Ontario* project had set out the framework for medical competencies that became known as CanMEDS (Neufeld et al., 1998) and is now used in a few countries (Frank and Danoff, 2007).

The CanMEDS Physician Competency Framework defines a competency as a set of high-level professional behaviours based on an amalgam of knowledge, skills, techniques, and attitudes combining in action.

The definitions of the following seven competencies are taken from RCPSC (2015).

1. Medical Expert

The *Medical Expert* competency is the cornerstone of the profession, and evolves as the evidence available from scientific research is updated. This competency concerns the ability to provide high-quality, safe care, including diagnostic and therapeutic skills, while respecting patients' preferences and choices, and following the rules of ethics. This central competency draws on the other professional competencies: Communicator, Collaborator, Leader, Health Advocate, Scholar, and Professional).

Medical expertise may be considered to have been, no doubt for well-nigh a century, the main and even the sole competency expected of physicians. Today, expectations vis-à-vis doctors have developed further, and several other competencies have been added (Frank et al., 2017)

2. Communicator

The *Communicator* competency concerns the area of professional relations with the patient, his family, and caregivers, facilitating the gathering and sharing of essential information for effective healthcare while respecting the patient's preferences and choices.

 ISBN : 978-2-923805-73-3

3. Collaborator

The *Collaborator* competency refers to the physician's skills in working effectively and with respect with the other professionals in order to provide the patient with safe, high-quality medical care. This competency supposes a sharing of knowledge and perspectives for the patient's benefit.

4. Leader

The *Leader* competency concerns skills to contribute to the best possible quality of care as clinicians, administrators, scholars or teachers in order to engage with other professionals in the development and enhancement of the healthcare system.

5. Health Advocate

The *Health Advocate* competency aims to build on medical expertise to develop the skills necessary to improve the health of communities or patient groups by sometimes speaking on their behalf and by supporting the mobilization of resources accordingly.

6. Scholar

The *Scholar* competency draws on the concern for excellence in practice through continuous learning following certification, and throughout their career, through teaching others (resident doctors, medical students, other health professionals, etc.), evaluating evidence, and contributing, as far as possible, to medical scholarship.

7. Professional

The *Professional* competency refers to the commitment to the health and well-being of individuals and society through ethical practice, high personal standards of behaviour, accountability to the profession and society, physician-led regulation, and maintenance of personal health.

The seven competencies identified in RCPSC (2015) overlap somewhat, as is no doubt inevitable in defining seven such broad areas or macro-objectives, but this framework allows for a more comprehensive and complex conception of the skills necessary to be an accomplished physician. It also makes it possible to meet the expectations of the public, who obviously expect continually updated, high-quality competency in medical expertise, but also, among other things, a high level of communication skills from doctors.

The seven competencies identified in RCPSC (2015) are one of the essential cornerstones of the infrastructure of RPCSC CBE (CBD) as applied to residency in use in Canada, including Québec. Where these competencies, practice, and assessment intersect, within the learning framework, is through Entrustable Professional Activities (EPAs).

EPAs are a new concept used as markers and beacons lighting the way for resident doctors to acquire competencies. EPAs are also a central element in the assessment of resident physicians' competencies, because they are used as it were as operational descriptors of the competencies to be developed. Note that the concept of EPA is used primarily in the medical world, although other fields appear to be showing an interest in this concept (Peters et al., 2017). EPAs are a type of learning objective in use primarily in Canada, the Netherlands, and Australia (O'Dowd et al., 2019).

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

8.0
Entrustable professional activities (EPAs)

The concept of Entrustable Professional Activity (EPA) was developed by ten Cate (2005; 2019; Englander et al., 2017; Touchie and ten Cate, 2016), who considers that a competency has to be specific, comprehensive (i.e., including knowledge, attitudes, and skills), durable, trainable, measurable, related to specific professional activities, and connected to other competencies. He also considers that the concept of EPA actuates the connection between teaching and assessment of a competency and the physician's professional duty.

8.1 Definition of EPA

An EPA has several attributes (RCPSC, 2014; Peters et al., 2017; Englander et al., 2017): (1) an EPA is an essential, integral part of the professional work in a given context; (2) it requires knowledge, skills, technical or other skills, and an attitude appropriate to the situation; (3) it leads to an expected, recognized outcome from the physician's professional work; (4) it is generally reserved for duly qualified personnel; (5) mastery of the EPA implies that it can be performed autonomously, without supervision in the performance; (6) it is performed within a given time; (7) it must be observable and measurable in the process and its outcome, leading to a binary qualitative judgment ("was performed well" or "was not performed well"); and (8) the EPA reflects one or more of the competencies to be acquired in the CanMEDS framework (RCPSC, 2015).

The notion of *entrustable* in the term "EPA" means that the activity will be fully accomplished when it can be performed with complete confidence by the resident doctor, without direct or remote supervision, implying autonomous, safe performance of the activity (ten Cate, 2013, 2019). We could also say that an EPA describes a complex objective (see the example following this section, Table 1—EPA #1 in Psychiatry, p. 21) that is operational, and thus measurable and observable, involving multiple fields of competency and whose high-level mastery is a minimum obligation of occupational training.

The concept of *milestone* is also central to the EPA structure. Milestones represent stages in the development of the EPA (ten Cate, 2013). Milestones refer both to the progress required to develop the EPA concerned, the EPA components, and the elements to be mastered to achieve mastery and autonomy in the performance of that EPA.

Each EPA must be mastered for the resident doctor to have access to certification and autonomous medical practice. Each specialty includes a number of EPAs, generally from 20 to 50 or so. Some parties consider that too large a quantity of EPAs can increase the educational red tape for the learner and the learning system (O'Dowd et al., 2019).

In the United States and elsewhere, the CBE used generally refers to a list of specific competencies, procedures, and stages or milestones rather than to EPAs to designate the different contents and stages that have to be addressed and mastered (for examples of different models of objectives in Orthopedics, see Myers et al., 2022).[23]

To provide an overview of the RCPSC CBE being applied in Canada and Québec, we will present four example of EPAs. These allow us to check out what they look like, while giving us a foretaste of the type of pedagogy underlying CBD (RCPSC CBE).

8.2 How an EPA works

Table 1 (p. 21) presents EPA #1 for Psychiatry. Each EPA is identified in its medical specialty. The title of the EPA reflects the perspective and general framework of the activity: *Obtaining a psychiatric history to inform the preliminary diagnostic impression for patients presenting with mental disorders.* Then, the EPA is outlined generally using three sections: *Key Features*, *Assessment Plan*, and *Milestones*.

The *Key Features* of the EPA specify what is involved (see "A" in Table 1), and what is sought in terms of content and competencies (see "B" in Table 1), and also stipulate in which context this EPA can be performed, observed, and assessed (C).

The *Assessment Plan* provides information on those who may observe and assess the resident doctor performing the EPA (D), the observation instrument to be used that can also indicate performance thresholds (E), type of medical problems concerned (F), number of observations that have to be done to receive a "Pass" (G), and

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number of minimal observations from certain specific professionals (H).

In the *Milestones* section, we find the EPA components and stages, and the reference to CanMEDS competencies (I) associated with knowledge, skills, techniques (J), attitudes and socio-professional behaviours (K) in which professional doubt (L) is sometimes noted.

Professional doubt is essential to the profession, since excessive confidence and trouble self-assessing accurately could tend to increase the risk of errors (3.5 Skill in self-assessment, p. 13). It is highly plausible that professional doubt is one of the cornerstones of the development of valid, functional self-assessment. Note that several *milestones* in the lists of EPAs for medical specialties explicitly and directly specify *seeking assistance* (when faced with a difficulty or the complexity of a medical situation, indirectly implying an awakening to *doubt*) as an important element in the competency and the emergence of the EPA (Peters et al., 2017). Professional doubt supposes a level of humility and an awareness of one's limitations that is an honorable attitude toward his profession from a professional. Professional doubt in medicine is probably essential for practitioners' professionalism and the quality of healthcare.

8.3 In short, an EPA is . . .

In light of Table 1, in short, we could say that an *entrustable professional activity* (EPA) is a complex professional objective that must be mastered at a high level of performance, operationalizable, and thus observable and measurable, involving several types of knowledge, attitudes, techniques, skills and abilities, which specify the context(s) of execution, implying the use of a grid (e.g., the Objective Structured Assessment of Technical Skills—OSATS—operating room assessment grid; see Niitsu et al., 2013[24] and Atesok et al., 2017) or a list of behaviours, an assessment form stipulating the number of direct observations and the professionals who may or must assess the resident doctor.

Successful completion of an EPA means the resident doctor can then perform this professional activity without direct or indirect supervision. This professional activity then becomes *entrustable* to this resident physician.

8.4 Other examples of EPAs

Appendix B (p. 66) presents EPA #7 for Orthopedic Surgery, Appendix C (p. 68), EPA #10 for Pediatrics, and Appendix D (p. 70), an element of Emergency Medicine training that is not considered an EPA.

EPA #7 in Orthopedic Surgery (Appendix B, p. 68), surgical management of fractures, is more technical than the EPA in Table 1, and exhibits the same desire to be explicit.

The seventh milestone of EPA #7 in Orthopedic Surgery specifies that the action must, among other things, proceed with economy of movement and flow. This concern is observed in other medical specialties where motricity is an important component. This may be explained by the fact that fluidity of movement (flow) is an indicator of mastery of an activity, skill, or competency (Binder, 2003). Flow or procedural flow is characterized by precision, lack of error, and speed of execution. Several grids for assessing medical acts assess this explicitly (see Niitsu et al., 2013).

Numerous studies in medical education observe and measure flow, designating it as a marker of facility with and mastery of a medical act (Levy, Pryor and McKeon, 2016; Lydon et al., 2017; Lydon et al., 2021). Moreover, data on procedural flow (effectiveness, speed, and precision of movements) tend to show, including in medicine, that it can be used to distinguish experts from novices (Norman et al., 2018).

The objective of EPA #10 in Pediatrics (Appendix C, p. 68) is *leading discussions with patients, families and/or other health care professionals in emotionally charged situations*. This EPA highlights unequivocally the importance of learning communication behaviours and empathy in this specialty. In the list of EPAs of other specialties we see similar content. The 10th milestone partly illustrates the role of *Health Advocate* and *Protector* of patients and their families which physicians have to take on in the *Professional* competency.

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Table 1
EPA #1 for Psychiatry

Obtaining a psychiatric history to inform the preliminary diagnostic impression for patients presenting with mental disorders

Key Features

- This entrustable professional activity (EPA) verifies medical school skills of obtaining a psychiatric history and synthesizing information for diagnosis. (**A**)
- This includes clinical assessment skills, including a mental status examination and a focused physical/neurological exam if clinically indicated, and synthesizing a preliminary diagnostic impression in a patient of low complexity. (**B**)
- This EPA may be observed in any psychiatry setting. (**C**)

Assessment Plan

Direct observation by psychiatrist/subspecialty psychiatrist, Core/TTP psychiatry/subspecialty psychiatry resident or fellow. (**D**)

Use Form 1 to collect information on (**E**):

- Case type: anxiety disorder; cognitive disorder; mood disorder; neurodevelopmental disorder; personality disorder; psychotic disorder; substance use disorder; other (**F**).

Collect 2 observations of achievement (**G**)

- At least 2 different case types
- At least 1 by psychiatrist (**H**)

Milestones

Medical Expert (**I-J**)

1. Apply diagnostic classification systems for common mental disorders
2. Perform a clinically relevant history including ID, HPI, and PPH
3. Perform a focused physical and/or neurological exam as clinically relevant
4. Develop a differential diagnosis relevant to the patient's presentation
5. Conduct a mental status examination
6. Develop an initial management plan for common patient presentations

Communicator (**I-K**)

7. Convey empathy, respect, and compassion to facilitate trust and autonomy
8. Use appropriate non-verbal communication to demonstrate attentiveness, interest, and responsiveness to the patient and family
9. Seek and synthesize relevant information from other sources, including the patient's family, with the patient's consent
10. Conduct an interview, demonstrating cultural awareness

Professional **(I-L**)

11. Demonstrate awareness of the limits of one's own professional expertise

Adapted slightly from RCPSC (2020). Entrustable Professional Activities for Psychiatry, Version 1.0

 ISBN : 978-2-923805-73-3

The third element presented in Appendix D (p. 70), in Emergency Medicine, is a little peculiar, because it is not identified as an EPA, despite being included in the list of EPAs for that medical specialty. This non-EPA concerns a professional objective that has to be acquired, but is not identified in that specialty as an EPA: *Evaluation and integration of new evidence in clinical practice*. This objective thus concerns the ability to read scientific research in one's field in connection with a specific problem, to consider and analyse the evidence from it in a critical manner, so as to derive from it possible teachings that can modify clinical practice. This objective reflects the concern to have physicians capable of drawing on scientific research in order to keep themselves up to date. While this objective is specifically identified as not being an EPA in Emergency Medicine, that is not the case everywhere, since EPA #5 in Orthopedic Surgery, *Performing critical appraisal and presenting current orthopedic literature*, covers much the same content, and is explicitly an EPA in that case. We have noted that this learning content, which appears to us to be essential in a physician's professional development, whether it is expressed in the form of a simple objective or an EPA, is not found explicitly in all specialties. This is particularly surprising, since this essential skill in medicine seems to present shortcomings, according to some researchers (Halalau et al., 2021).

Reading the lists of EPAs for the different specialties reveals a certain lack of consistency, already observed by others (Edgar et al., 2018; Hawkins et al., 2015; Holmboe et al., 2020; O'Dowd et al., 2019), such as the example given above concerning Emergency Medicine.

9.0
Overview of research on EPAs, milestones

In this segment, we present research which studies the notion of both milestones and specific competencies, and research on programs explicitly using the concept of EPAs in one form or another.

Research conducted to validate, partly or overall, the usefulness of EPAs and milestones obtains variable, but sometimes encouraging results, including in Pediatrics (Bartlett et al., 2015), Orthopedics in Sports Medicine (Osborn et al., 2021), Emergency Medicine (Beeson et al., 2015; Holmboe et al., 2020; Hamstra et al., 2021), Internal Medicine (Hauer et al., 2016; Hauer et al., 2018; Holmboe et al., 2020), and Family Medicine (Holmboe et al., 2020). However, studies of the amount of practice required for certain medical procedures or operations to reach a point where all residents demonstrate a high level of competency conclude that there is great variability depending on the types of procedures or operations (Brown et al., 2017; Hopkins et al., 2019). Some researchers also point out great variability in EPA or milestone assessment results in Internal Medicine (Warm et al., 2016)[25] and Anesthesiology, depending on the program (Tanaka et al., 2021) which raises concerns and requires further investigation on the subject (see also in this regard Sections 16.0—p. 28—and 17.0 on deliberate practice—p. 29—and Sections 21.0, 22.0—p.31—, and 23.0 on mastery learning—p. 32).

Schott et al. (2015), in a study on Emergency Medicine, are concerned about the reliability of the milestones used. Holmboe et al. (2020), in a longitudinal study on three specialties (Internal, Family, and Emergency Medicine), note that mastery of milestones can provide useful predictive information, but that assessments vary greatly by specialty and competency. In Psychiatry, Bahji et al. (2021) conclude, in a review of experimental literature, that EPAs concerning addiction intersect only partially with the curriculum and the notions that have to be acquired on that subject. They recommend that EPAs be better defined and further research be conducted to ensure the adequate development of resident doctors' competencies in addiction. O'Dowd et al. (2019) note in their review of literature on EPAs in a dozen medical specialties that studies on the topic focus primarily on the development of lists of EPAs, with only 24% (12/49) being devoted to assessing EPAs and the effects of their implementation. The authors consider the quality of the research to be variable.

A worrying phenomenon was highlighted in some recent research with respect to the stability of the high-level mastery of EPAs and milestones (see also the work on deliberate practice that may shed light on this problem, p. 28 and p. 29). Some researchers in Pediatrics note, between the end of residency and the continuation of studies as fellows, a worrisome decline in competencies that were previously mastered (Vu et al., 2021). Imanipour et al. (2022), in a meta-analysis on the effects of CBE,

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show, in some research, a decrease in acquired competencies after a relatively short period of time, in physicians, resident doctors, and nursing students. Research will have to be conducted on this phenomenon in order to determine its profile and consequences so as to try to offset this weakness (Imanipour et al., 2022; Vu et al., 2021).

Since the vast majority of published studies are carried out in the United States and elsewhere than in Canada, one can only speculate what that can mean for EPAs, milestones, and RCPSC CBE.

It is understandable that an undertaking as vast as introducing CBE in all medical specialties cannot take place without some faults, and we imagine the RCPSC is well aware of this. It is patently clear that the EPAs and milestones of the RCPSC's CBE require massive support from scientific studies for their impact and helpfulness to be validated.

9.1 Criticisms from the outset

Some authors express their reservations concerning this pedagogy as applied to the medical world. For instance, Boyd et al. (2018) conducted a critical analysis of studies published on CBE applied to the medical education between 1996 and 2017 based on a conceptual framework inspired by the philosopher Foucault (Dosse, 2012; Foucault, 1969). Boyd and his colleagues detect a certain discourse of infallibility in the literature about CBE that can silence dissenting voices and prevent its rigorous examination.[26]

Other authors express concerns that this modus operandi reduces medical education to mere mechanics, to checklists that distance it from the complexity and quintessence of medical practice (Brook, 2009; Grant, 1999; Hodges, 2010; Huddle and Heudebert, 2007; Klamen et al., 2016; Reeves, Fox and Hodges, 2009; Talbot, 2004; Wear, 2009; Whitehead, 2010). The criticism by Whitehead (2010) stands out from other critiques of CBE, among other things by pointing out that medical effectiveness is largely based (as in other professions) on pattern recognition and the ability to call that recognition into question when necessary. Whitehead (2010) is concerned at the possibility that CBE may not lead to such learning (pattern recognition) because the structure of the pedagogy in use does not directly foster its development.

Do these criticisms and doubts concerning CBE applied to the medical education reflect the reality? Part of the reality? Of course, the great confidence exhibited by certain supporters of RCPSC CBE cannot replace scientific proof. The only way to achieve clarity is to measure and scientifically research the objective impact of CBE applied to the medical education and its components on physicians' professional skills, the quality of care, and patients' clinical outcomes. There is no alternative.

EPAs are only one component of the RCPSC's iteration of CBE. Before going directly to the central issue of the overall assessment of the effectiveness of RCPSC CBE, we will continue "unpacking" some of its characteristics in order to verify RCPSC CBE's possible impact on learning. Identifying these salient characteristics also enables us to determine more accurately the type of pedagogy in use.

 ISBN : 978-2-923805-73-3

10.0
Some salient features of CBE as applied to medical residency

Reviewing various texts from the RCPSC along with articles on CBE applied to the medical education in Canada and elsewhere helps us identify certain characteristics of the pedagogy in use. Among these characteristics are: *operationality and explanation of objectives, learning by observation, modeling and exercises, procedurization, ePortfolio,* and *self-regulation of learning*. Through this content, along the way, other themes arise, such as *technology-enhanced simulation* and *standardized patients*. Three other themes appropriately step into this section: *mastery learning, deliberate practice,* and, to a lesser extent, *competency-based progression*.

This overview enables us to determine the type of pedagogy underlying the RCPSC's CBE, and to take note of its potential impact on learning, according to the scientific research.

10.1 Operationality and clear statement of objectives

Simply reading the EPAs and milestones for medical specialty programs was already highly revealing of the underlying pedagogical structure and, as a result, of the pedagogy in use in RCPSC CBE.

EPAs are influenced by the professional competencies identified in the CanMEDS framework (RCPSC, 2015). These competencies are defined in such a way as to make it possible to identify the detailed outlines of each one of them. Then come the EPAs and milestones. The EPAs are given explicit titles, whereby often even newcomers can understand what they concern overall. Analysis of the EPA task leads to precise, operational milestones. Note, though, that the internal consistency of an EPA and its milestones is no guarantee of its relevance and accuracy; only rigorous scientific research can validate EPAs and their milestones.

The specifications of the EPAs observed in the *General Characteristics* and *Assessment Plan* sections seem to identify accurately the context of the EPAs and the conditions for their assessment. Milestones divide up and explicitly benchmark the development of the EPAs, providing a general description of clear, observable professional behaviours, describing the deployment of the EPAs.

In brief, the thrust of RCPSC CBE clearly presents professional objectives, through EPAs and milestones, that are operational and explicit. Operationality, clear definition of objectives and frameworks for learning are attributes of explicit learning (Hughes, Riccomini and Morris, 2019) and of the behavioural approach in education (Hughes et al., 2017).

In general pedagogy, the use of explicit operational objectives, which owes its origin to Tyler (1949), Gagné and Briggs (1974), and Mager (1997), tends to have a generally positive impact on learning (Bassett and Kibler, 1975). The supporters of constructivist pedagogies generally have little inclination to formulate operational objectives, since they view such objectives as fostering a restricted, mechanical vision of learning which distorts the act of teaching.[27]

10.2 Learning through observation, modeling, and exercises

CBE applied to the medical field uses several means to foster learning and development of EPAs. Observation, learning by modeling, and exercises are noted directly through the use of attentive observation with their own eyes of medical acts performed by experts and the supervised use of simulator devices allowing for medical acts to be practised in the absence of actual patients (McGrath et al., 2018; Nousiainen et al., 2018). The use of videos presenting medical acts, of dummies, models of the human body, and equipment, cadavers, and virtual-reality applications allowing for the practice of medical procedures are ways used at different stages in training and medical residency that directly and expressly support the idea that resident doctors carry out their learning through observation, modeling, and exercises.

10.3 Elements that creep into the storyline

Several studies looking at CBE in medical education do so by including *technology-enhanced simulation*, *standardized patients*, *mastery learning*, *deliberate practice*, and *competency-based progression*, or a blend of those elements. So in our analysis we address those themes that are both peripheral and central. The research cited with regard to the above elements often claims to involve CBE or establishes explicit links between CBE and what they are experimenting with.

 ISBN : 978-2-923805-73-3

11.0
Technology-enhanced simulation (TES)

Technology-enhanced simulation (TES) consists in using means including virtual-reality applications and devices representing the human body with varying degrees of accuracy linked to computer applications that provide feedback. TES can be high- or low-technology. Low-technology TES generally seeks not to reproduce the reality of an operation, but to exercise the learner's motor control (Sandberg et al., 2017).

The use of TES, which still appears to be fairly uncommon in Canada and Québec, obtains useful results in certain areas. The Department of Health in England has directed that a procedure should not be performed on a patient, the first time that it is performed (Cates, Lönn and Gallagher, 2016), and that, among other things, obviously fosters the use of TES.

12.0
Overview of research on use of TES

The meta-analysis by Chernikova et al. (2020b) indicated a mean effect of 0.85 for the use of TES, among other things, in the training of teaching staff, doctors, and managers.[28] In medical pedagogy, TES, which is used to practise medical acts before those acts are performed on real patients, seems to lead, within some pedagogical frameworks (*mastery learning*, *deliberate practice*, and *competency-based progression*), to positive effects with regard to professional skills, and sometimes quality of clinical care (Cook, Hatala, Brydges et al., 2011; McGaghie et al., 2015; Griswold-Theodorson and al, 2015; Huang et al., 2016; Reznick and MacRae, 2006; Zendejas et al., 2011).

The meta-analysis by Cant and Cooper (2017) in Nursing showed that TES significantly improved clinical knowledge compared with the base level. Khan et al. (2018) carried out a literature review on the use of TES to determine whether this pedagogical tool can supplement or replace early conventional endoscopy training in, among other things, diagnostic oesophagogastroduodenoscopy and colonoscopy for health professions trainees with limited or no prior endoscopic experience. The authors consider that they cannot decide in favour of the TES because of the methodological weakness of the selected research.

Piromchai et al. (2015) conducted a review of experimental literature in residency training programs in Otolaryngology and Head & Neck Surgery. These researchers noted that none of the studies evaluated whether virtual-reality training improved clinical competencies with real patients. But they observed that the data support the use of TES in surgical training because resident doctors develop technical skills as good as, if not better than, those acquired through conventional training. Frank et al. (2014) performed a narrative review of 19 studies concerning the ripple effect of TES on knee, shoulder and hip arthroscopy. Only 42% (8/19) of the studies evaluated performance *before and after* TES, which is very low. Of that number, 75% (6/8) showed an improvement after training. No studies investigated the transfer of competencies acquired through TES in the operating room on real patients. The authors concluded that the data tend to confirm that using TES in arthroscopy improves performance on . . . arthroscopic simulators, but could not say more than that as to the clinical effects, owing to the lack of studies measuring the effects in the operating room.

Polce et al. (2020) conducted a literature review including a meta-analysis on the use of orthopedic simulators. The authors observed a decrease in errors, increased efficiency, flow, and performance in execution of tasks carried out on simulators or cadavers, the latter being an approximation of the reality, while not completely so. Polce and his colleagues noted high heterogeneity in type of simulator, training protocol, and measuring tools used, making interpretation of the data less robust. We would add that the duration of the experiments, and thus the training, is very variable, and sometimes very short (from 30 minutes to 13 weeks), the quantity of subjects is small (from 14 to 48 students), maintenance of performance over time was not verified, and no measurement of the effect on the real task was carried out.[29]

Agyeman et al. (2020), in a brief narrative review, believed it has not been shown that competencies ac-

 ISBN : 978-2-923805-73-3

quired by means of TES in Orthopedics are generalized to real situations with patients. On the other hand, the researchers considered that such an approach combined with analysis of movements and a behaviour checklist offered a solution for controlling the financial costs associated with medical training.

Myers et al. (2022) performed a narrative review of research in Orthopedic Surgery in a context of CBE where resident doctors practise on low-technology simulators (e.g., *cigar box*! see Sandberg et al., 2017; see also Agyeman et al., 2020) and higher-technology[30] simulators within the framework of competency-based progression (CBP).[31] The researchers concluded that the use of simulators and CBP led to significant competency gains for resident doctors under CBP compared with those not using it, on measurements of procedural errors, time to complete task, and performance flow, but generally in a TES (i.e., artificial) environment, and more rarely on a cadaver. Finally, the meta-analysis by Mazzone et al. (2021) looking at, among other things, training on laparoscopic surgery, coronary angiography, and arthroscopic procedures observed a 60% reduction in performance errors and a 15% reduction in procedural time in simulated tasks, following practice using TES combined with *deliberate practice* compared with conventional learning approaches.

This overview is relatively encouraging, but unsatisfactory owing to the lack of evidence of the effect of training with TES on situations involving real intervention with patients. Too little research has evaluated the effect of virtual training on physicians' clinical performance in real situations and on results obtained with patients.

12.1 Impact of TES in real life

Kennedy, Maldonado and Cook (2013) carried out a meta-analysis on the use of TES in training on bronchoscopy. With real patients, they observed clinical outcomes that were not better than with more traditional teaching, which is not so bad even if one could hope for an improvement in the quality of interventions with TES.

The goal of the research by Cates, Lönn and Gallagher (2016) was to gauge the usefulness of training using TES compared with live tutored/mentored training in close contact with highly experienced cardiologists trying to teach a procedure they have never done themselves, namely, carotid artery angiography (CA). To that end, the researchers used a randomized methodology and blinded assessment with 12 interventional cardiologists who had operated on a mean volume of 15,000 cases, but with no experience in CA. Six cardiologists used the Vascular Interventional Simulation Trainer (constituting the TES experimental group) and six used live tutored/mentored training with a cardiologist very experienced in the CA procedure (constituting the control group).

The Vascular Interventional Simulation Trainer (VIST) is high-fidelity, virtual TES quite accurately recreating the CA environment. Following their training, each member of the two groups performed a complete CA as lead surgeon on the operation, with a real patient, and this was video recorded. The operation was supervised, but not mentored. The cardiologists in the TES group first had to show a high level of performance to be entitled to carry out their first CA operation on a patient. Each video was assessed by assessors who were blinded as to the operator's identity and status. Three performance measurements were made: total procedure time; fluoroscopy time; and intraoperative errors. The TES group performed the procedure 17% faster and used 21% less fluoroscopy, but the differences are not statistically significant (the number of subjects was too small). On the other hand, the cardiologists in the TES group made significantly (49%) fewer intraoperative errors than the control group. The authors concluded that the results suggested that TES can be a more effective way for experienced physicians to acquire the skills they need to perform a new procedure. Of course, this does not mean that these results are applicable to resident doctors, but they do encourage investigation of this TES.

The results of the experimental research by Cates, Lönn and Gallagher (2016) are intriguing, but certain weaknesses limit its scope. The number of subjects is obviously low (N = 12), but the greatest weakness of this article is the lack of certain information. For instance, the respective duration of training of the TES experimental group and the mentored control group was not specified. Were they equal? If the TES experimental group was able to spend more time practising on the device, which was possibly always available, unlike the mentor for the control group, the difference may be attributable simply to the time spent practising, which was higher for the experimental group. If that variable is the main explanation for the results, this

 ISBN : 978-2-923805-73-3

does not, however, disqualify using the TES, but clarifies the reasons for its impact, where applicable.

The development of expertise requires, among other things, regular, intense practice along with precise feedback and rigorous supervision, something that TES may possibly provide. Training with a mentor is constrained by the *natural* number of cases in a given period. TES makes it possible to offer numerous fictional cases on which physicians can practise repeatedly, with no limits, an element that can be decisive in the development of their expertise. Also, Cates, Lönn and Gallagher noted that some research (see Nallamothu et al., 2011) seems to indicate, with respect to carotid stenting, that high-level mastery of a procedure can be maintained through the intermittent use of TES (see also Gallagher, Jordan-Black and O'Sullivan, 2012). It is therefore possible that appropriate use of TES, at least for certain medical procedures, could eventually become comparable to the use of flight simulators by pilots to acquire and maintain their skills. But for now, there are still pieces missing from the puzzle of SAT's effectiveness.

13.0 Standardized patients (SPs)

Standardized patients (SPs), little used in Canada and Québec, are real patients or actors *pretending to be patients*, trained to answer questions and, among other things, to react to palpations from resident doctors in line with a pre-set script (Barrows, 1993) so that the residents practise diagnostic skills and identification of potentially significant clues. The use of SPs, which is also a form of direct exercising of learning, was first seen in the early 1960s (Barrows and Abrahamson, 1964; see Fink et al., 2021).

14.0 Overview of research on use of SPs

Research by Satterfield et al. (2012) and Wamsley et al. (2013) in the field of substance use disorders shows the effectiveness of using SPs to learn how to take a history, make a diagnosis, and plan the appropriate treatment. Shirazi, Emami and Yakhforoshha (2021) reported positive results for post-residency fellows in oncology using SPs to practise their professional skills in announcing *bad news*, as measured by a test targeting those communication skills. Shahidullah and Kettlewell (2017) studied the use of SPs to train resident doctors on the development of behaviours conducive to good health in their patients, and obtain mixed results, but considered that SPs can be a helpful tool to use. Herbstreit et al. (2017), in research using SPs in Emergency Medicine (three scenarios: acute chest pain, stroke, and acute dyspnea/asthma) with medical students, presented a small significant improvement in results on clinical examination, but no difference in results on the written exam. Piot et al. (2020), in a meta-analysis looking at, among other things, the use of SPs in Psychiatry residency, concluded that simulated intervention is effective in this field. The meta-analysis by Chernikova et al. (2020b) concurred, drawing on their pool of research dealing with SPs in medicine, with the mean effect going as high as 2.27, a non-standard result.

With respect to Nursing, Oh, Jeon and Koh (2015), in a meta-analysis on the use of SPs, observed mean effects of 0.38 on acquisition of knowledge, 1.86 on communication skills, 0.61 on perceived self-efficacy, 0.77 on motivation to learn, and 0.72 on clinical competencies. The study by Tuzer, Dinc and Elcin (2016) showed that the use of SPs is more effective than the use of high-fidelity TES for the acquisition of knowledge in Nursing students with respect to cardiac, chest, or pulmonary examinations.

 ISBN : 978-2-923805-73-3

15.0
In brief, then, SPs and TES

The state of research on TES and SPs in the medical field, including CBE in medical pedagogy, while not consistent, tends to illustrate that these paths for training may possibly be effective in certain circumstances, for certain types of learning. Future research will be needed to confirm this, as it has yet to be demonstrated.

The fact remains that the use of TES and standardized patients in medical training is an unequivocal demonstration that this field is based explicitly, once again, on learning by observation, modeling, and exercises, three central elements of explicit teaching.

The impact of these elements is demonstrated in general pedagogy. The *modeling and exercise* duo is central to explicit teaching (Hughes et al. 2017), whose impact on skills development is amply supported by scientific research (Hughes, Riccomini and Morris, 2019). Observation is an element naturally included in modeling. The importance of sustained exercise is common in the learning of many vocational fields, among others, with a motor component, such as medicine (Hodges et al., 2007; Maslovat et al., 2010).

The concept of *deliberate practice* developed at the end of the 20th century, concerning, among other things, exercise, often overlaps with forms of organization of learning and teaching promoted by CBE in medical pedagogy, without this always being explicitly recognized.

16.0
Deliberate practice

In medical education, the crucial role of intense exercises with appropriate feedback stems from research conducted in the context of *mastery learning*, which we will address specifically below, as well as from the work arising from the concept of *deliberate practice*. The concept of *deliberate practice*, formulated by Ericsson, Krampe and Tesch-Römer (1993) in the field of high-level expertise and elite performance, has been present in medical education since the concept emerged (Ericsson, 2015; Mazzone et al., 2021; McGaghie et al., 2021). Despite some obvious links with CBE, deliberate practice is not formally incorporated into CBE in medical pedagogy.

According to the concept of deliberate practice, expertise is developed through exercises by building on a number of characteristics: (1) a clearly defined learning objective; (2) very strong motivation to improve, which justifies *long-term constant deliberate effort* involving optimum concentration; (3) regular, explicit, precise feedback from an expert (trainer or master); and (4) numerous opportunities to practise the learning pursued (Ericsson, 2008; Ericsson, Krampe and Tesch-Römer, 1993). This intense, deliberate practice prompts reflection concerning the action, solving of the problems encountered, and a sequence and increasingly precise, flowing execution of movements when motor activities are required. An expert in sport, chess, music, medicine, physics, etc., generally requires at least 10,000 hours of intense practice (with feedback and supervision), spread over 10 or so years, to attain high levels of expected performance (Ericsson, 2004; Ericsson, Prietula and Cokely, 2007). It should be emphasized that expertise declines over time (and as the practice of the task is spaced out), but that this phenomenon can be offset partially or totally through the maintenance of deliberate practice to sustain the high level of expertise (Ericsson, 2004).

Research on the impact of deliberate practice reinforces the notion of the considerable importance of intense exercises in developing a high level of expertise (Ericsson, 2015; McGaghie et al., 2011b; McGaghie et al., 2021). The quantity of deliberate practices is indeed a better indicator of expertise than professional experience and academic aptitude (Ericsson, 2008; Ericsson, Krampe and Tesch-Römer, 1993).

 ISBN : 978-2-923805-73-3

17.0
Overview of research on deliberate practice

Research on deliberate practice in medicine tends to be positive (McGaghie, Barsuk and Wayne, 2020; McGaghie et al., 2021). The meta-analysis by McGaghie et al. (2011a) on deliberate practice involved a total of 633 learners, including 389 residents, 226 medical students, and 18 fellows. The overall effect size for clinical skills is 2.00 (McGaghie et al., 2021), an unprecedented magnitude. The results gathered by Mazzone et al. (2021) presented above are also very positive. While RCPSC CBE does not apply deliberate practice, the clear desire to increase the exercises performed by resident doctors, as well as the quantity and quality of the feedback they receive, is indirectly supported by the research on deliberate practice.

Drawing on the work and reflections of Ericsson (2015, 2008), McGaghie et al. (2011b), McGaghie et al. (2021), and Myers et al. (2022), it is possible that the level of integration of deliberate practice, CBP, or mastery learning may potentially be considered to be directly linked to the level of effectiveness of the use of TES and SPs, in circumstances where those educational methods can be relevant to the learning of professional behaviours.

The importance of observation, modeling, and exercises for achieving learning is largely demonstrated by the accumulation of evidence in both general and medical education. While these elements are not specific to explicit teaching,[32] they are usually more openly solicited and studied scientifically in a systematic manner in explicit teaching than in constructivist pedagogies.

18.0
Procedurization

Procedurization consists in operationalizing a task, skill, or competency describing a sequence of motor, verbal, and cognitive behaviours that illustrate the task, skill or competency concerned, within a specific time frame. The use of forms, descriptive grids, and lists of professional behaviours in CBE applied to the medical education reflects the procedurization of professional acts. This is both the base facilitating the learning of professional acts, a reminder of the sequence of behaviours necessary for optimum deployment of an activity, a checklist of crucial elements to avoid forgetting them, and a pointer to the components to be gauged in order to determine the level of mastery of a competency. Lists of acts to be performed in the operating room, before, during, and after, as well as observation grids of expected behaviours during medical activities, explicitly mentioned in the EPAs and milestones of CBE in medical pedagogy, are manifest examples of procedurization.

Procedurization is a behavioural topographical standardization of tasks, skills, and competencies. It provides a representation that is intended to be faithful to the act, but is still always an approximation of it, nevertheless allowing for concrete, direct teaching. Procedurization is not a characteristic unique to CBE, and has long been present in medicine (Haynes et al., 2009), observable from the outset through the description of medical treatments. Procedurization is inevitable in medicine in order to provide a framework for teaching, to ensure the quality of care, avoid errors, and assess medical acts. Most medical activities are subject to an explicit procedure. When a new treatment or new equipment is introduced, the search for optimum procedurization becomes an essential issue. The study by Crossley et al. (2019) on the skill to perform mechanical thrombectomy on ischemic stroke patients is an example of the research needed for procedurization to establish the parameters of a validated reference procedure.

 ISBN : 978-2-923805-73-3

19.0
Overview of research on procedurization

The impact of learning procedurization in general pedagogy yields some interesting results (Cooke et al., 2011; Engelmann, 2007; Slavin et al., 1996). Procedurization is one of the characteristics of explicit teaching (Boyer, 1993), the behaviourist approach, deliberate practice, and mastery learning in the acquisition of simple and complex skills. One of the methods frequently used in education to procedurize learning is to use scripts. The rationale is usually that of facilitating learning and teaching so as to make it more explicit, which could accelerate its acquisition.[33] In that regard, direct instruction surely represents the pinnacle, in general pedagogy, of the detailed development of scripts. Siegfried Engelmann, originator of the concept of *direct instruction*, explained the justification for scripts: "With scripts, we were able to teach new trainees more in two weeks than we had previously been able to teach in more than four months." (Engelmann, 2007, p. 20). Nonetheless, supporters of constructivist approaches are generally resistant to the use of a pre-set, directed procedure prescribed for all, with children and adults, because that goes against the freedom to choose *one's personal procedure* (Guilmois and Popa-Roch, 2021).

20.0
Feedback and formative assessment

In general pedagogy, feedback (including the use of formative assessments) is identified as one of the variables with the greatest influence on learning (Hattie and Timperley, 2007; Lipnevich and Smith, 2018). In medical pedagogy, some literature and research echoes this (Eppich et al., 2015; Sonnadara et al., 2013; Wagner et al., 2019), as in CBE in medical education(Alman et al., 2013; Ferguson et al., 2017; Griewatz, Simon and Lammerding-Koeppel, 2017; Harris et al., 2017; Holmboe et al., 2010; Lockyer and al, 2017b).

The challenges of feedback in the medical world do not appear different from those in general pedagogy. Some researchers have observed that the feedback given to resident doctors in surgery is often minimal in close to 50% of cases, and that when it is given, it is generally unidirectional and insufficiently specific, and thus not very functional or contributing to the best possible learning (Ahmed et al., 2013). Others indicate that medical faculty members are loath to assign low marks to poorly performing resident doctors for fear of discouraging them (Dudek, Marks and Regehr, 2005; McQueen et al., 2016). The study by Wagner et al. (2019), in the context of RCPSC CBE, attempted to resolve these weaknesses in the field of Orthopedic Surgery under CBE. The authors described the development, implementation, and evaluation of a framework aimed at improving feedback practices with resident doctors. Following the execution of targeted medical activities, a feedback form has to be completed by the resident's supervisor. Having this feedback form completed promptly is a problem, according to the research by Wagner and his colleagues, as residents sometimes have to push their supervisors to complete the form or send it to them within a reasonable time frame. That study, conducted within the framework of Canadian CBE (RCPSC CBE), sheds some light on resident physicians' feedback and its challenges. Similar difficulties were also observed by the *Fédération de médecins résidents du Québec* (FMRQ, 2020, 2022a, 2022b).

RCPSC CBE aims to increase the quantity and quality of feedback, among other things through more frequent formative assessments involving in vivo observation (Alman et al., 2013; RCPSC, 2014; Harris et al., 2017; Holmboe, 2004; Holmboe et al., 2010; Ferguson et al., 2013; Ferguson et al., 2017; Lockyer et al., 2017b). Application of this orientation requires residents' supervisors to buy in voluntarily, failing which residents find themselves in a very uncomfortable position, not at all conducive to their learning and well-being.

Feedback and the high frequency of formative assessments are characteristics shared by numerous pedagogical approaches, including explicit teaching, the behavioural approach, deliberate practice, competency-based progression, and mastery learning. Constructivist approaches also consider feedback to

 ISBN : 978-2-923805-73-3

be essential, but they are usually all opposed to the systematization and structured supervision of its use (Guilmois and Popa-Roch, 2021).

A number of researchers in medical education consider, like Eppich et al. (2015), that relevant feedback (concise, operational, and frequent) is central to high-level learning in the context of the deliberate practice and mastery learning.

Mastery learning has prompted a great deal of research in medical pedagogy in the past few years, although there is little such research these days in general pedagogy.

21.0
Mastery learning (ML)

Mastery of a skill or competency means achieving a high level of performance in line with certain explicit standards of execution. Recognition of mastery has to be based on assessments (including observations) demonstrating regularity in performance, stability, and sometimes also flow.

One of the patent aspects of the pedagogical approach of ML, which emerged in the late 1960s in general pedagogy, was the obligation to manifest mastery of learning *Unit #1* objectively, by means of a formative assessment, before being able to move on to *Unit #2*, and so on (Bloom, 1968; Keller, 1968). Like CBE, ML demands the attainment of excellence for all, but at different learning paces.

Since it first appeared in general pedagogy, CBE integrated the principle whereby one learning segment had to be mastered before moving on to the next segment. Frequent functional feedback was also a point of intersection between CBE and ML. It can be stated firmly that ML and CBE share a section of ontological fibre (Hodge, 2007; Klamen et al., 2016).

22.0
Overview of research on ML in general pedagogy

ML was moderately in vogue in the 1970s and 1980s in general education, and the measured impact was generally positive in terms of certain affective measurements and academic performance (Anderson, 1994; Block and Burns, 1976; Guskey and Pigot, 1988; Katims and Jones, 1985; Kulik and Kulik, 1987; Kulik, Kulik and Bangert-Drowns, 1990a; Slavin, 1990). The results available at that time were largely positive, with mean effects on academic performance generally varying from 0.40 to 0.94, while hovering between 0.40 and 1.33 on measurements of affective variables (e.g., interest in subject matter, attitude toward school, self-esteem, school self-concept, etc.). Slavin (1990) calculated a mean effect of 0.27 in his meta-analysis, considerably lower than earlier meta-analyses. Meta-analyses present considerable variance between studies (Anderson, 1994), and that is the clue that *other* variables influence the impact of ML. Additional research is needed to clarify this, but that is not going to happen.

The City of Chicago adopted an ML program in reading from pre-school to 8th grade in 1978-1979. Chicago is one of the U.S. cities known for its pupils' poor academic performance (Katims and Jones, 1985; Thompson, 2014). The adoption of the program was not universally lauded, far from it, despite the positive preliminary results.[34]

Katims and Jones (1985) observed, following the implementation of the Chicago ML program, that the correlation between performance at the beginning and the end of the academic year fell from 0.34 to 0.03 ($p < 0.05$), and that would seem to indicate that the program reduced students' dependence on their prior performance. Alongside this weak correlation, the increase in mean performance, from 0.73 to 1.03 (*raw data*), and the decrease in the standard deviation, which fell from 0.58 to 0.29, confirm that the ML program in Chicago had a beneficial effect on the performance of Chicago students overall (Katims and Jones, 1985). Thompson (2014) reported that students aged 10-13 obtained on the standardized Iowa Test of Basic Skills, only seven months into implementation of the Chicago

 ISBN : 978-2-923805-73-3

ML program, an average learning gain of 1.5 years for 10-year-olds, 1.2 years for 11-year-olds, and 1.1 years for 13-year-olds. May Elementary School, which led Chicago schools in suspension rates prior to the ML program, presented only five suspensions during the first full year of implementation of the ML program.[35] The Chicago ML reading program was dropped in 1986. Adventure over.

Between 1980 and 1990, virulent theoretical criticism of the constructivist trend with respect to learning to decode in reading (phonics) and the rigour of ML—a pedagogical approach considered mechanical—inundated the public and university arena (Goodman, 1985; Jones, 1994).[36] This criticism led to a change of course in the academic world in the USA, with the consequence of promptly quashing general interest in ML, including scientific research, despite the encouraging empirical data.

Despite this fizzling out of ML in general education, among the conclusions of the research from that time, we note that ML can lead to substantial learning gains, particularly for average and weak students, while significantly reducing variations between students (Anderson, 1994; Bloom, 1987; Guskey, 2010). But this method comes at a cost: increased duration of learning for some or most of students (Anderson, 1994; Kulik and Kulik, 1987; Kulik, Kulik and Bangert-Drowns, 1990b; Slavin, 1990).

This brief overview illustrates the short life of ML in general education. After 1994, there were few or no major advances in research in this field. On the other hand, in medical pedagogy, at the dawn of the 21st century, ML was discovered.

23.0
Overview of research on ML in medical education

ML has led to research in medical education, often explicitly dovetailing with CBE. The meta-analysis by Cook et al. (2013) on ML using TES in order to train doctors, medical students, nurses, and other health professionals, whether practising or in training, concludes that it has a size effect of 0.73 on patient outcomes, and a significant effect of 1.17 on professional skills, but notes that this occurs by spending more time on learning, as had been observed in general education in the 1970s and 1980s for that approach. Moreover, the work of Brown et al. (2017) and Hopkins et al. (2019) tends to indicate that the amount of practice of certain medical procedures or operations varies greatly in order for all residents to demonstrate the same high level of competency.

ML is an approach whose effects in medical education seem positive in the development of high-level performance, in the exercise of complex skills with resident doctors and health professionals (McGaghie et al., 2015; McGaghie et al., 2021), including nurses and physicians (Huang et al., 2019).

Bisgaard et al. (2018) performed a narrative review of experimental studies with resident doctors in Anesthesiology looking, among other things, at the procedure of central venous catheterization. Other medical procedures were also included in the review, such as general anesthesia, airway management, spinal anesthesia, and epidural anesthesia/analgesia. The authors selected 38 studies, and looked at the impact of CBE and ML on procedural competency, retention of skills, and patient care as evaluated by fewer complications. They saw ML as a more rigid form of CBE, but more explicit in its performance expectations. Bisgaard and his colleagues reported that 20 studies presented positive effects on procedural competency and retention of competencies. Three studies demonstrated a return on investment for the healthcare system and patients by reducing infection rates involving the central venous catheter. The researchers conclude that CBE has positive effects on patient care and is cost-effective for the health care system, but that the most consistent results are found in ML research, noting that this finding is fragile because the studies involved are from only two research teams.

ML is a pedagogical approach whose data converge in both general pedagogy and medical pedagogy. Explicit teaching, the behaviourist approach, deliberate practice, and competency-based progression (CBP) have much in common with ML.

The supporters of constructivism generally perceive the *rigidity* of ML (e.g., a unit to be mastered before the next unit can be addressed; high criterion for deter-

 ISBN : 978-2-923805-73-3

mining that the unit is mastered; etc.) as a powerful disincentive to its use.

Research on ML applied in medical pedagogy indirectly supports the usefulness of CBE, since the latter pursues an objective of high-level mastery of competencies by all physicians. Its explicit or implicit use in CBE medical education contributes to reinforcing its adherence, whether voluntary or not, to explicit teaching.

24.0 ePortfolio

The ePortfolio is a popular assessment method in the constructivist movement, where it is often described as an important accompaniment to pedagogical changes with a constructivist flavour, while also being a means to introduce those changes and maintain them over time (see Babaee [2020] and Fontana [1995] for an overview of the discourse from authors defending the use of the portfolio and ePortfolio in general education).

The ePortfolio is currently used in most versions of CBE applied to the medical field, including the RCPSC's iteration.

In the medical world, the ePortfolio (and its ancestor, the paper portfolio) is essentially a file used for assessment and monitoring of resident doctors during their residency, on which is based, among other things, the decision-making process leading to certification. This way of assessing resident physicians allows for documenting and following how their development progresses, and noting down the acquisition of EPAs and competencies during residency. The use of the portfolio is encouraged because it proposes an assessment process that is intended to be real, based on a series of data including numerous direct observations of professional acts (RCPSC, 2014; Heeneman and Driessen, 2017; Hong et al. 2021). The portfolio includes assessments from supervisors, interpretations of laboratory results carried out by the resident doctor, and case analyses, along with more traditional formative and summative assessments (Carraccio et al., 2002; RCPSC, 2014; Heeneman and Driessen, 2017; Hong et al. 2021; Kassab et al., 2020).

For several years, a more *reflective* tone has been imposed on the portfolio, incorporating into it a regular exercise of reflection and objectivation in writing, in the form of narrative and explanatory texts, written by the resident doctors, illustrating their progression, including their difficulties and learning (Cunningham et al., 2021; Hong et al., 2021; Kassab et al., 2020). Some authors develop tools to frame the assessment of these types of written documents, but their validity has yet to be confirmed (Heeneman and Driessen, 2017; Kassab et al., 2020). In Québec, reflective tasks appear to be little used, and vary by medical specialty.

The use of the portfolio has been a satellite idea in education for a century (Holland, 2007) that was adopted by the advocates of constructivism. It has been commonly used with very young preschool children (Laski, 2013), since the advent of kindergartens in the 19th century in the USA.[37] We also find it being used in the vocational fields of visual arts, music, architecture, and advertising to replace or complement the resumés of people working in those areas and offering their services.

25.0 Overview of research on the ePortfolio in general education

The idea of the portfolio began to gain traction in general education at the elementary and secondary levels in the early 1980s (Grace and Shore, 1992; Liu and Liu, 2019). The first general application of the portfolio in elementary school took place in Vermont and Kentucky in the early 1990s, and the assessments of their effectiveness several years later revealed substantial shortcomings (Holland, 2007). First, there was a problem with the interpretation of the overall elements of the portfolio and the value hierarchy concerning its informational elements.

Koretz (1992) observed that the judgment of the elements (generally tasks) and the portfolio as a whole

 ISBN : 978-2-923805-73-3

varied considerably from one assessor to another. The portfolio in Vermont was so unreliable that its use was not recommended for making decisions at the school or State level (Nidds and McGerald, 1997). Another difficulty concerned the context in which the tasks making up the portfolio were produced, which could vary from one school district to another, one school to another, one class to another, and one individual to another (Holland, 2007). For instance, among the varying, not always explicitly named contexts is the presence of additional instructions provided before the task is performed, time allowed to carry out the task, quantity and type of assistance received, if any, during performance of the task, possibility (or not) of revision after performing the task, quantity and type of assistance with revision, etc.

Some researchers note that putting together the portfolio is very time-consuming for teacher and pupil, while being very costly for the school system (Koretz et al., 1994). Following the identification of these weaknesses, Kentucky officially abandoned the portfolio in the late 1990s (Holland, 2007).[38]

At the post-secondary level, Bryant and Chittum (2013) carried out a review of the scientific literature concerning the ePortfolio, and observed that between 1996 and 2012, only 15% (18/118) of the research presented empirical data on students' results, and only 2% (2/118) of the studies used valid, reliable measurements in addition to a comparison (control) group. The authors concluded that the paucity of empirical data meant it was not possible to conclude that the ePortfolio had positive effects on student performance at the post-secondary level, despite its popularity.

Rhodes et al. (2014) also considered that the research world has to go beyond case studies and anecdotal stories to foster research using more rigorous methodologies. The ePortfolio at the post-secondary level has led to numerous articles, essentially qualitative research and argumentative theoretical studies. For instance, Scholz, Tse and Lithgow (2017) conducted a review of literature concerning post-secondary students' and their instructors' perception of their use of the ePortfolio. This type of research does not make it possible to gauge the effect of the ePortfolio on learning the content of training compared with another learning assessment and monitoring approach. The authors half-heartedly recommended the use of the so-called best practices of the ePortfolio, while specifying that this is nevertheless no guarantee of its success.

In sum, in general education, the use of the ePortfolio is not evidence-based. The experiments conducted on large samples of elementary school students tend to indicate that the portfolio is not reliable, takes a lot of time, and is costly. At the post-secondary level, the paucity of rigorous scientific research precludes reaching any kind of conclusion. Despite these negative results and the lack of data at the post-secondary level, it is still possible that the picture may be different in medical pedagogy.

26.0
Overview of research on the ePortfolio in medical education

Data available on the topic of the ePortfolio in medical education is neither consistent nor clear. Use of the portfolio is, however, very widespread in medical schools around the world (Driessen et al., 2007). O'Sullivan et al. (2004) conducted longitudinal research over four years on the validity of the portfolio, involving 18 resident doctors in Psychiatry. They observed that assessment of the portfolio correlated with a Psychiatry knowledge test but not with an assessment of clinical performance. This research is a fairly typical example of the studies conducted on the portfolio (and the ePortfolio): descriptive study, with no control group, with measurements of the satisfaction and perceptions of the protagonists, in this case, resident doctors and their supervisors. This research may potentially be useful, but remains over-represented and of little relevance when the basic question is: "Does independent variable X (*here, the portfolio*) have an effect on dependent variable Y (*here, resident doctors' learning or clinical performance*)?" The research by O'Sullivan et al. (2004) does not answer this question. Only experimental or quasi-experimental research, thus with a control group (or objective measurements of learning compared against recognized standards) can allow us to start answering such a question.[39]

In a qualitative study on the cognitive process of 18 as-

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sessors (physicians from various specialties) invited to assess medical students' ePortfolios, Pool et al. (2018) observed that the assessors differed substantially in their judgments of the ePortfolios submitted to them and in their projections of the candidates' future professional quality. The findings of this study tend to demonstrate that the assessors' reasoning and decision-making vary in line with their conceptions of assessment and the physician's role. Pool and his colleagues considered that their data confirm the importance of having ePortfolios judged by several assessors, and recommended that the latter have the task of specifying in detail their conceptions of assessment and the judgments they make on the ePortfolios submitted. Pool et al. (2018) also suggested that the portfolios be designed so as to facilitate selection and navigation between the portfolio's different *evidence*. This latter comment from the authors is an indication that the difficulty of processing and hierarchizing the information from the ePortfolio, a problem already seen in general education, appears to be repeated in medical pedagogy.

The literature analysis by Driessen et al. (2007) presented mixed results, concerning the expected use of the portfolio, namely, to make it possible to follow the evolution of the learning and make a general judgment on that learning. They observed slightly more consistent results in the context of pre-MD studies, but not in residency. The researchers noted moderate reliability within the groups of assessors, while observing that the overall criteria given to the assessors as well as discussions among the latter were seen positively by them.

In 2009, Buckley et al. conducted a scientific literature review on the impact of the portfolio based on 69 studies covering studies in medicine, nursing, physiotherapy, and other disciplines. These researchers concluded that the validity and quantity of studies on the pedagogical impact of the portfolio at the university level were limited. Several results are based essentially on the perceptions of those involved, only 13% (7/69) of the studies measured students' competences or attitudes directly. Buckley et al. (2009) expressed the view that while the use of the portfolio encourages students to engage in reflection, the quality of that reflection cannot be taken for granted, and time spent drawing up the portfolio can reduce or obliterate time devoted to other more arid learning, unless the portfolio requires them to carry out such learning.

Uygur et al. (2019) noted that the use of the ePortfolio incorporating reflective texts into the MD program has a positive impact on students' reflection if they receive clear instruction and feedback on their reflections. But, while reflection is always a good idea, that does not mean that patient outcomes and quality of care are positively impacted by the use of the reflective ePortfolio—that has yet to be demonstrated.

In a recent review of scientific literature in Anesthesiology with respect to resident doctors, Weller, Naik and San Diego (2020) concluded that the lack of studies on the essential components of CBE, including the ePortfolio, makes it impossible to draw any firm conclusions.

27.0
In brief, then, the ePortfolio

The use of the ePortfolio is favoured by the constructivist movement, as we mentioned earlier, but not so much by the explicit teaching movement. In theory, though, the idea of basing oneself on the assessment of learning primarily from professional achievements in real life rather than on theoretical pen-and-paper assessments makes good sense in CBE , from a rational, logical viewpoint. Surprisingly, evidence of the value of this idea has been slow coming.

As we said earlier, in general education the scientific literature on the portfolio bemoans the weakness of the research conducted and reaches conclusions rather unfavourable to its use, despite the fact that this assessment method is still used in many schools and academic settings, impervious to the observations of scientific research and the lack of evidence supporting its use. In medical pedagogy, the same observations are made concerning the consulted research: marked weakness in the research methodology used to date, most of the published studies being purely descriptive. This situation does not allow for determining clearly the effect of using the ePortfolio on learning, including clinical results, or for concluding whether the portfolio

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or a particular type of portfolio is preferable to other assessment and monitoring methods in CBE or medical education.

There is not a great deal of research on the impact of the ePortfolio on clinical performance in family medicine (Danilovich et al., 2021), and, to our knowledge, there is very little in the medical specialties. Moreover, the scattered, infrequent data in medical specialties provides no very clear indication. Worse, a number of researchers see no correlation between the ePortfolio, its assessment, and clinical practice, including in Psychiatry (O'Sullivan et al., 2004).

The ePortfolio is a concept closer to the constructivist discourse than to explicit teaching, which is put off by the vagueness of the concept and its use. Nevertheless, if one day scientific research comes to demonstrate objectively the importance of its use, explicit teaching will have no choice but to incorporate it. For the moment, though, there is no urgent need to call for help.

28.0 Self-regulation of learning

One of the features of RCPSC CBE is the increase, compared with the old residency formula, in resident doctors' responsibility for their own learning (Carraccio et al., 2016; Frank et al., 2010a, 2010b). When the learners manage their learning, the skill of *self-regulating* learning is perceived as a central element (Woods, Mylopoulos and Brydges, 2011). Self-regulation is explicitly mentioned in the context of RCPSC CBE as a skill that is required in the medical profession (Frank, 2005). Although self-regulation often refers to a *personal construction of learning*, one of the principles on which the constructivist philosophy is built, non-constructivist authors also refer to it in a more social and cognitive behavioural conceptual universe (Bandura, 1991; Usher and Schunk, 2018).

28.1 Responsibility for learning

Self-regulation of learning in residency is defined by the fact that responsibility for tracing the learning path lies with the learners themselves. Resident physicians orient the progression of their learning based on the EPAs and their milestones. In concrete terms, the residents supervise their development in the EPAs in their specialty, seek opportunities to practise those EPAs and the associated milestones in clinical situations, and seek opportunities to demonstrate their competencies to one or more assessors. *Resident doctors are also responsible for identifying these assessors and ensuring their availability to assess the EPA as well as the milestone(s) concerned.* Following the residents' performance, the assessor has to complete a form which the residents must receive within a certain time period to attach it to their ePortfolio. If the assessment is negative, i.e., if the assessor considers the medical task not to have been mastered at the expected level, it is up to the resident physicians to identify (with the possible support of the assessor or supervisor) the necessary activities for improving their performance, to carry them out and then go through the previous process again to be assessed. Compared with the old type of residency where all the resident doctors' activities are generally prescribed and above all managed by the supervisors (staff physicians), responsibility for learning in RCPSC CBE lies more broadly on the resident physicians' shoulders.

28.2 Why hand over responsibility for learning to the learners?

Several authors in the medical education world want greater self-regulation of learners' learning, an element that is generally the trademark of learner-centered pedagogy (Carraccio et al., 2002; Carraccio et al., 2016; Frank et al., 2010a; Skjold-Ødegaard and Søreide, 2021), with a constructivist flavour. RCPSC CBE, in adopting the shift of responsibility for learning toward the resident doctor, imposes self-regulation of learning which implies, in the eyes of those encouraging it, greater flexibility in the organization of learning, greater transparency of standards, objectives, and procedures, and greater involvement from resident physicians while offering the possibility that they can progress at their own pace, within a certain time frame. Pursuing self-regulation in resident doctors is said to have advantages for the learners (residents) and for the pedagogical framework.

There are numerous arguments in favour of the development of self-regulation in resident doctors, such as the fact that residents will have to continue pursuing their learning on their own for the rest of their careers in order to

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stay up to date. So it is *theoretically* preferable for resident physicians to be called upon to develop their self-regulation as early as possible. Some researchers observe that the skill of self-regulating one's learning develops informally in different ways (Woods, Mylopoulos and Brydges, 2011), while others maintain that adequate self-regulation of one's learning requires specific external intervention prior to the clinical experience (Cho et al., 2017). It is useful to remember, at this point, that the available data concerning the skill of self-assessment among would-be doctors and the general public, as we have explained (3.5 Ability to self-assess, p. 13) are not very positive (Kämmer, Hautz and März, 2020; Lu, Takahashi and Kerr, 2021).

The debate on the place of self-regulation of learning in general education, along with that of the effectiveness of learner-centered pedagogies, has been running in the form of different discourse and under various names for more than a century (Bissonnette and Boyer, 2018; Boyer et Bissonnette, 2021; Sitzmann and Ely, 2011; Winne, 2021). Learner-centered pedagogies have been attacked head-on for several years (Chall, 2000; Kirschner, Sweller and Clark, 2006). One of the definitions of self-regulation often mentioned considers that learners self-regulated in their learning manifest it by being active in metacognitive, motivational, and behavioural terms in order to attain their learning objectives effectively (Zimmerman, 1986).

29.0
Overview of self-regulation of learning in general pedagogy

In 1996, Hattie, Biggs and Purdie stated that research on self-regulation in general education did not make it possible to maintain that this variable could have an effect on children's academic performance. They also said that the theory underpinning self-regulation had no doubt jumped the gun on evidence in its pedagogical applications—and, we would add, regrettably so, as this frequently happens in pedagogy. Since the late 1990s, though, numerous studies have been published.

Several studies in general education on the development of self-regulation of learning are based on correlational analysis. For instance, the meta-analysis by Dent and Koenka (2016) explores the link between academic performance and components of self-regulation in children from pre-school to high school. They established a slight mean correlation (r = 0.20) between these two variables with components of self-regulation (e.g., self-planning, self-assessment, self-supervision, etc.—considered by some to be meta-cognitive skills). The literature review by Kesuma et al. (2020) on self-regulation at the secondary level also emphasized that certain aspects of self-regulation are correlated with academic performance.[40]

The meta-analysis of experimental research conducted by Dignath and Büttner (2008) looks, among other things, at the impact of self-regulation programs on the academic performance of children at elementary and high school. The size effect on academic performance is 0.61 at the elementary level and 0.54 at the secondary level, results that are considered significant. Pandey et al. (2018) also conducted a meta-analysis on the effect of interventions and self-regulation programs with a clientele of children from pre-school to elementary school (fewer than 1% of research subjects were at high school). The authors calculated a mean size effect of 0.40 on academic performance. Note, however, that these results incorporate a variety of interventions and programs, including those aimed at the control (self-regulation) of social behaviours and emotions by means of yoga and mindfulness exercises. The quality of the selected research is variable. The studies by Pandey et al. (2018) focussing on self-regulation of academic learning obtain a mean effect of 0.34 on academic performance.

Winne (2021), in an article on cognition, metacognition, and self-regulation of learning, notes that the correlation between self-regulation and performance is generally modest. He nevertheless concluded that learners who benefit from appropriate instruction on the self-regulation of their learning can enjoy better performance.

Sitzmann and Ely (2011), in a meta-analysis looking at self-regulation and the concepts deriving from it, with a clientele of young people aged 18 and over, observed that persistence, effort, and self-effectiveness are correlated with performance, but that planning, self-supervision, seeking help, and controlling emotions are not, despite the fact that those skills are usually assumed to be significant elements in self-regulation.

Theobald (2021) conducted a meta-analysis looking at the impact of university programs to develop self-regulation of learning, among other things, on students' academic performance and motivation. The results showed a size effect

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of 0.37 on performance and 0.39 on motivation of the university clientele.

In general education, between the judgment of Hattie et al. in 1996 and now, there appears to be some difference in the data. While the table is very far from clear yet, the fact remains that self-regulation of learning seems to correlate from weakly to moderately with academic performance. The way in which self-regulation influences performance is not yet clear, and other experimental research is required before its dynamics can be better described. The effective path for positively influencing academic learning through self-regulation is, at best, under construction.

30.0 Overview of research on self-regulation of learning in medical pedagogy

In medical education we see a similar image to that in general education, but magnified. The research conducted is still massively descriptive and correlational.

Self-regulation of learning is made up of several skills, including self-planning, self-supervision, and self-assessment. These skills can be subdivided into other skills or subskills. For instance, self-determination of objectives may be seen as one of the underlying skills comprising self-planning. In medical education, among others things in the context of residency, *self-determination of learning objectives* is seen as an essential element in self-planning, and ultimately in self-regulation (Larsen et al., 2017). The context of residency, where patients' needs, resident physicians' learning needs, and the medical program's assessment standards can come into conflict, sometimes even being hard to reconcile, complicates *self-planning of learning objectives*.

Artino et al. (2012) studied the links between the use of self-regulation of learning in 304 medical students and their perceptions of the clinical environment in which they practise. The researchers observed that the students' perception of their clinical environment can influence the manifestation of procrastination and avoiding asking for help (when necessary)—symptomatic of poor self-regulation. If the students perceive their learning environment as being focussed on improvement and understanding, they have much less tendency to procrastinate. Some research on the work climate in the medical world concurs (Braithwaite et al., 2017; Chang and Mark, 2011; Maillet, Courcy and Leblanc, 2016).

Sawatsky et al. (2020) conducted a study on 153 resident doctors in Internal Medicine in a hospital setting. The study involved measuring the quality and relevance of the objectives the residents set themselves, which constitutes a situation of self-planning of learning, one element in self-regulation. The authors observed that the resident physicians identified a broad range of themes in their self-determined learning objectives, but these were of low quality. Sawatsky et al. (2020) concluded that residents could benefit from advice in self-determining their learning objectives. The descriptive research by Jouhari, Haghani and Changiz (2016) conducted with 363 Iranian doctoral students presented a link between academic performance and certain measurements of self-regulation involving time management, self-assessment, and concentration on studying. Of the students, 20% (73/363) had already taken training in self-regulation and study techniques. The authors expressed the opinion that the students needed to be trained and supervised in the different measured spheres of self-regulation and study techniques.

Ross et al. (2021), in an article on CBE, ML, and development of the skill to self-regulate defended the idea that effective CBE requires the use of ML. According to those authors, the findings of research in the past few years support the hypothesis that ML fosters the development of adaptive learning behaviours, including those supposed by self-regulation of learning. Through the explicit high-performance requirements of ML and its structured operation, it is presumed that effort and tenacity, self-assessment of performance, self-determination of learning objectives, self-supervision of activities, and the search for activities conducive to learning are directly solicited, and that their development is thus fostered. Ross and his colleagues therefore advised that CBE adopt a modus operandi that exercises and fosters behaviours that self-regulate learning, such as ML, considering that this will instill and reinforce fundamental behaviours throughout physicians' training and professional lives.

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

31.0
So, the concept of self-regulation …

In short, it seems that the concept of self-regulation of learning, which is a characteristic of RCPSC CBE, was not clearly and soundly validated through evidence in either medical pedagogy or general pedagogy. This concept dangles attractive possibilities, particularly in medical pedagogy, where the autonomous pursuit of learning required by continuing education imposes the development of self-regulated learning. It is possible that this pedagogical concept is almost indispensable, at least in continuing education, and that we have no choice but to seek conditions to make it operational and effective.

Self-regulation is a concept much more often associated with constructivist approaches, but it also has behavioural and cognitive behavioural roots (Bandura, 1991; Usher and Schunk, 2018). Through these roots, the adoption of this concept by explicit teaching would be facilitated, and more certainly so if its relevance and an effective way of developing it are finally demonstrated scientifically.

32.0
Which type of pedagogy underpins RCPSC CBE, and does it work?

Aside from the ePortfolio, and to a lesser extent self-regulation of learning, all the salient characteristics presented in CBE applied to medical education are elements generally associated with explicit teaching. Explicit teaching is based on a considerable amount of evidence that tends to prove its effectiveness compared with constructivist pedagogies on academic performance and certain affective variables (Bissonnette et al., 2010; Chall, 2000; Guilmois and Popa-Roch, 2021; Rosenshine, 2009).

Some salient elements of RCPSC CBE may potentially be conducive to learning, as we noted earlier, but that does not mean, indeed far from it, that the effectiveness of CBE has been fully demonstrated, even if the results from certain salient elements seemed to show some remote glimmers of light. The isolated measurement of one, two, or three components of CBE over a short period of time is not a measurement of the effect of CBE overall, over one year or over the duration of residency (generally 2-5 years). So research has to be consulted that tries to measure the effect of CBE on professional learning and clinical performance. Since the implementation of CBE is also motivated by the desire to enhance the quality of care delivered to patients, it is therefore essential that the effect of CBE on that aspect be assessed.

Before directly presenting the research on CBE applied to medical education, we will address the effects of CBE in other fields.

33.0
Impact of CBE as applied in fields other than medicine

In some studies on CBE in medical education, reference is made to the fact that CBE had previously been implemented in other fields (RCPSC, 2014; Frank et al., 2010b; Frank et al., 2017; Hodges, 2010; Hodge, Mavin and Kearns, 2020; Imanipour et al., 2022; Laurin, Audetat Voirol and Sanche, 2013), which might lead one to believe that the effectiveness of CBE has already been demonstrated in certain fields—and that is not quite accurate (Klamen et al., 2016).

33.1 Use of CBE in general pedagogy

Laurin, Audetat Voirol and Sanche (2013), in an article concerning CBE as applied to family medicine, refer to the *Renouveau pédagogique*, the year 2000 reform in elementary and secondary education in Québec (Ministère de l'Éducation du Québec [MEQ], 2001), as if that school curriculum reform were a precursor boding well for CBE as now applied to medicine. The 2000 educational reform can indeed be associated with CBE (Rochon, 2020), among other things, through its central element focussing on development of competencies. On the other hand, the version of CBE adopted by the educational reform is a completely lightweight, not to say feeble, iteration of CBE.

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First of all, this educational reform in no way incorporates the pursuit of high performance or the obligation to master one content before passing on to the next. Similarly, multiple feedback and formative assessments are not part of its core DNA. Nor is the search for operationality guaranteed by observable, measurable learning objectives a major concern of this reform. The Ministry of Education's iteration of CBE underlying the 2000 reform is a constructivist version from which the vital elements of CBE have been so thoroughly removed that one can even doubt it really belongs to CBE.

Worse still, this educational reform at the elementary and secondary levels is not a model to be followed for implementing a new educational approach, but is rather an example not to be followed. This reform was a major change imposed on the school system, backed by no evidence from scientific research, with no rigorous, objective pre-experimentation prior to its widespread implementation, with no systematic measurement of its effects in course of implementation, and with no objective, systematic measurement following its implementation. This implementation is a fairly good representation of the *perfect, typical example of what not to do* in a school system from a rational, rigorous, scientific point of view (Baillargeon, 2013; Boyer, 2021; Boyer and Bissonnette, 2021; Bissonnette, 2008). Scientific studies, few and far between, of this school reform, conducted after its widespread implementation, all present results varying from mixed to somewhat negative (Boyer and Bissonnette, 2021). In no way, then, can this year 2000 school reform in Québec be referred to as a conclusive trial of CBE or of any other educational trend.

That being said, for the past 50 years or so, CBE has been an approach that has been more or less popular at the primary and secondary levels, in line with the random turbulence of ideas popular in the school world. We will now take a look at research on CBE in general education which more clearly claims its attachment to the foundations of CBE.

34.0
Overview of research on CBE in general pedagogy

Donnelly (2007) looks at the application of CBE at the elementary and secondary levels in different countries, including Canada (Ontario), the USA, South Africa, and Australia. In all those countries, the predominance of CBE in their school systems fades after a few years, collapsing under an avalanche of criticisms and weaknesses. Among those weaknesses is the objective decline in performance on standardized tests, the burden of the application for teaching staff, the complexity of managing lists of objectives, and the low acquisition of essential knowledge. Donnelly estimated that CBE in elementary and high school was a failure in all those countries. In 2002, some even considered that the death of the CBE movement at the elementary and secondary levels went back to 1995, and that since then research on the subject had dried up to the point that it was hardly referred to at all any more (Blyth, 2002; Donnelly, 2007), a view that would be proven wrong by events in future years.

Brodersen and Randel (2017) observed that the majority of elementary and early high school students in Colorado (Grades 3 to 8) receiving CBE successfully completed their learning in reading and mathematics within the traditionally prescribed time frame. Some of those students (from 43% to 47%) even completed their learning a little more quickly. But the authors observed that the evaluation of pupils' competencies carried out by teaching staff in schools using CBE correlated weakly with Colorado's standardized tests, in both reading and mathematics. In other words, teaching personnel's evaluations, which indicated attractive results, were not validated by outside measurement. The narrative review of literature from preschool to Grade 12 by Evans, Landl and Thompson (2020), covering the recent period from 2000 to 2019, emphasized that most research did not measure the effect of CBE on performance or gives it little importance. The researchers concluded that, overall, the impact of CBE on student performance was mixed, with some studies reporting a negative impact while others indicated a positive effect, albeit a limited one in certain grades.

At the post-secondary level, Kelly and Columbus (2016) calculated in a narrative review of studies on CBE that only 26.8% (102/380) of the studies were quantitative. Of that

 ISBN : 978-2-923805-73-3

26.8%, the majority were descriptive (survey, quantified observations, students' perceptions, etc.), and only 4% (15/380) used an experimental protocol measuring students' academic performance *before and after* so as to evaluate the development of their competencies, but without necessarily comparing their results to those of a control group. Note that several studies were based on self-assessment (and thus on perception of performance), and that only a few studies compared CBE with more conventional teaching. As a result, the authors concluded that scientific research still had no rigorous answers to offer on CBE to guide education policy at the post-secondary level.

In general education, while the first applications of CBE go back more than 50 years, and some schools have tried it for several years, no rigorous demonstration has been made of its effectiveness or ineffectiveness. That is due, among other things, to the low number of experimental and quasi-experimental studies, the mediocrity of the research protocols, and the ubiquity of descriptive and correlational research limited to studying the details surrounding CBE or dissecting the internal workings of CBE in order to enhance its effects, as if CBE already had a proven track record.

A certain abandonment of CBE observed at the primary and secondary levels in the late 20th century cannot be attributed to scientific research, even if worrisome results were seen with respect to children's performance and teaching staff's perceptions.[41] Nor was the adoption by the Ministère de l'Éducation du Québec, at the very start of the 21st century, of a reform loosely based on CBE the reflection of new inroads by scientific research indicating positive effects (Boyer and Bissonnette, 2021). The truth of the matter is that general education and the changes introduced in it are not influenced in any decisive way by scientific research, reason, and rigour, even when those changes are piloted by Québec's education ministry.

Klamen et al. (2016) aptly mentioned the fact that the introduction of CBE in medical field appeared to ignore the failures of general CBE at the elementary and secondary levels.

Furthermore, while the effects of CBE in general pedagogy were positive (or the reverse) and solidly supported, that would not mean that its use in other fields and with other clienteles would inevitably yield the same results. So, what is the situation elsewhere?

35.0
Enthusiasm for CBE in non-medical vocational training

Several professional fields and several well-known U.S. vocational institutions have implemented CBE in the past 15 years. The next few years are likely to be boom years for this type of pedagogy (Gravina, 2017; Mathewson, 2015; Vasquez, Marcotte and Gruppen, 2021). One of the reasons for this enthusiasm for CBE in vocational education is that it theoretically allows some atypical students (e.g., returning to school after experience on the labour market, work-study terms, etc.) to complete their vocational training more quickly by using the knowledge acquired through their experience of life and the world of work (Baker, 2015; Gravina, 2017; Kelchen, 2015; see also the promotional material in WGU, 2020). Also, the fact that CBE blends easily with distance education and that this appears to be appreciated by some atypical students who have to combine work, study, and family life partially explains the current and anticipated enthusiasm for this pedagogical approach over the next few years.

Educational institutions, for their part, can train more students at lower cost (Gravina, 2017), particularly with the CBE-remote learning combo.[42] The student clientele can in theory benefit from this, if they cover the learning content more quickly than in conventional training (Baker, 2015; Gravina, 2017; Kelchen, 2015; WGU, 2020). But Kelchen (2015) reminds us that a percentage, no doubt considerable, of the student clientele will progress more slowly and that the cost for those students is likely to be higher than with conventional training.

Another justification for the dissemination of CBE in the galaxy of types of vocational training is the very strong support from the world of work in general, and in particular from industry with that educational orientation. A close link is explicitly established, voluntarily and naturally, between learning programs using CBE and the needs expressed by industry (and

 ISBN : 978-2-923805-73-3

the work world), directly influencing the content of learning (Boritz and Carnaghan, 2003). In that context, the needs of industry literally dictate its training-related expectations to post-secondary institutions, with sometimes no desire to envisage anything other than its very short-term needs, as was observed in Australia (Smith, 2010).

CBE in vocational training contributes to further commercializing education and the school system in the West, by removing from learning programs anything that does not contribute directly to strictly labour market needs, ignoring broader citizenship education (Baillargeon, 2009; Ford, 2014; Gravina, 2017). This criticism, supported by several authors, carries little weight in the face of the tsunami of CBE in vocational education.

All in all, there appears to be unanimity among governments, educational institutions, the world of work, student clientele, and education faculties[43] around the idea that CBE has to be disseminated and applied in all vocational training, in the short term. This demand is sometimes accompanied by a call, rarely heard, to carry out more experimental research to confirm its validity (McClarty and Gaertner, 2015; Porter, 2016).

36.0 Overview of research on CBE in non-medical vocational education

Mulder, Weigel and Collins (2007) were interested in *teaching by competency* in vocational education in four countries (UK, Germany, France, and the Netherlands). They expressed numerous criticisms, including the inconsistency of the concept of competency, lack of one-to-one relationship between the competency defined by a program and performance in real practice, as well as the underestimation of the various organizational consequences of the implementation of CBE, including numerous assessment-related issues.

In accounting, Boritz and Carnaghan (2003) acknowledged the popularity of competency-based programs, but they noted weaknesses in the definition of competencies, implementation of the approach, and its evaluation. The authors stressed that there are many CBE approaches, but that there is little research supporting them within the context of university training in accounting. Henri, Johnson and Nepal (2017) observed, in engineering, that students and their professors usually responded positively to the use of CBE and that some research tended to indicate that CBE is effective on future engineers' performance. Henri and his colleagues noted, however, that some competencies associated for instance with communication were lacking in students, but they saw this more as a reflection of weak program content than of CBE itself.

In social work, according to McGuire and Lay (2020), CBE has been the recommended framework for training in the U.S. since 2008. In an article on CBE, reflective pedagogy, and experiential learning, McGuire and Lay considered that reflective pedagogy (and indirectly CBE) has the potential to train social workers well and make them people capable of pursuing their vocational training, but the evidence they submitted of that is theoretical.

In pharmacy, Udoh et al. (2021) conducted the first meta-analysis in that field. They selected nine studies to conduct their meta-analysis, only two of which had a control group. Of those two experimental studies with a control group, only one presented results favourable to CBE. Some of the research selected measured performance by means of peer assessment and self-assessment by pharmacists-in-training. Udoh nd his colleagues considered, despite the paucity of the data submitted in their meta-analysis, that their results tended to indicate enhanced performance of pharmacists-in-training who benefitted from CBE. Katoue and Schwinghammer (2020) reached the same conclusions in a narrative review of CBE literature in pharmacy, identifying no experimental research, unlike Udoh et al. (2021), who identified two such studies. Katoue and Schwinghammer specified, among other things, that the implementation of CBE in pharmacy required a strong institutional orientation, appropriate design and management of study programs, and special attention to training of teaching staff. For our part, we consider that the conclusions of Udoh et al. (2021) and Katoue and Schwinghammer (2020) have little basis

 ISBN : 978-2-923805-73-3

from a rigorous, scientific point of view, particularly as far as the effectiveness of CBE is concerned.

The use of CBE in vocational training in fields other than medicine is increasingly the norm. Experimental research measuring the benefits of CBE compared with a more conventional pedagogy are extremely rare. The effectiveness of CBE in vocational training outside the medical field is not yet established, despite the claims from some authors. The popularity of CBE in those vocational fields along with the numerous studies describing CBE as the training solution in the 21st century constitute ideological posturing or marketing to elicit the veneration of CBE, but do not in any way reflect a rigorous, scientific attitude.

37.0
CBE was definitely used in other fields before being used in medicine, but . . .

RCPSC (2014), Frank et al. (2010b), Hodge, Mavin and Kearns (2020), Frank et al. (2017), Laurin, Audetat Voirol and Sanche (2013), Imanipour et al. (2022), and numerous other authors mention that CBE is used in many domains, and they are absolutely correct in that. On the other hand, in light of the information presented, if the idea is to imply indirectly that this high visibility means CBE has proven itself, well then they drop the ball. The effectiveness of CBE in general education and in many professional fields, in comparison to a more conventional pedagogy, has not been proven, despite all the fuss of dynamic, enthusiastic discourse in favour of CBE. Does that mean the same observations are going to be made in the field of medicine? Not necessarily.

An influential report concerning the future of medical education in the United States, produced for the Carnegie Foundation, recommended *an approach based on development of competencies* (including CBE) in medicine, considering it the be-all and end-all of pedagogy (Cooke, Irby and O'Brien, 2010). An article in the esteemed journal *The Lancet* also encouraged the use of CBE in medical training (Frenk et al., 2010).

38.0
Foreword on evaluation of CBE applied to the medical field

CBE has spread in the medical world, in part echoing Whitehead's (2010) image, like a forest fire in a July heatwave. Some researchers in medical education believe the rapid adoption of CBE in medicine has happened and has spread widely by consensus rather than through a substratum of evidence justifying it (Imanipour et al., 2022; Klamen et al., 2016; Prideaux, 2004; Morcke, Dornan and Eika, 2013; Norman, Norcini and Bordage, 2014).

38.1 Appetizer: peripheral research assessing the impact of CBE applied to medical education

In our view, studies on EPAs and milestones (9.0 Overview of research on EPAs, milestones, p. 22) are, in themselves, partial assessments of the effectiveness of CBE in particular when those assessments use the rate of medical errors, level of professional competencies measured in clinical situations, and patients' clinical outcomes compared with recognized standards. Also, some research in medicine using ML or CBP and some studies using deliberate practice, all pedagogical approaches with affinities with CBE, sometimes expose data that can shed, to some degree, useful light on possible effectiveness. When research in these areas presents results illustrating a significant decline in adverse events, the demonstration of those approaches in medical education becomes particularly eloquent, justifying more extensive experimentation. Nevertheless, measuring the effects of ML, CBP, and deliberate practice on the performance of a procedure does not imply that residency based entirely on ML, CBP or deliberate practice would obtain the same results, *nor even* that the application of those approaches across the board is achievable. Measuring one element of training, a medical procedure, or an EPA and its milestones is not the equivalent of assessing CBE in a medical specialty spread over several years and comprising different types of EPAs and milestones.

 ISBN : 978-2-923805-73-3

Nonetheless, it may be supposed that the systematic accumulation of studies on EPAs and milestones in each medical specialty could be one of the *partial* indicators of the overall effect of CBE, if resident doctors' knowledge and skills are measured, along with clinical effects on patients. On the other hand, such an approach remains incomplete and inadequate if it does not embrace, fairly quickly, measurement of the effects of a broader content over one year and, eventually, over the entire duration of training to access certification. For the moment, some research looking at several medical specialties seems to indicate that mastery of some EPAs and milestones under CBE can lead to an increase in certain skills and competencies in resident physicians (Bartlett et al., 2015; Beeson et al., 2015; Hamstra et al., 2021; Hauer et al., 2016; Hauer et al., 2018; Holmboe et al., 2020; Osborn et al., 2021).

On the other hand, the sky is not uniformly blue. Deficiencies have been identified in the development of EPAs and their milestones. Studies tend to reveal that in some programs and some specialties, there are EPAs and milestones with irrelevant content, and missing elements or medical procedures that should be included and are not (Bahji et al., 2021; Holmboe et al., 2020; Schott et al., 2015; Tanaka et al., 2021; Warm et al., 2016).

Similarly, in the area of indirect analysis of the potential effectiveness of CBE, the narrative review of literature in Orthopedic Surgery by Myers et al. (2022), looking at the joint use of CBE with simulators (low- and high-technology) and competency-based progression (CBP) to some extent supports the use of CBE with CBP in that specialty. The literature review by McGaghie et al. (2021) on ML and deliberate practice obliquely supports CBE insofar as, once again, the means put in place to develop the targeted competencies tie in with a framework similar or identical to ML and deliberate practice. That said, there remains the question of generalization: Can the data observed in Orthopedic Surgery be generalized, for instance, to the Orthopedics, Neurosurgery, and Psychiatry programs as a whole? One can envisage CBE being relatively effective in Orthopedic Surgery, not very effective in Neurosurgery, and totally ineffective in Psychiatry. Theoretically, anything is possible.

In the remainder of this section, we will above all be looking at studies that lay some claim to evaluating considerable parts of CBE or CBE as a whole in the medical field.[44] A number of studies described in the segment on EPAs (p. 22), deliberate practice (p. 28), and ML (p. 32) could have appeared in the next segment, and vice versa.

39.0 Overview of research on RCPSC CBE

Some research was carried out at the start of the RCPSC's experimentation with CBE. This research, in Orthopedic Surgery, seems to be behind the generalization of CBE to all medical residency programs aside from Family Medicine[45] in Canada, including Québec.

39.1 Studies by Ferguson et al. (2013) and Nousiainen et al. (2018) concerning implementation of RCPSC CBE

Only two papers have been published concerning the implementation of CBE in Canada.[46] These were the only papers that present quantified results, and not theoretical analyses or merely measurements of perception of RCPSC CBE.[47] Ferguson et al. (2013) and Nousiainen et al. (2018) looked at the trials of CBE carried out in Orthopedics, at the University of Toronto. The first experiments involved a *pure* version of CBE, inasmuch as the duration of residency was in no way predetermined by a time frame (Ferguson et al., 2013; Nousiainen et al., 2018). As a result, resident doctors in Orthopedics could complete their residency more or less quickly, in line with the pace at which they mastered the EPAs under RCPSC CBE.

39.2 RCPSC CBE experiments from 2009 to 2015

The results in *Table 2* (next page) provide a partial view of the situation, and that is clear from the first glance, owing to the lack of data, which were not published or simply do not exist.

The results show (*Incomplete totals*) that 49% of residents completed their training in four years, 37% in five years, and 11% abandoned their residency before completing it.[48] With respect to abandonment by resident physicians

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

in conventional residency, no data were provided that would have allowed for a comparison concerning that element with CBE. The number of residents in traditional residency was mentioned only for the 2009-2010 trial (N = 9). On the other hand, in 2014-2015, there could be no resident doctors in conventional residency, because all residents starting in Orthopedic Surgery in Toronto were then included in CBE.

The total number of resident doctors in the experiments for which we have some information is 44—a limited sample.

Table 2
Presentation of data available on RCPSC CBE experiments in Orthopedics from 2009 to 2015 (Ferguson et al., 2013; Nousiainen et al., 2018)

Cohort of residents in RCPSC pilots	Number of residents trained with CBE (Experimental group)	Total number of residents trained in traditional residency (Control group)	Number of residents trained with CBE having completed training in 4 years	Number of residents trained with CBE having completed training in 5 years	Abandoned/suspended residency in CBE (Experimental group)
2009-2010	3	9	2 (67 %)	0	1 (33 %)
2010-2011	11	ND	6 (55 %)	4 (36 %)	ND[a]
2011-2012	ND	ND	ND	ND	ND
2012-2013	ND	ND	ND	ND	ND
2013-2014	12	ND	5 (42 %)	4 (33 %)	3 (425 %)
2014-2015	9	NA*	4 (44 %)	5 (56 %)	0
Incomplete totals*	35	9	17 (49 %)	13 (37 %)	4 (11 %)

ND = No data available; ND[a] = No data for one candidate; NA* = Not applicable because there could not be a control group; Incomplete totals = Totals presented are incomplete since numerous data are not available.

The first experiment in 2009-2010 consisted of three resident doctors in RCPSC CBE selected out of the 12 accepted in Orthopedic Surgery at the University of Toronto (Nousiainen et al., 2018), with the control group therefore comprising nine residents (in traditional residency). The candidates had to apply to be accepted in the program using CBE in Orthopedics, possibly until 2012-2013. The rules for acceptance were not set out in the two articles concerned. This selection poses a problem, because the performance of resident doctors under CBE might potentially be attributable to the selection bias at the outset. Were the residents selected the most proactive or those most motivated with regard to their learning, with the best prior performance on several academic and clinical measurements? This question cannot be answered with the data available. Alman et al. (2013) and Ferguson et al. (2013) mentioned the possibility that this bias could undermine the results observed.

Of the three residents in 2009-2010, two completed residency in four years, while the third put his residency on hold to undertake other studies (Nousiainen et al., 2018). In the 2010-2011 experiment, according to our

 ISBN : 978-2-923805-73-3

recompilation of the data, since no table clearly presents these results in either article, of the 11 resident doctors enrolled in the CBE program, six completed it in four years, and four in five years. For 2011-2012 and 2012-2013, the data were not shared in the articles consulted, with no reason given. Were the experiments suspended?

That is unlikely, but no explanation was provided for this sidelining in any of the many studies we consulted, published between 2009 and today, concerning RCPSC CBE.

The 2013-2014 experiment was conducted with a hybrid implementation of CBE, an approach where mastery of competencies is central, but combined with more traditional time-based milestones—which is the current CBE formula in Canada and Québec. Of the 12 resident doctors, five[49] competed the program in four years, four should complete it in five years, and three put their residency on hold to undertake other studies. For 2014-2015, of the nine resident physicians in Orthopedics, four were expected to complete their residency in four years, and five in five years (Nousiainen et al., 2018).

39.3 Abandonment or suspension of residency

The abandonment or suspension of residency by four resident doctors under CBE between 2009 and 2015, according to our recompilation of the data, is not given much of an explanation (Nousiainen et al., 2018). The authors mentioned that those residents had undertaken to do a Master's or PhD in another scientific field. Did they suspend their residency because they were heading for a failure? Was it a personal decision or their response to an invitation from those responsible for their training? The motivation behind their abandonment is important information. Also, is the suspension or abandonment rate higher than the usual average in conventional residency? Unfortunately, there is no data to help us answer those questions.

39.4 Is learning more quickly necessarily an advantage?

Ferguson et al. (2013), Nousiainen et al. (2018), and the RCPSC (2014) seem to feel that a residency of shorter duration could be proof of the effectiveness of RCPSC CBE. Moreover, Ferguson et al. (2013) and Nousiainen et al. (2018) essentially present only data concerning the duration of resident doctors' training to demonstrate the value of RCPSC CBE.

Nonetheless, a shortened residency is not necessarily an undeniable asset for learning, even if it is carried out in line with competency quality criteria (Wear, 2009), in view of what we know of, among other things, the development of expertise from deliberate practice.[50] Development of high-level expertise involves many hours of practice (± 10,000 hours), accompanied by feedback and close supervision (Ericsson, 2008, 2015; Ericsson, Krampe and Tesch-Römer, 1993; 16.0 Deliberate practice, p. 28). We also know that this expertise is not permanent, and can erode in certain circumstances, such as when there is a decrease in practice or a practice out of colleagues' sight (Ericsson, 2004, 2015; Lockyer et al., 2017a). In that context, it is plausible that shorter exercising time, even when high quality criteria are met, might make the expertise more fragile over time. Is that actually the case? We do not know. The only way to know for sure would be to conduct rigorous experimental and longitudinal research on the subject.

Some say that learning more quickly in medical residency could apparently have financial benefits for society, since medical training in surgery costs more than $100,000 per year per resident (Ferguson et al., 2013; van Rossum et al., 2018). That claim is debunked by van Rossum et al. (2018). While the monetary benefits for resident doctors are very clear, their pay is multiplied threefold or fourfold (or more) once they are certified, and van Rossum et al. (2018)[51] estimate that this remuneration largely wipes out the $100,000 in savings generated by reducing resident physicians' residency training.

39.5 What is not measured in the Canadian experiments

Table 2 shows the lack of formal assessments of resident doctors' knowledge under CBE and in conventional residency, even if the introduction of CBE is intended, among other things, to improve this area. Similarly, neither professional skills nor patient outcomes are measured and explicitly shared, despite the fact that the creation and implementation of RCPSC CBE was motivated primarily by those aspects (RCPSC, 2014; Frank et al., 2017).[52]

 ISBN : 978-2-923805-73-3

39.6 Level of satisfaction and Hawthorne effect

In the studies by Ferguson et al. (2013) and Nousiainen et al. (2018), the level of satisfaction of resident doctors participating in CBE was advanced as an argument for the effectiveness of RCPSC CBE, without presenting it in any detail. While we agree that the satisfaction of those receiving services or training is significant, and will look at this ourselves below (43.0 Perception of RCPSC CBE by Québec's resident doctors, p. 52), it cannot be a demonstration of the effectiveness or even the quality of the services received. Moreover, the Treasury Board of Canada (1998) points out, talking about the evaluation of government and other programs, that "[this design entails] *asking participants if they "liked" the program. Grateful testimonials are offered as evidence of the program's success. Campbell, among others, criticizes this common evaluation approach.* (…) [this design owes] *its popularity in part to a poorly thought-out evaluation*" (p. 52). In the same field of investigation, but on the *medical front*, patients' level of satisfaction does not appear to correlate with the objective outcomes of medical treatment or surgical operations (Lyu et al., 2013).

The Hawthorne effect in scientific research is well documented (Cook, 1962), and the mere fact of knowing one is taking part in research or benefitting from a *new* or *innovative* approach generally has a positive influence on our perception, even when the research generates few, neutral, or negative effects (Sedgwick and Greenwood, 2015).

39.7 Normative presentation of experimental or quasi-experimental research

Usually, the structure of an article reporting on experimental (or quasi-experimental) research has standard sections: theoretical context including presentation of problem, one or more research questions asked, or one or more hypotheses put forward, description of methodology, description of measurement tools, presentation, analysis of results, discussion, and conclusion including limitations of findings submitted. The article by Ferguson et al. (2013) moved considerably away from this structure for presenting experimental research in pedagogy or any other field. The article by Nousiainen et al. (2018) reported the results from several experiments, but they provided no more clarity in terms of the results and methodology of those experiments than the article by Ferguson et al. (2013).

The studies on RCPSC CBE at the University of Toronto can be described as *exploratory studies*. Moreover, Ferguson et al. (2013) called them *preliminary results*, while Nousiainen et al. (2018) named them *pilot studies*. In view of the crucial challenges underlying the application of RCPSC CBE in medical residency, these two exploratory studies should have led to much more robust studies in order to validate at least partially some of the components and some of the effects of RCPSC CBE.

Table 2 does not allow for comparison of the results for resident doctors under CBE and in conventional residency, on any measurement, but it does summarize the entire effort to demonstrate the effectiveness of RCPSC CBE publicly. This substantial weakness perhaps explains why, to flesh out the argument a little more, Ferguson et al. (2013) and Nousiainen et al. (2018) used the findings of Sonnadara et al. (2012).

39.8 Sonnadara et al. (2012)

The research by Sonnadara et al. (2012) indicated that first-year resident doctors under CBE manifest technical competencies comparable to fifth-year residents in conventional residency, and substantially better than the other first-year residents, also in conventional residency. Time to break out the bubbly? No. The snag is that the research by Sonnadara et al. (2012), based on a *limited sample of 18 resident physicians divided into three equal groups*, measured the effect of a Surgical Boot Camp in Orthopedic Surgery, and not directly the effect of RCPSC CBE.

This research compared a group of six first-year resident physicians (PGY-1s) in CBE, a group of six PGY-1 residents in traditional residency, and a group of six fifth-year (PGY-5) residents in traditional residency on their performance following an Orthopedic Surgical Boot Camp lasting less than one weekend. The fact that PGY-1s in CBE posted a performance comparable to PGY-5s in conventional residency and substantially better than PGY-1s in conventional residency may be attributable first to the selection bias for accessing CBE, more intense exercising of medical procedures scheduled from the start of residency under CBE, or a combination of CBE's selection bias and intense exercising. Sonnadara et al. (2012) concluded by recommending that the Boot Camp be introduced in residency with and without CBE.

 ISBN : 978-2-923805-73-3

Even if one were to conclude that the research by Sonnadara et al. (2012) demonstrates some degree of effectiveness in CBE in Orthopedics for a limited content (the Camp learning module is only a very small segment of the training in Orthopedic Surgery), the fact remains that the demonstration of this single study with such a limited sample is slim.

40.0
In short, research conducted specifically on RCPSC CBE

The research by Ferguson et al. (2013) and Nousiainen et al. (2018) are the only published experimental studies looking at the effects of CBE as applied in Canada, and they are limited to Orthopedic Surgery. Are Orthopedic Surgery, Pediatrics, Psychiatry, and Neurosurgery sufficiently comparable fields to infer that if CBE works in residency in one of these specialties, it will have the same impact in the other specialties? To judge by the research in general pedagogy dealing with the generalization and transfer of learning (Péladeau, Forget and Gagné, 2005), the answer would be: probably not. In medical pedagogy, some data concerning the transferability of learning (Norman et al., 2018) follows a tangent similar to general pedagogy.

The presentation of the data reported by Ferguson et al. (2013) and Nousiainen et al. (2018) is flawed. The methodology of those experiments is also weak. The results with resident doctors under CBE and in conventional residency are not presented or compared explicitly. The authors of these articles do not appear to us to be unaware of the limitations of their demonstration, since Ferguson and his colleagues go so far as to state: "Without question, we have not yet proved that a new model of orthopaedic training can work" (Ferguson et al., 2013, p. 5).

In conclusion, it is clear that the effectiveness of Canadian CBE (RCPSC CBE) was not demonstrated in Orthopedics or any of the medical specialties *before* it was applied to all residency training in all healthcare systems in Canada.[53]

What about research measuring the impact of CBE elsewhere in the world and in Canada after its implementation began to be widespread? The next section attempts to answer that question.

41.0
CBE applied to medical education around the world

Morcke, Dornan and Eika (2013), in a narrative review, looked at the origins, theoretical basis, and empirical evidence of the effects of CBE prior to access to medical residency. So this article does not concern residency, but can provide some potentially relevant information. Their review covered research published between 1999 and 2010. Of the eight studies selected, the measurements of effects concerned the results on knowledge tests, direct observations of performance in real or simulated situations, and self-assessment of performance and satisfaction. The overall data afford a hazy picture of the effects of CBE. These researchers felt, in light of their review, that CBE was adopted in medicine on the basis of very little evidence. They also considered that the applicability of CBE to the more complex aspects of clinical performance was not clear. Morcke, Dornan and Eika (2013) concluded[54] that despite the obvious attractions of CBE, research demonstrating its effects was sparse in undergraduate medical education.

The article by Weller, Naik and San Diego (2020) is a narrative review of 23 studies on CBE in Anesthesiology in relation to resident doctors in many countries. This research includes descriptive studies, analytical studies, experimental research, and literature reviews from the United States (7), Australia and New Zealand (5), the Netherlands (3), Canada (2),[55] the United Kingdom (2), France (1), Denmark (1), Switzerland (1), and Ireland (1). The authors noted that no study measured the impact of CBE as a whole. The studies focus on certain segments of CBE. The authors cited, among others, the review by Bisgaard et al. (2018) on CBE and ML in Anesthesiology, demonstrating an improvement in procedural competencies in Anesthesia, better retention of

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skills, and enhancement of clinical outcomes. It should, however, be remembered that the review by Bisgaard his colleagues provided greater support for ML than for CBE (23.0 Overview of research on mastery learning in medical education, p. 32). They also mentioned the research by Weil et al. (2017) on the learning curve[56] for tracheal punctures for jet ventilation, thoracic epidural analgesia procedures, and fibreoptic nasal intubations performed by 18 French resident physicians. Weil his colleagues noted that only a few residents achieved the anticipated level of competency in these procedures within the learning time allowed. The residents in this study were aiming for a high level of mastery of the procedures studied—this dovetails with CBE, without any explicit mention being made that their residency was being carried out wholly within such a pedagogical framework. Weller, Naik and San Diego (2020) stated that they had found few studies in Anesthesiology where it was possible to gauge the effects of CBE in that specialty and to indicate best practices.

Imanipour et al. (2022), whom we have previously cited, conducted a meta-analysis on the effects of CBE with subjects who were physicians, resident doctors, and nursing students. The meta-analysis included experimental or quasi-experimental trials, four of them conducted in Iran, one in Israel, one in China, two in Taiwan, and one in the United States (nine studies in all). The research compared CBE to conventional pedagogy, the dependent variable measured being participants' clinical performance. Three studies concerned physicians and resident doctors, and the other six involved nursing students. The standard mean deviation on clinical performance measurements was 1.074. On the other hand, three out of nine studies posted non-significant results ($p > 0.10$), and the Iranian trials presented standard differences in means ranging from 1.327 to 3.216, clearly atypical figures higher than in the studies conducted in other countries. The researchers had no explanation for this phenomenon. Moreover, they emphasized that their body of research revealed very high heterogeneity that was statistically significant ($p < 0.001$). This heterogeneity essentially came from the Iranian studies, but there was no significant difference in the Iranian studies between the studies in nursing and those in medicine. A meta-regression analysis of research findings indicated that the effect of CBE was declining with recent publications: the more recent the studies, the lower the mean size effect. Since this meta-analysis brings to light some striking results, we will take the time to analyse it in a little more detail.

An important element in designing a meta-analysis in pedagogy (Bissonnette and Boyer, 2021; Cheung and Slavin, 2016) is the time frame of the experiments, which have as far as possible to approximate a time frame comparable to the reality of the learning or practice in the field concerned. In the article by Imanipour et al. (2021), entitled "The effect of competency-based education on clinical performance of health care providers: A systematic review and meta-analysis," the experiments lasted from 2 to 3,699 hours, and three studies out of nine lasted less than 20 hours. Claiming to provide an overview of the general effect of CBE on the learning of resident doctors or nursing students on the basis of studies so far from the time-based reality of the learning involved is a risky business.

Only three research studies out of nine have a considerable time frame (Castel et al., 2011; Fan et al., 2015; Wu et al., 2014), totalling 324 hours, 126 hours, and 3,699 hours respectively, with Russian doctors requalifying in the West for the first study, and nursing students for the other two. Two of these studies (Castel et al., 2011; Wu et al., 2014) obtained results favourable to CBE, but not statistically significant ($p > 0.10$). The mean size effect of these three studies is 0.25, a far cry from the 1.074 calculated by Imanipour et al. (2022). This brief analysis and the heterogeneity of the studies (see on the latter aspect: Buteau and Goldberg, 2015; Wang et al., 2021) undermine the conclusions presented in that meta-analysis.

Danilovich et al. (2021) looked at CBE in family medicine in residency and continuing education. It should be noted that CBE applied to family medicine in Canada and Québec is different from CBE used in the other medical specialties. For instance, CBE in family medicine, known as *Triple-C*, uses, among other things, the concept of *key competencies* rather than EPAs to describe the professional competencies to be acquired.

Danilovich et al. (2021) conducted a narrative review of a selection of 37 studies published between 2000 and 2020 measuring the effects of CBE on various variables. Of the studies, 43% (16/37) were produced in Canada, 62% (23/37) concerned resident doctors, 8% continuing education, 30% (11/37; mixed studies) continuing education and resident physicians. By contrast,

 ISBN : 978-2-923805-73-3

only 32% (12/37) can be classified as quantitative research, as 68% (25/37) of the studies selected essentially involved qualitative research, reviews, reflections, and editorials. Danilovich his colleagues noted the scarcity of reliable quantitative data and the total lack of research assessing the effects of CBE on, among other things, patient outcomes. The authors mentioned that there was a gap between medical faculty professors' skills and what CBE demands of them, as had been pointed out 10 years earlier by Holmboe et al. (2011) for medical trainers in the USA and Canada. Danilovich and his colleagues also noted the lack of studies, follow-up, and links among medical studies, residency, and continuing education.

Although the qualitative review by Danilovich et al. (2021) in family medicine shed little light on the effects of RCPSC CBE, it shows us that the weakness of the scientific research is not limited in Canada only to RCPSC CBE.

The narrative review by Brydges et al. (2021) aimed to conduct a critical review of the available evidence from the application of CBE in more than 20 medical specialties, including, among others, medical students, residents, physicians, dentists, dentistry students, and nursing students. Of the 189 studies selected, 37% (69/189) measured performance in a clinical context, 80% (152/189) were quantitative studies, and 5% (9/189) used a dual method of research (both quantitative and qualitative). Only a small subset of the studies selected, 4% (8/189), measured the effect of CBE on patient care. The high percentage of *quantitative research* (80%) estimated by the authors may imply that this meta-analysis unearthed numerous experimental and quasi-experimental studies, but that was not the case: we calculate that only 21% (40/189) of their research base consisted of experimental or quasi-experimental studies.

The review by Brydges et al. (2021) extracted from those 189 studies a number of hypotheses underlying CBE concerning aspirations (what the implementation of CBE seeks to produce), conceptualization (what defines and characterizes a competency), and competency assessment practices. Brydges and his colleagues considered that, for the 15 central hypotheses underlying CBE, the evidence base was substantial, but that the results were somewhat mixed. While acknowledging that the state of research can be seen as disappointing and likely to fuel criticisms of CBE in medicine, the authors suggested that, in a somewhat optimistic perspective that clashes with the quality and strength of the data supporting the core principles of CBE, it should be seen instead as an opportunity to right the boat and move towards producing clarifying studies to establish *how* and *why* CBE *works*!

The authors of this review stated that the researchers who produced the selected studies predominantly used quantitative research methods. According to the authors, taking up a discourse popular among constructivists, such a propensity to favour quantitative studies would have the effect of restricting the scope of the research questions and would limit the diversity of the evidence available to enable the medical community to understand CBE and guide its implementation. According to Brydges et al. (2021), what is needed is to produce more qualitative studies and mixed methods to help understand why, how, and where CBE works best. Amazing.

Brydges et al.'s own data do not prove the effectiveness of CBE in medical education at all. For instance, according to our estimates,[57] 17% (2/12) of their results support assumption #1: *"Competency-based medical education in medical education is more efficient"*; 20% (3/15) of their results support assumption #2: *"Competency-based medical education training guarantees trainees are ready for practice, regardless of their eventual clinical context"*; 18% (6/34) of their results support assumption #3: *"Competency-based medical education frameworks are inherently clear and intuitive"*; but, paradoxically, 78% (7/9) of their results nonetheless support assumption #4: *"Competency-based medical education training improves patient care."* The marbled scene the authors present is therefore not one of great clarity or robustness, and this fact should temper any lyrical momentum.

The simple analysis of these results does not allow us to declare that CBE is effective. At most, we can suggest that the effect of CBE on patient care appears to be positive, but without altering the subjects' clinical skills (assumptions #1 and #2), which is nonsense. At least a partial confirmation of assumptions #1, #2, and #4 would have been needed for us to be able to say anything positive about CBE overall. If these three assumptions were to be invalidated, the implementation of CBE would totally lose its justification. So it is surprising that Brydges and his colleagues considered there to be a lack of qualitative research, which usually looks

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at the how and why of CBE, *before* having an objective demonstration that CBE is effective in relation to developing physicians' professional competencies and enhancing patient care.

A number of researchers acknowledge that scientific research on CBE applied to medical education, despite its rapid spread, is very limited (Gruppen et al., 2017). The proof of the effect of CBE will, or will not, come from experimental, quasi-experimental, and longitudinal research. CBE in medical pedagogy definitely needs numerous experimental and quasi-experimental studies on the enhancement of physicians' professional competencies and patient care. Without those data, all the noise around CBE is nothing but *idle distraction*.

42.0
Is CBE in medical residency evidence-based?

Numerous authors and researchers in medical education mentioned as early as the late 20th century that the introduction of CBE in medicine was occurring without being supported by any evidence warranting it. We can state that this is still the case in 2022. The available evidence is scattered and quite inadequate for CBE in medical residency to be considered scientifically and solidly supported. The relevance of RCPSC CBE has yet to be demonstrated.

Similarly, it is astonishing that RCPSC CBE applied to medical residency never led to even a minimal demonstration of its effectiveness *before* it was implemented across Canada.

At the very start of this text, we wondered whether the pedagogical changes being made by the medical world are supported by evidence *to the same extent* as their professional actions are in their practice. Our answer is obviously a negative one. Curiously, the medical world does not apply the same rigour in choosing and monitoring the pedagogical methods it applies in medical pedagogy as for the advancement of knowledge and delivery of medical treatments.[58]

Fields of research parallel or close to CBE seem promising, such as *mastery learning*, *deliberate practice*, and *competency-based progression*. Other complementary fields, such as *technology-enhanced simulation* and *standardized patients*, also offer possibilities of effectiveness, but that has yet to be demonstrated.

To date, we have focussed on the scientific validity of CBE. One important aspect of the implementation of a pedagogical approach remains to be explored, although it is not a determinant with respect to demonstrating the effectiveness of the approach: the perception of those experiencing this new approach on the front lines, namely, resident physicians.

A pedagogical approach appreciated by the learners which generates positive feelings in them but does not foster their learning and development is of no use. A pedagogical approach not appreciated by the learners which generates negative feelings in them, but fosters their learning and development is an approach that is bound eventually to fail, not to mention the psychosocial cost for the learners. Therefore, we will now look at measurements of resident physicians' perception of RCPSC CBE in Québec, as gathered and submitted by the *Fédération des médecins résidents du Québec* (FMRQ).

 ISBN : 978-2-923805-73-3

43.0
Perception of RCPSC CBE by Québec's resident doctors

The RCPSC's CBE program began to be implemented in Québec resident physicians' training in 2017. Since then, the FMRQ has conducted four surveys of resident doctors enrolled in RCPSC CBE[59] in order to gauge their perceptions. To our knowledge, *the FMRQ was the only body in Canada* to have, on the one hand, directly measured resident doctors' perceptions before 2022 and, on the other hand, to have published its observations and recommendations. Unfortunately, those reports did not garner the readership they deserved.

43.1. First FMRQ survey (2018)

In 2018, the FMRQ carried out the first survey on 26 resident doctors out of 32[60] (81%) in the first year of residency, in the two specialties (Anesthesiology and ENT/Head and Neck Surgery) that had introduced RCPSC CBE. The residents met by the FMRQ took part in semi-structured interviews. The report produced by the FMRQ (2018) revealed in some extracts from the discussion section that some annoyance was generated from the outset by the implementation of RCPSC CBE:

[...] residents [...] do not wish to terminate their residency before the time previously required, either—a possibility dangled before them by some people—but [...] are instead fearful of being incapable of ticking off all the EPAs and milestones required without having to prolong their residency unduly. (p. 13)

[It] is important to emphasize once again the high level of anxiety experienced by residents following implementation of [RCPSC CBE].[61] *They acknowledged the virtues of this new approach, which fosters learners' involvement in their own professional path. But they reported a lack of administrative and educational support in training sites for ensuring the completion of EPAs. In addition, programs' and staff physicians' lack of sensitivity with regard to learners' increased pedagogical responsibilities is hard to go through on a daily basis.* (p. 14)

FMRQ (2018) also raised some questions:

Did the Royal College trigger the process too quickly? Did the medical faculties take the prior steps needed to implement [RCPSC CBE] in their training sites? Have staff physicians and supervisors taken the true measure of the change? (p. 14)

Following these interviews and the observations arising from them, the FMRQ (2018) made 15 recommendations for enhancing and facilitating implementation of RCPSC CBE.

We present some of them below:

Quality information concerning [CBE] should be provided to medical students before they begin residency.

Training for residents concerning [CBE] should be given before residency begins or at the latest in the first week of residency.

All teaching faculty called upon to provide feedback on EPAs, during both discipline-specific and off-service rotations, should receive prior and ongoing training. Supervisors' participation in such training should be documented and mandatory.

The number of EPAs, milestones, and observations required under [CBE] must make allowances for practical constraints in the different training sites.

The evaluation criteria for EPAs and milestones should be clearly set out.

Appropriate, regularly updated information systems infrastructure should support EPA evaluation and monitoring.

The medical faculties and the programs should be aware of the additional workload and stress that [RCPSC CBE] brings. To that end, resource persons should be available as required. (FMRQ, 2018, pp. 15-17)

43.2 Second FMRQ survey (2019)

In 2019, the FMRQ conducted a second survey to measure implementation of CBE, taking into account the recommendations it had made in its report released the previous year. In view of the larger number of resident physicians being trained under RCPSC CBE, a questionnaire was produced by the FMRQ and admin-

 ISBN : 978-2-923805-73-3

istered to all residents in each of the programs concerned. As the FMRQ points out, the questionnaire was developed to reflect the main recommendations made in the 2018 report. The questionnaire comprised some 60 questions, including 12 extended-answer questions. The questionnaire was administered after seven months of exposure to CBE for the resident doctors in the programs concerned in 2018-2019, and after 19 months for those who began their training in July 2017.

The resident doctors, including clinical fellows, from all programs under CBE for 2018-2019 and all Québec medical faculties, were invited to answer the questionnaire electronically (N = 173). The CBE programs targeted by the survey were: Anesthesiology and ENT/Head and Neck Surgery (Cohorts 1 and 2), and for 2018-2019 (Cohort 2), residents physicians in Critical Care Medicine, Forensic Pathology, Medical Oncology, Nephrology, Surgical Foundations, and Urology. The response rate to the questionnaire was 67% (116/173), or 85% of Cohort 1 (2017-2018) and 63% of Cohort 2 (2018-2019).

This second report produced by the FMRQ (2019), entitled Implementation of Competence by Design in Québec — Year 2: Ongoing Issues once again raised a number of problems associated with the implementation of programs using RCPSC CBE.

It should be noted that 49% of resident doctors considered training of faculty members in their specialty [who should be providing feedback on their EPAs] to be inadequate or very inadequate [...]; (p. 4)

Resident doctors reported the same difficulties as last year in obtaining daily evaluations. (p. 6)

The rules governing decisions concerning promotion of resident doctors from one stage to another within the framework of the [RCPSC CBE] competence curriculum are unclear or completely unclear for 61% of respondents; (p. 7)

Resident doctors noted a considerable increase in the red tape associated with implementation of [CBE], and distress levels have increased accordingly: 93% of respondents in Cohort 1 reported experiencing duplication of evaluation methods in their learning sites, compared with 57% of resident doctors in Cohort 2; (p. 10)

Furthermore, several comments were made as to the excessive number and the complexity of EPAs and milestones. Resident doctors said they were dissatisfied, and even disheartened, by the number of EPAs, milestones, and observations to be attained; (p. 12)

When we asked resident doctors to rate their level of satisfaction with [RCPSC CBE] on a scale from 1 to 10 (1 representing the lowest and 10 the highest satisfaction level), we obtained a weighted average of 4.1 (3.7 for Cohort 1, 4.2 for Cohort 2); (p. 15)

As we mentioned earlier, the responsibility inherent in completing EPAs is left to resident doctors, who have to identify their own learning opportunities and find supervising physicians who are ready to carry out the observations and complete an EPA evaluation form. In the current context, this represents a demanding additional task for many resident doctors, who generally do not manage to obtain enough direct or indirect observations to complete the requirements for each EPA. Even when resident doctors are successful in obtaining direct observations, the feedback is often not up to their expectations; (p. 15)

Several reported that [CBE] is *"the most stressful element in their residency." Others regret performing their residency in a program under [CBE], or are bitter at being guinea pigs for a training and evaluation system that was implemented too quickly, requiring a great deal of improvisation by both the faculties and the Royal College in the implementation phase.* (p. 16)

The FMRQ (2019) concluded as follows:

The application of [RCPSC CBE] in Québec in 2018-2019 remains problematic in many respects (…). A number of improvements were noted in our survey compared with Year 1 of [CBE], particularly as regards resident doctors' preparation at the start of training, and the number of EPAs and milestones. Nonetheless, much remains to be done before we can claim that [CBE] has been implemented at all successfully. (p. 17)

The FMRQ (2019) also noted: *"We cannot neglect to mention here that, last year, voices were raised across Canada daring to propose a moratorium on implementation of [RCPSC CBE]."* (p. 18) Rumour has it that these criticisms came from the medical faculties.

The FMRQ (2019) stressed that:

 ISBN : 978-2-923805-73-3

This state of improvisation may leave an unfortunate impression that the instigators of this reform of postgraduate medical education methods appear to favour rapid, sustained implementation to the detriment of better planned implementation with the best chance of success. (p. 18)

The FMRQ (2019) ended its second report with a recommendation that the RCPSC introduce a rigorous mechanism for implementation of CBE.

43.3 Third FMRQ survey (2020)

The FMRQ carried out a third survey in 2020 on all resident physicians who began in July 2019 in a program based on RCPSC CBE. Once again, an electronic questionnaire was sent to those residents, to gauge the impact of implementation of CBE. Also, the FMRQ (2020) set up discussion groups with resident doctors midway through their postgraduate education in the first specialties where CBE was applied. It should be emphasized that the survey, conducted via questionnaire and discussion groups, was completed before the COVID-19 pandemic broke out in Québec.

The questionnaire, targeting resident physicians who had started residency under CBE, comprised some 40 questions, including six extended-answer questions. This questionnaire was completed after seven months of exposure to CBE for residents starting their residency under CBE, at the same time as the one administered the previous year.

A total of 358 resident doctors having recently started under CBE in July 2019 were asked to complete the questionnaire. The participation rate was 45% (161/358), with a margin of error of 5.7%, 19 times out of 20. Thirty-two resident physicians in Anesthesiology and ENT/Head and Neck Surgery who had started under CBE in July 2017 were contacted, and 20 (63%) of them agreed to take part in discussion groups.

The FMRQ (2020) report raised numerous problems, most of which are recurrent, with the implementation of RCPSC CBE. Added to these observations were more specific effects on resident doctors' health, as follows:

The overall perception of [CBE] is mainly negative.

It's a good theoretical model, but hard to apply in practice.

[RCPSC CBE] as currently applied is described as futile.

In theory, there are more opportunities for feedback, but according to respondents this feedback is still of poor quality.

Resident doctors see little added pedagogical value, for a much heavier workload and cognitive load.

All resident doctors have the impression of carrying out two parallel residencies, one applied to reality and the other in line with the artificial requirements associated with [RCPSC CBE].

Some even believe they will be less well trained than their non-[CBE] colleagues. (p. 19)

In this third survey, the FMRQ (2020) asked questions about mental health, drawing on a survey conducted by the Canadian Medical Association (CMA) in 2019 on resident doctors starting under RCPSC CBE.

The FMRQ (2020) mentioned that:

Resident doctors express a great deal of distress with respect to their experience with [RCPSC CBE].

They report numerous symptoms of exhaustion, insensitivity, and anxiety.

2/3 [67%] of them say they are disheartened by the administrative burden involved in [CBE].

39% of resident doctors present signs of depression.

Several resident doctors are concerned that [CBE] can prolong the duration of their residency. (p. 18)

In the CMA (2018) survey, 38% of Canadian resident doctors reported a high level of burnout. In the FMRQ (2020) survey, the rate on the burnout question was 42%. The CMA poll presented other findings on Canadian resident physicians' mental health (Depression/Screening, Suicidal ideation [lifetime and in the last 12 months]), but we find the data provided on this subject by the FMRQ to be insufficient for comparison purposes.

The thesis by van Vendeloo (2021) concerning the effects of CBE in the Netherlands demonstrated the existence of a link between resident doctors' burnout and supervising physicians' behaviours. Supervisors effectively overseeing residents by giving them a great deal of meaningful feedback and adapting tasks to residents' level of competency

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have a positive impact on residents' well-being.

Unfortunately, one must remember that resident doctors in Québec report rather poor-quality feedback. So there may be a link between that data and the fact that 67% of resident physicians perceive the task to be onerous, and 39% of them show signs of depression—although the existence of such a link should be verified rigorously. The study by Mion, Journois and Libert (2018), however, indicates links between burnout and depression in American Anesthetists. Also, the systematic literature review conducted by Pereira-Lima et al. (2018) shows links between doctors' symptoms of depression and high risk of medical errors. As a result, we find it imperative that resident physicians' medical health be measured and taken care of, particularly when a pedagogical paradigm switch is occurring in residency.

The FMRQ (2020) concluded as follows:

I*n short, it has to be acknowledged that the introduction of [RCPSC CBE] in Québec remains problematic three years after the Canada-wide transition by the first two programs […].*

We note especially that the understanding and application of all these theoretical concepts remain completely different from one university, program, training site, and supervising physician to another. A great deal of work also remains to be done with respect to the [CBE] assessment and progression process.

Also, most resident doctors noted that the number of observations required per EPA was still excessive. Several questioned, too, the match between EPAs and the reality of their practice in their specialty, and that is a matter for some concern. [...]

According to the survey and our discussion groups, [...] direct feedback actually completed is infrequent, and when it does happen, it takes considerable effort from resident doctors to obtain it. Furthermore, quality feedback that really makes a difference for their learning is extremely rare, particularly since the EPA format leaves little room for constructive comments. (p. 21)

The FMRQ (2020) identified two worrisome trends that started to be seen from the very outset of implementation of RCPSC CBE:

The first trend is the perversion of the fundamental concepts of [CBE] to the detriment of resident doctors, and the appearance of performance-related language in discussions concerning this approach. Resident doctors increasingly perceive their list of EPAs as a checklist to be completed as quickly as possible. They feel to be in competition with one another, and develop strategies to check off all their EPAs as efficiently as possible, particularly by identifying supervising physicians most likely to have them pass an EPA without asking too many questions. [...]

When resident doctors say they have the impression of missing out on clinical experiences really relevant to their learning and their future careers or not having the time to study and prepare their clinical cases, because they are too busy reviewing their EPA list, planning how best to have them completed, and chasing after supervising physicians to have them fill them out, this is just as worrying. [...]

The second trend, as discussed in our previous reports and confirmed again this year, is the appearance of an extremely high level of stress, anxiety, and exhaustion with the higher cognitive load that the introduction of [RCPSC CBE] in residency programs entails. [...]

Finally, the danger is high that resident doctors will simply become cynical toward [CBE] when one sees the mismatch between the considerable effort put in by everyone since [CBE] was introduced and the meagre benefits arising from it. The general impression can apparently be summarized in a lack of gains on the pedagogical front, as if the application of [CBE] by the programs runs completely contrary to the philosophy of the theoretical model developed by the Royal College. (pp. 22-23)

Statements made in FMRQ (2020) show a considerable gap between the supposed virtues of programs based on RCPSC CBE and their implementation and the effects perceived by resident doctors. *"For the moment, the implementation model is neither up to the promises nor even a pedagogical advance; rather, it represents a step backward, particularly as regards resident doctors' wellness."* (p. 23)

The FMRQ (2020) ended its report with the following words: "It has to be acknowledged now that a significant course correction effort is [nonetheless] needed for what could well be a ship adrift." (p. 23)

The recommendations of this third report are comparable to those of the previous years.

 ISBN : 978-2-923805-73-3

43.4 Fourth FMRQ survey (2022a)

The FMRQ conducted its latest survey on resident doctors who began their residency in programs implementing RCPSC CBE in July 2020 and those midway through their training in March 2021. The FMRQ used the same questionnaire as the previous year, administering it at the same time of year to resident doctors who recently entered programs using CBE. For those midway through their program under CBE, a new questionnaire was drawn up, inspired by the questions used in the discussion groups with those midway through their residency the previous year.

Five hundred and twenty resident doctors newly trained in one of the specialties using RCPSC CBE in 2020-2021 were invited to complete an electronic questionnaire. The participation rate was 38.5% (200/520), with a margin of error of 5%, 19 times out of 20.

Below are some facts emerging from the FMRQ report (2022a) concerning the answers given to the first questionnaire.

We asked [resident doctors] about the number of EPAs, milestones, and observations required in each of the programs. No improvement is seen in this regard, since the majority of residents still find that the required number of milestones (58%), EPAs (59%), and observations per EPA (73%) is excessive. In fact, the proportion of resident physicians newly under [CBE] who find the required number of EPAs excessive has increased since last year (59% in 2021 vs 51% in 2020). (p. 9)

The proportion of residents stating that the EPAs and milestones specific to their specialty under [CBE] accurately reflected practice in their main training sites has not changed since last year: half (52%) of resident physicians said this was the case, much the same percentage as last year (49%). (p. 9)

A*lmost all survey respondents were assessed under [CBE], but 80% reported that the "traditional" assessment mode is still used, to offset the shortcomings of assessment under [RCPSC CBE].* (p. 11)

More than 60% of resident physicians only rarely or never receive feedback on their EPAs, a percentage that has held steady for three years. (p. 11)

The FMRQ (2022a) pointed out that resident physicians posted only a weak result of 5 out of 10 in their level of satisfaction with the feedback obtained on their EPAs. This could be attributable to the infrequent post-observation feedback they receive, as mentioned earlier. The FMRQ (2022a) also noted a significant increase in the red tape involved in implementation of CBE as reported by resident doctors.

The FMRQ once again questioned resident doctors about their mental health. Owing to the arrival of COVID-19, though, we believe it is hard to interpret these results, as they cannot be dissociated from the pandemic. An important element concerns the overall level of satisfaction with CBE. In that regard, the FMRQ (2022a) pointed out that:

On average, resident physicians newly under [CBE] rated their satisfaction level with [CBE] at 3.1 out of 10, one of the lowest scores observed since we began using that scale in our surveys and consultations (2018). (p. 13)

Another questionnaire was designed for resident doctors midway through their training in a program using RCPSC CBE. This questionnaire contained some 10 questions relating to the issues that emerged from the discussion groups on the third survey.

So 203 resident physicians[62] midway through their training in one of the CBE specialties in 2020-2021 were invited to complete this electronic questionnaire. The participation rate was 40.4% (82/203), with a margin of error of 8%, 19 times out of 20.

From the FMRQ (2022a) report, we present some important elements concerning the responses provided to this second questionnaire.

In short, 87.8% of resident doctors surveyed felt there were too many EPAs; 85.4% said there were too many milestones; and 86.6% said there were too many observations to be completed at this stage. (p. 14)

Concerning the number of EPAs, 81.5% of resident doctors said they *"spent their time running after EPAs to be completed," instead of taking advantage of all the learning opportunities residency offers. Also, 77.8% agreed that they would not have the time to complete all the EPAs by the end of their residency.* (p. 14)

 ISBN : 978-2-923805-73-3

(…) we asked whether residents agreed or disagreed that the more EPAs they did, the more feedback they received, and the more they learned. [...] 91.4% disagreed with the statement. (p. 15)

Worse still, all respondents (100%) said they completed EPAs solely because they were required to do so, but that in their view it made little difference in their preparation for exams, or their future practice. (p. 15)

(…) 92.6% (said) they rarely if ever have the chance, with their teaching physicians, to plan ahead for EPAs and milestones to be completed in a given period. Also, 87.7% said the wording of several EPAs was not designed to be really helpful on a day-to-day basis. Furthermore, 81.5% of respondents found it impossible to know all the EPAs by heart, so as to be able to recognize them and carry them out when the opportunity arose. Finally, 92.5% found it embarrassing, indeed downright awkward, to be constantly having to ask already overworked teaching physicians to "complete" EPA observations. (p. 15)

In addition, 83.8% of resident physicians said feedback from faculty was actually in the form of checklists, containing little by way of pedagogical pointers, and 93.8% said they were consequently still assessed under the model already in place before [CBE] was introduced. (p. 15)

Also, 71.3% [of resident physicians] admitted to tending to select faculty who have the reputation of filling out EPAs properly to complete their EPAs. (p. 15)

In the discussion, the FMRQ (2022a) made several observations that it is important to mention.

Despite targeted improvements with respect to familiarity with the theoretical aspects of [CBE], our resident doctors unfortunately drew a dismal profile of [CBE] in 2020-2021. The survey of those newly under [CBE] in 2020-2021 highlighted similar problems to the previous years, despite the growing experience of several programs which started out under [CBE] a few years ago. Also, the poll of resident physicians halfway through residency in [CBE] programs in 2020-2021 confirmed on every point what had emerged from discussions with residents halfway through residency under [CBE] in 2019-2020. (p. 17)

What is all the more deplorable about the implementation of [RCPSC CBE] is that it is largely failing in its pedagogical goals of improving feedback, and thereby resident doctors' training. Our data clearly indicated that residents are not consistently receiving quality feedback following EPA observations. (p. 18)

The FMRQ (2022a, p. 18) then asked a key question: "what use (is) the [RCPSC CBE] model (…) if it does not provide quality feedback and coaching?" Note that *improving the quantity and quality of feedback* is one of the arguments repeated to justify this new model of medical residency training.

The FMRQ (2022a) ended by stating that RCPSC CME was a failure.

What then can we say four years after its introduction about this learning model proposed by the RCPSC? Pedagogical benefits missing in action. Increased cognitive and emotional load. Detrimental effect on resident doctors' mental health and learning. Simply put, the current implementation model does not work. After all the effort and resources expended on implementing this system, then, we can only question the appropriateness of continuing with this model, which appears to offer no real, measurable pedagogical benefit. Implementation of [RCPSC CBE] appears to have been premature and incomplete, and the guinea pigs paying for these failures are our resident doctors. (p. 18)

The FMRQ (2022a) added: *"The fundamental problem, though, is the usefulness of having led our medical faculties to carry out a genuine revolution in how learners' progress at the postgraduate level is assessed, with no clear evidence of any pedagogical benefits."*

Finally, it addresses a strong criticism to the RCPSC:

Whereas the Royal College chose to launch its project hastily, even if it had to rectify the collateral negative impact along the way; this explains our members' highly legitimate impression of being the guinea pigs for a pedagogical experiment. In fact, the RCPSC's implementation strategy appears to target a "militant" approach, the strategy thus being to "push" the cultural change in training sites by all possible means, and as rapidly as possible.[63] *We are better able now to understand why we sense within the Royal College a resistance to any in-depth criticism of [CBE]. All this time, as we have tried to propose improvements in the model, we have instead in its main designers seen consistent attempts to counter our observations, rather than to take them on board.* (FMRQ, 2022a, p. 19)

 ISBN : 978-2-923805-73-3

43.5 Additional FMRQ survey (2022b)

The FMRQ conducted a comparative survey on 800 resident doctors whose findings will be published at a later date. But part of these results was presented in April 2022, at the Canadian Conference on Medical Education (FMRQ, 2022b). Entitled *Pedagogical interaction between staff physicians and Québec resident doctors: Myth and reality*, this report showed among other things that resident doctors trained with CBE perceive the quality of feedback received in their training sites more negatively than do their colleagues trained in conventional residency and those in family medicine in *Triple-C*-type CBE.

The outline below is based on three groups of 125 resident doctors each (RCPSC CBE; conventional residency; *Triple-C* CBE in family medicine). The differences observed between the groups are statistically significant.

Proportionally more resident physicians assessed under RCPSC CBE (55.3% versus 32% in conventional residency and 18.6% in Triple-C family medicine) said they had generally had to run after their staff physicians to have them observe, teach, or assess them. ($p < 0.001$)

The difference with respect to the availability of staff physicians is particularly marked between the groups, to the disadvantage of the RCPSC CBE group, who perceive that it is harder to have access to staff physicians for their training.

Of resident physicians under RCPSC CBE, 70.2% said they generally had the opportunity, for each rotation, to talk with their staff physicians and discuss with them the pedagogical objectives to be attained, while that figure rose to 82.4% for residents in conventional residency, and 85.9% for family medicine residents in Triple-C CBE. ($p < 0.05$)

The accessibility of staff physicians to discuss learning objectives appears to be greater in conventional residency and *Triple-C* CBE than under RCPSC CBE.

Of resident physicians under RCPSC CBE, 54.5% said that since the start of the academic year they had benefitted from the expertise of clinical instructors and their supervision and coaching, compared with 70.5% for residents in conventional residency, and 69.2% for family medicine residents in Triple-C CBE. ($p < 0.05$)

Resident doctors under RCPSC CBE felt they received much less support from clinical instructors than the other two resident groups.

These results overall tend to indicate that training under RCPSC CBE does not achieve, in the view of the resident physicians concerned, the pedagogical objectives concerning improvement in follow-up and feedback, despite the fact that, once again, the increase in and quality of feedback are fundamental arguments regularly advanced to justify the adoption of CBE in residency (RCPSC 2014; Harris et al., 2017; Holmboe, 2004; Holmboe et al., 2010; Ferguson et al., 2013; Ferguson et al., 2017; Lockyer et al., 2017b).

43.6 Foreword to What we should learn from the FMRQ reports

Reading the FMRQ reports in chronological order reveals some worrisome weaknesses in the application of a significant paradigm shift in residency, from the very first year of implementation of RCPSC CBE. The first report made proposals aimed at resolving the problems raised. The following reports largely repeated the same observations, while continuing to make pragmatic recommendations. Between the first report and the latest available report (2022), the flaws observed appear to have crystallized.

The FMRQ conducted surveys of its constituents from the start of implementation of RCPSC CBE. But it did not plan for measuring resident doctors' perceptions prior to implementation of CBE so as to have a basis for comparison. This weakness necessarily narrows the possible interpretations of what is observed. Similarly, from the beginning of implementation of CBE, it would have been helpful to measure perceptions of the quality of training held by different groups of resident physicians in Québec under and not under CBE, so as, once again, to have points of comparison. Fortunately, the FMRQ has carried out a first comparative study (FMRQ, 2022b).

We recommend that the *FMRQ and other bodies representing resident doctors in Canada* institute a yearly measurement of their members' perceptions as part of their organizations' ongoing activities. The objectives of this measurement should include resident physicians' perceptions concerning the learning framework, work (workload, functionality, quality of learning, feedback, support,

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etc.), and their psychological state (anxiety, depression, feeling of competency, and resilience). An annual campaign targeting members, directly explaining the importance of completing this questionnaire, should also be planned.

In Québec, we recommend that a public invitation be made to the main stakeholders in the healthcare world to read the report drafted yearly by the FMRQ, and that an annual meeting be convened so that those actors take note of the findings of the report and take any necessary action.

44.0
What we should learn from the implementation of RCPSC CBE in relation to Québec's resident doctors

In light of the surveys conducted by the FMRQ, it has to be observed that implementation of RCPSC CBE appears to have been difficult. The hurdles encountered, as perceived by the resident doctors in the different specialties over the years, are very numerous, and seem to have become fixtures, as the FMRQ's most recent published surveys (2022a, 2022b) reveal.

Despite the improvement over the years of some elements of RCPSC CBE, the situation is clear: it is rather poorly perceived by resident doctors in Québec. The anticipated improvement in feedback under RCPSC CBE does not appear to have materialized, despite being one of the motivations underpinning the urgent implementation of CBE. Feedback is considered absolutely essential for all learning. Under RCPSC CBE, feedback was going to be improved, detailed, augmented, and easily accessible, but that is far from what Québec resident physicians are reporting. In fact, feedback is perceived much more negatively by residents under RCPSC CBE than by those in conventional residency. With regard to this fundamental aspect, the situation appears not to have improved, but rather to have deteriorated.

The accessibility of supervisors for EPA assessments, and the persistent, deep discomfort experienced by resident doctors who have to chase after their supervisors to obtain the results of their assessments can lead to the emergence of the worrisome behaviour of seeking out the most flexible supervisors who assign *the right mark without asking too many questions, and perhaps even without observing the element to be assessed*, as several residents themselves put it. The fact that resident physicians raise this concern is on the one hand encouraging, since it indicates that they care about the quality of their learning, but at the same time it is worrisome for the integrity and effectiveness of the training they receive.

In short, the FMRQ's reports tend to indicate that resident doctors are finding this paradigm shift difficult,[64] five years after its introduction, and that they still cannot see the benefits from it.

45.0
Conclusions and questions

The significant changes that implementation of RCPSC CBE in the early 21st century was going to entail, and the inadequacy of empirical evidence to support its conception should, at least, have imposed the conduct of experimental research in Québec and elsewhere in Canada in order to provide a rigorous measurement of the effects of this new training model on professional skills, quality of care, and clinical outcomes. It should all have begun with pilot studies, gradually growing in content, number of subjects, and measurements of dependent variables (professional skills, knowledge, quality of care, patient outcomes, etc.), depending, of course, the results obtained in the pilot studies. Increasingly generalized implementation, following *positive* results from the studies, should have taken place within the framework of *Rational results-based management* (Boyer and Bissonnette, 2021) in order to continue to track the effects and make the necessary adjustments. These numerous research studies should have been organized, coordinated, and monitored by the medical faculties, Québec's college of physicians (CMQ), and Ministries of Health in Canada. This necessary avalanche of research and rigour never happened. Five years down the road, there has

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still been no rigorous demonstration of the effectiveness of RCPSC CBE.[65]

Québec resident doctors' perception of RCPSC CBE is distinctly more negative than from residents in conventional residency or *Triple-C* CBE in family medicine. At the very least, this negative perception reflects a great deal of discomfort on the part of resident physicians with the RCPSC CBE, which should have been of concern to many official and decision-making bodies in the field: Royal College of Physicians and Surgeons of Canada, *Collège des médecins du Québec*, Ministry of Health, medical faculties and medical associations.

We have identified no publication from *Collège des médecins du Québec* (CMQ) concerning any follow-up[66] or reaction whatsoever to the FMRQ's first three reports. This radio silence is surprising. Should we take that to mean the CMQ considers the FMRQ's reports to be irrelevant? Who has responsibility for pedagogy and medical education in Québec? Is it the Royal College of Physicians and Surgeons of Canada? Has the CMQ checked the validity of the evidence motivating this paradigm shift in residency, and then deemed the change to be warranted? Who should be following up on this shift and its effects in Québec?

The medical faculties, for their part, appear to have questioned the implementation of certain facets of RCPSC CBE on financial grounds (FMRQ, 2020a, p. 21). On the other hand, we found in the public domain no document issued by the medical faculties manifesting any reaction whatsoever to the FMRQ's reports. Whence this silence or this lack of interest from the medical schools? Do the medical faculties not have a responsibility for medical education? Did Québec's medical schools evaluate the evidence and deem it sufficient to justify this paradigm shift? Did they follow up on this paradigm shift and measure its effects?

What is the role of the Québec Ministry of Health in this issue? We found no official reaction from the Ministry of Health to the *Fédération des médecins résidents du Québec*'s reports, and no documents testifying to any follow-up on implementation of the Royal College's CBE. Did the Ministry conduct follow-up on implementation of RCPSC CBE? Did it seek accountability from anyone? The RCPSC or the *Collège des médecins du Québec*? Did the Ministry ask for a presentation of the evidence underpinning this pedagogical paradigm shift in medical residency? Did the Ministry of Health expect the Ministry of Education to conduct the follow-up?

Since 2017, the *Fédération des médecins résidents du Québec* has constantly sounded the alarm, proposing functional adjustments to RCPSC CBE.[67] Why was the FMRQ the only organization to have measured its members' perceptions? Why did the resident associations and federations outside Québec not do so?

Overall, 38% of Canadian resident doctors reported a high level of burnout (AMC, 2018), but older studies indicate that this problem cannot stem from RCPSC CBE, because it was present well beforehand (Thomas, 2004). Studies such as that by Mion, Journois and Libert (2018) demonstrate a link between residents' burnout and depression, while other studies, such as the one by Pereira-Lima et al. (2019) tend to indicate a bidirectional relationship between the symptoms of depression and medical errors. Finally, van Vendeloo (2021) showed, following the introduction of a CBE program, the existence of a link between resident doctors' burnout and supervising physicians' behaviours. These data suggest a possible sequence of links that can weaken the socio-emotional balance of young adults in residency, their learning, and the quality of patient care. This type of data is well known, and has been circulating in the medical world for several decades.

Medical school admission criteria mean the faculties select young adults who are successful with a certain ease in all academic subjects, including natural sciences. It seems to us quite acceptable to place high demands on them, particularly since they will hold, as we often hear, our health and sometimes our lives in their hands. But, knowing the high demands for medical training, the level of stress inherent in the medical field, the robust stock of knowledge to be acquired, and the workload in residency,[68] would it not be appropriate to exercise caution in making changes in medical education so as to avoid submerging residents and unnecessarily undermining them with unvalidated pedagogical approaches? Should changes not be made in medical training largely based on the evidence available in general education and medical education? Would it not be wise to conduct pilot experiments first, before generalizing their application to all residents, involving a sufficient number of subjects and a control group, meas-

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uring rigorously and objectively the targeted learning, effects on patient care, clinical outcomes, and reduction in adverse medical events?

Can there be a way other than rigour, scientific trials, and *Rational results-based management* to improve medical practice and medical education? There are those who may maintain that such an approach to change does not move fast enough, and that the healthcare system's need for improvement is urgent. But should we then, to speed up the changes we believe are desirable, fall back on mere theoretical deductions, to an essentially ideational functioning, as was the practice before the 19th century?

Five years into implementation of RCPSC CBE in Québec, has the quality of patient care improved? Have resident doctors' professional skills improved? Has the rate of adverse events declined? We do not know, because these elements have not been rigorously measured. Some researchers may have data that can partly address some of these questions, but for now, those researchers do not appear to have compiled and organized those data to answer those in the public arena.

What is the use of making a pedagogical paradigm shift in response to certain weaknesses in the previous paradigm if we do not measure rigorously the effects of this new paradigm on the weaknesses we say we want to correct?

It is clear to us that the priority should be to invest in medical pedagogies that have begun to yield some attractive data and sometimes some strong evidence, such as *mastery learning*, *deliberate practice*, and *competency-based progression*,[69] rather than in pedagogies that claim to explain everything, without having demonstrated, on the one hand, their relevance other than theoretical and, on the other hand, their objective effectiveness in the field.

Conducting scientific research and using *Rational results-based management* means accepting with the humility of the atheist pilgrim that we cannot be certain of the effectiveness of a pedagogy *before* we have drawn on the available evidence and rigorously carried out the necessary monitoring and experimentation.

Future pedagogical changes in medical residency should be carried out with the medical world's usual caution. Before moving ahead, the same rigour should be harnessed, developing a rationale built on relevant evidence in a general scientific framework necessarily involving prior experimentation supporting the validity of the changes, before their generalization is encouraged.

Like the cathedral builders, we must be guided by rigour and tenacity. There can be no shortcuts.

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Appendix A
Problem-solving applied to medical education

It was at McMaster University, in Hamilton, Ontario, in the late 1960s, that problem-based learning (PBL) was introduced in medical learning (Barrows and Tamblyn, 1980). But PBL really took off worldwide in medical pedagogy only in the 1980s and 1990s (ten Cate, 2005).

Some authors consider that PBL has not proven itself, or has presented inconclusive results for many years, but without affecting the medical world's strong attachment to this pedagogical approach.

Albanese and Mitchell (1993) conducted a meta-analysis of research published between 1972 and 1992 in medical pedagogy that compared PBL with traditional teaching. The authors stressed that students (before residency) who received PBL training appreciated their experience, and obtained results comparable to and sometimes better than students in the control group (traditional teaching) with respect to clinical performance and faculties-made tests. But students in PBL obtained weaker results on scientific knowledge tests, and considered themselves to be less competent in that field than the students in the control group.

It is important to mention that in several studies, the experimental group (PBL) often consisted of students who volunteered to learn with PBL. So there is often a form of active or passive selection of the student clientele in PBL. It is quite plausible that students who choose (or have been chosen) to learn with PBL already had psychological and cognitive characteristics different from those who do not make that choice or were not chosen.

Also, in some studies, the number of places in PBL was limited, probably making PBL more attractive. These elements represent potential biases that can contaminate the results. Despite the relatively positive results observed by Albanese and Mitchell (1993), they ended their article by advising the medical education world not to make any major changes in their programs in order to incorporate PBL before obtaining solid evidence concerning that approach. Their recommendation was not followed.

Vernon and Blake (1993) conducted a review comparable to that carried out by Albanese and Mitchell (1993), covering the period from 1970 to 1992, based on a larger number of studies, but some studies intersected with those of Albanese and Mitchell (1993). Vernon and Blake also selected studies including a smaller sample than those selected by Albanese and Mitchell (1993).

Vernon and Blake observed that students following PBL programs perceived their training more positively than students in traditional education. On clinical performance measurements, a mean effect of 0.28 was calculated in favour of students in PBL, along with a negative effect of -0.09 on knowledge, which is non-significant. On the other hand, students in PBL obtained a significant negative mean size effect of -0.18 on the National Board of Medical Examiners Part I (NBME I) exam. The authors noted that the results on the NBME I exam revealed strong heterogeneity and significant differences among the different programs, casting doubt on the potential generalization of the results. As with the literature review by Albanese and Mitchell (1993), students' selection bias for PBL was repeated. The reviews by Vernon and Blake (1993) and Albanese and Mitchell (1993) made much the same observations concerning the effects of PBL, but Vernon and Blake stood out by concluding nevertheless that the results generally supported the superiority of PBL over traditional pedagogies.

In a review of meta-analyses, narrative reviews, and research during the period from 1980 to 1999 with students (before residency), Colliver (2000) concluded that after 30-40 years of PBL's influence in medical pedagogy, there was no substantial, convincing scientific evidence that it enhances future physicians' medical knowledge and clinical performance. On the contrary, research and meta-analyses presented null or negative mean size effects, particularly when the subjects of the studies were distributed at random between the experimental group (PBL) and the control group (traditional pedagogy).

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Colliver (2000) emphasized that in the research conducted by Hmelo (1998), students in PBL made greater use of reasoning by hypothesis then reasoning based on patients' clinical data, a notable weakness. Professional reasoning based on patients' data is one of the important characteristics of how medical experts work. This bad habit among students in PBL may be attributable to the fact that this reasoning by hypothesis is explicitly taught in PBL. Students in PBL, in overusing *reasoning by hypothesis* to the detriment of *reasoning based on patients' clinical data*, are quite simply doing what they have practised with similar problems, likely in the absence of relevant knowledge, a highly plausible learning situation in PBL. According to Colliver, what he observed from overall research in PBL was downright disappointing, and far below the expectations generated by the claims made for that pedagogy.

In the meta-analysis by Koh et al. (2008), no effect from PBL on doctors' competencies was observed, but the authors emphasized anyway that there is an effect on resident doctors' future social and cognitive competencies, after they receive their certification. Knowing that 53% (7/13) of the research reviewed by Koh and his colleagues used self-assessment to measure the effects of PBL and considering that self-assessment is not a reliable skill that is well mastered by humans, including physicians (see 3.5 Ability to self-assess, p. 13), how can we react to this without smiling?

Al Wadani and Khan (2014) concluded that the review of experimental studies showed that there is not sufficient well-designed research to conclude that PBL is an effective pedagogical approach in ophthalmology. The meta-analysis by Brice (2017), looking at research conducted between 2003 and 2016 using PBL in undergraduate medical education, indicated that there was no statistically significant impact on attitudes and general results among the medical student population.

The meta-analysis by Zhang et al. (2018) looked at learning by students, interns, and probationers in radiology in China. Contrary to what is generally observed, the experimental group (PBL) obtained better results than the control group in measurements of knowledge, the mean size effect being a significant 1.20. In terms of measurement of competencies, the mean size effect was to the advantage of PBL, at 2.10, which may be qualified as a *huge effect*.

The characteristics of the research have an impact on the results observed (Cheung and Slavin, 2016). For instance, the number of subjects in a study is negatively correlated with the results obtained, to the point where it is recommended for a meta-analysis that research be selected with samples of at least 250 subjects (Cheung and Slavin, 2016). Similarly, the duration of trials is negatively correlated with the results obtained (Cheung and Slavin, 2016). Out of 17 studies selected by Zhang et al. (2018), five had a sample ≤ 50 subjects, and eight had an *unknown* duration of experimentation. These two methodological weaknesses alone undermine the solidity of what this review presented. The authors note significant heterogeneity in the studies, and recommended further research to confirm the results they observed. Significant heterogeneity is sufficient grounds for limiting possible generalizations from a meta-analysis (Buteau and Goldberg, 2015; Wang et al., 2021).

Zhang et al. (2018) noted, along with other researchers (Wang et al., 2016), that the results for PBL in China differ from and are more positive than those obtained in the West. Among the explanations proffered, those researchers considered that the difference in results might be cultural. That is possible, but the methodological weaknesses of research in the field of PBL in medicine, both in China and in the West, prevent any strong statement that there is any real difference in results between these two worlds.

Many authors defend the use of PBL in medical pedagogy, including Qin, Wang and Floden (2016), who measure, among other things, some positive effects of this approach on improving the medical education environment according to the Dundee Ready Education Environment Measure. Neville (2009), in a narrative review, analysed the positions and arguments used in 475 articles in favour and not in favour of PBL. Based on these articles, swinging massively between opinion texts and descriptive research, the author concluded that this pedagogical approach is relevant for medical education. Hartling, Spooner, Tjosvold and Oswald (2010), in a meta-analysis of 15 studies selected from a pool of 6,000 references (articles and other), observed that 12 out of the 15 studies finally chosen found no difference

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favouring PBL in knowledge acquisition. The authors concluded that the results concerning the effectiveness of PBL were conflicting, noting the many methodological weaknesses in research on PBL. The results of the meta-analysis by Sayyah et al. (2017) looked at research conducted in Iran with a clientele of students in health care (e.g., Nursing, Dentistry, Medicine). The results were positive, and the authors encouraged the medical world to use PBL more often.

The meta-analysis by Schmidt, van der Molen, te Winkel and Wynand (2009), occasionally cited in the field as evidence of the effectiveness of PBL, is a fine example of the type of meta-analysis on the question of the effectiveness of PBL. This meta-analysis presents positive effects, but the data on which it is based vary considerably, a sure warning sign to the informed reader. In recalculating the mean size effect of the research selected by Schmidt, van der Molen, te Winkel and Wynand (2009), we have withdrawn the five results that are based on self-assessment of the subjects taking part in the research—self-assessment not being a reliable measurement of performance and of real facts. We also withdrew: (1) the only result that just measures recall of information concerning two clinical cases; (2) the only result essentially measuring the duration for treating two clinical cases; (3) the two results looking only at communication, one of which is based on a self-assessment; (4) the five results measuring only the self-assessment of the quality of the medical education received; and (5) the 10 results measuring the duration of medical studies based on only two pieces of research. We kept the results of knowledge and reasoning tests concerning a clinical context. The profile we derived from this, based on 36 size effects, is neither fish nor fowl (really!). The mean size effect, without weighting each size effect, is 0.30, with a variance of 0.34. This very high variance is seen from the scale of the results, the smallest being -1.02 and the largest 1.89. The median is 0.18, corresponding to close to half of the mean (0.30).[70] Such a strong variance, generally indicating that other variables are contaminating the results observed, calls for great caution in interpreting the results (Wang et al., 2021).

Chernikova et al. (2020a) carried out a meta-analysis of 35 studies on PBL concerning the skill to diagnose in medical education and teacher training. Analysis of their findings determines that more directive scaffolding[71] is more effective for learners who have a less developed wealth of knowledge. More advanced learners, for their part, benefit from less strict scaffolding that leaves more room for self-regulation. The size effect of scaffolding in PBL on the ability to diagnose is 0.41 for learners with less knowledge and 0.59 for those who are more advanced. In other words, PBL with scaffolding could be effective, for both novice and more advanced learners, insofar as the form of scaffolding is adapted to those two clienteles. Types of scaffolding providing high levels of orientation are more effective for less advanced learners, whereas types of scaffolding based on high levels of self-regulation are more effective for advanced learners (this logic dovetails with the framework of explicit teaching). By contrast, the mean size effect is 0.23 when the results obtained in medicine are isolated (compared with 0.58 in the context of teacher training). The results of and conclusions from this meta-analysis justify the pursuit of experimental research in PBL, manipulating the degree of scaffolding. The lower effectiveness of PBL in medical education is intriguing.

The article by Hung, Dolmans and van Merriënboer (2019) proposed an interpretation of the history of research on PBL in medical education. Those researchers divided the historical path of the research on this topic into three major waves. The first wave of PBL research ran from 1990 to 2005 or so, and focussed on answering the question: "*Does PBL work?*" This wave was characterized by contradictory results and polarizing positions from researchers, without any resolution of the question. The second wave, roughly from 2005 to 2015, abandoned the first question and focussed on: "*How does PBL work?*" This second wave of PBL research aimed to investigate the effects of implementation constituents, the effects of the types of assessment, and the types of implementation. It was no longer sought to find out whether *PBL is effective*, but to describe its components and weigh its effects. It has then to be understood, without any fanfare, that it was assumed that PBL was effective and that the first question was answered positively and sufficiently clearly, which was not the case according to Hung, Dolmans and van Merriënboer (2019). The third wave, which began around 2015 and is still with us today, looked at the question: "*How does PBL work in different specific contexts?*" Once again, it was supposed that the effectiveness of PBL has been clearly demonstrated. Hung, Dolmans and van Merriënboer (2019) ended by proposing that the fourth wave of research on PBL should try to answer the question: *Why does PBL with particular implementation*

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

characteristics for specific outcomes work or not work in the condition where it is implemented?"

We are quite happy with this last proposal from Hung et al. (2019), which returned indirectly to the initial question on PBL (*"Does this pedagogical approach work?"*) Should the first step not have been to verify the validity of this pedagogical approach in terms of effects on relevant measurements of performance (and other variables) compared with traditional practices before studying in depth the mechanics of PBL? Should one not have waited to have sufficient evidence **before** generalizing its application and focussing the research on dissecting its structure?

After 60 years of PBL applied to medical education, and despite the pace at which it became generalized, this approach is still not evidence-based. But ten Cate (2005) considered that the adoption and implementation of CBE applied to medical education was even faster than with PBL.

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Appendix B
EPA #7 in Orthopedic Surgery

Performing technical skills in the surgical management of fractures

Key Features

- This EPA focuses on performance of the fundamental surgical technical skills for fracture care in the operating room, in the context of the following procedures: treatment of basic hip fractures (femoral neck/intertrochanteric) managed by fracture fixation using screws, sliding nail/plate, or cephalomedullary nail; open reduction and internal fixation of simple fracture patterns (e.g. diaphyseal fractures, simple periarticular fracture patterns); and closed reduction and IM nail fixation of simple fracture patterns (mid-diaphyseal fractures (e.g. femur and tibia).

- The technical skills of this EPA include surgical approach; safe use and interpretation of fluoroscopy; application of internal fixation (interfragmentary screws, compression plate, intramedullary nail); appropriate use of AO techniques to manage fracture; and appropriate soft tissue management and closure.

- Performing the reduction is not required for this EPA.

Assessment Plan

Direct observation by orthopedic surgeon, fellow, or Core or TTP resident

Use Form 2. Form collects information on:

- Procedure: cannulated screws; sliding hip screw; IM nail; diaphyseal plating; periarticular fracture plating

Collect 3 observations of achievement

- At least 3 different procedures

Milestones

<u>Medical Expert</u>

1. Pre-operative plan: Assess clinical information to determine/confirm diagnosis and appropriateness of procedure
2. Case preparation: Position patient correctly, understand approach and required instruments, be prepared to deal with probable complications
3. Knowledge of procedure: Understand steps, potential risks, and the means to overcome them
4. Technical performance: Perform steps of procedure efficiently, avoiding pitfalls and respecting soft tissues
    - Surgical approach
    - Safe use and interpretation of fluoroscopy
    - Application of internal fixation (interfragmentary screws, compression plate, intramedullary nail)
    - Appropriate use of AO techniques to manage fracture
    - Appropriate soft tissue management and closure
5. Visuospatial skills: Demonstrate 3D spatial orientation, position instruments/hardware where intended.
6. Post-procedure plan: Establish an appropriate complete post procedure plan
7. Efficiency and flow: Demonstrate planned course of procedure, economy of movement and flow

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Collaborator

8. Professional and effective communication/utilization of assistants and OR team

Communicator

9. Provide information about the procedure, operative findings and patient status to the family in a clear, accurate and timely manner

RCPSC (2019). *Entrustable Professional Activities for Orthopedic Surgery, Version 1.0*

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Appendix C
EPA #10 for Pediatrics

Leading discussions with patients, families and/or other health care professionals in emotionally charged situations

Key Features

- This EPA focusses on the application of advanced communication and conflict resolution skills to address difficult situations that may involve patients, families, and/or members of the health care team.
- This EPA may be observed in any scenario that is emotionally charged. Examples include managing conflict (parent/physician; patient/physician; patient/parent; physician/health care professional), disclosing unexpected complications and/or medical errors, addressing non-adherence with treatment plan (e.g., vaccine refusal), and breaking bad news.
- This EPA does not include end-of-life discussions (TTP).
- This EPA includes documentation of the encounter.
- This EPA may be observed in a simulation setting.

Assessment Plan

- Direct observation by supervisor with review of documentation

Use Form 1. Form collects information on:

- Type of communication: addressing non-adherence with treatment plan; breaking bad news; disclosing unexpected complication and medical errors; managing conflict
- Setting: inpatient; outpatient; ICU; simulation
- Adolescent: yes; no
- Interpreter: yes; no

Collect 5 observations of achievement.
- At least 3 different types of communication
- At least 1 from each of (sic) setting
- At least 1 observation of a communication with an adolescent
- At least 4 different supervisor observers

Milestones

<u>Communicator</u>

1. Ensure the physical environment is suitable for the nature of the situation (e.g., privacy, safety)
2. Recognize when strong emotions (such as, anger, fear, anxiety, or sadness) are affecting an interaction and respond appropriately
3. Respond to non-verbal communication and use appropriate non-verbal behaviours to enhance communication
4. Establish boundaries as needed in emotional situations
5. Share information and explanations that are clear and accurate

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

6. Use strategies to verify and validate the understanding of the patient and/or family
7. Communicate in a manner that is respectful, non-judgmental and culturally aware
8. Answer questions from the patient and/or family

Collaborator

9. Listen to understand and acknowledge other perspectives

Professional

10. Intervene when behaviours toward colleagues and/or learners undermine a respectful environment

Communicator

11. Document the clinical encounter to reflect discussion and decisions.

RCPSC (2021). *Entrustable Professional Activities for Pediatrics, Version 1.0*

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

Appendix D
Emergency Medicine

Training element not considered to be an EPA in Emergency Medicine

Appraising and integrating new evidence into clinical practice

Key Features

The focus of this (non-EPA) assessment is the critical appraisal and integration of new evidence into clinical practice.

Elements to include in the appraisal and integration of new evidence into clinical practice are:

- Description of current practice (i.e., clinical background and context)
- Well-formulated question
- Process used to identify one or more sources of evidence relevant to the question
- Interpretation and critique of the evidence, using a structured approach
- Determination of the validity and risk of bias of the evidence
- Application and potential integration of the evidence into clinical practice

Assessment Plan

Resident's submission of a written report reviewed by program director or Competence Committee

Use Form 4

Collect 1 submission of satisfactory achievement

RCPSC (2018). *Entrustable Professional Activities for Emergency Medicine, Version 2.0*

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Notes

1.0
Introduction

1. Medical residency is the paid postgraduate traineeship, generally of 2-5 years' duration, which resident doctors have to perform in order to obtain their right to autonomous practice (some specialties require 6-7 years of residency). In France, this traineeship is known as *clinicat* or *assistanat*. Resident doctors then practise the medical acts of their specialty, under the supervision of certified physicians or residents more advanced than they are. In Québec and Canada, resident doctors are both students, through their affiliation with a university, and paid healthcare system employees.

2. In Québec, 60% of resident physicians are women.

2.0
Reminders of the past

3. In 1903, at the New York Academy of Medicine, another thinker of medical education, William Osler stated that it was important for medical education to be based on practice and supervised clinical experience, described as the *natural method of teaching* (Osler, 1932). Overall, Osler's approach dovetailed with William Halstead's conception of residency.

4. Abraham Flexner did not limit his criticism to medical education. For example, in Baltimore in 1915—in a speech on the question, "Is social work a profession?"—he answered in the negative (Austin, 1983). His reception from the social work world was not excessively enthusiastic.

5. While the Flexner Report underscored the flagrant lack of scientific rigour in medical education and medicine, the conception of medicine and medical education defended in that report goes well beyond an appeal for scientific rigour, in line with the positivism of the era. For instance, according to Flexner, physicians' social roles are manifold, including prevention, and have to be integrated into medical education (Flexner, 1910, p. 26). This and several other recommendations were not implemented.

In the early 21st century, in medical education, considerations beyond purely medical expertise were revived (Sales and Schlaff, 2010) and, as we shall see, found a favourable echo in *competency-based education* in residency (see the segment of this text: 7.1 RCPSC CBE competencies (CanMEDS), p. 17). On the other hand, to be more specific, it can be stated that the social component of the medical profession had always been in the air since 1910 (Whitehead, 2010), but without having a marked impact on physician training until quite recently.

6. It should, however, be noted that a number of the proposals in the Flexner Report had already been put in place in some universities prior to its publication (Koch, 2019).

7. Certain approaches or elements of approaches have been partially rehabilitated for certain disorders, such as phototherapy in dermatology (Bae et al., 2017; Fulop et al., 2009), whereas others remain scientifically invalid, such as homeopathy (National Health and Medical Research Council, 2015).

Note that the Flexner Report contributed to the closing of medical schools owing to the strong prejudices of the early 20th century, such as racism and misogyny. Medical schools in the USA dedicated to training black doctors or women were closed because those clienteles, according to the authorities, *absolutely could not meet* the level of rigour recommended by the Flexner Report (Hodges, 2010).

3.0
Atmosphere of recent years

8. A mega-analysis is an analysis comprising several meta-analyses.

9. The basic formula for calculating the size effect of research is: $(X^e - X^c)/\partial^2$. Readers interested in meta-analy-

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sis in medical research are invited to read the article by Wang et al. (2021).

10. This corresponds, according to Baker et al. (2004), out of the 2.5 million yearly hospital admissions in Canada, to 185,000 patients dealing with undesirable events, 70,000 of which are potentially avoidable.

11. The *Dunning-Kruger effect*, or Kruger and Dunning's concept of *overconfidence*, describing the tendency to overestimate one's skills despite being barely or not at all qualified, is contested by some researchers (Gignac and Zajenkowski, 2020). That does not, however, invalidate the data indicating the low ability of humans, physicians included, to self-assess accurately.

12. But research nevertheless tends to indicate that high-quality, rigorous medical education can have a positive impact on the quality of patient care up to 15 years after the end of residency, as the example of Asch, Nicholson, Srinivas, Herrin and Epstein (2009) in Obstetrics shows.

4.0
Competency-based Education (CBE)

13. CBE has given rise to different programs differentiated, among other things, by the definition of what a *competency* is (Boritz and Carnaghan, 2003), the importance of the elements underlying the development of competencies (e.g., the relative presence of knowledge to be acquired before or at the same time as other knowledge, the place given to skills and attitudes, etc.), model learning situations for fostering development of competencies, the way in which these competencies are assessed, and the sources deciding what defines the competencies and desired outcomes. Regulatory authorities, industry, and experts can define the expected competencies and performances in line with an institutional or pedagogical philosophy (Cahapay, 2021), whether utilitarian or otherwise. Behind all these distinctions, rival theories are activated, some of which often gravitate around the behaviourist or constructivist axis, and can be placed or not at the service of strict utilitarianism, or of a humanism embracing or not a broad historical and philosophical culture.

5.0
Brief description of CBE in general pedagogy

14. Progression within the program generally requires that learning *Unit A* be mastered before the learner can move on to learning *Unit B* (these formative tests, sometimes combined with observations, assess knowledge and skills).

6.0
Constructivist reframing of CBE in general pedagogy

15. Some say it is primarily *radical constructivism* which contests the use of uniform, standardized measurements, but that version of constructivism is increasingly *the* dominant version in pedagogy and in education faculties.

16. Constructivist approaches in pedagogy are often described as recent innovations, at the leading edge of scientific research. That was the story in 1960, 1980, 2000, and still today, in 2022. This claim to innovation is generally false, since the existence of constructivism and the pedagogical approaches it fosters goes back at least a century (Boyer, 2021).

17. PISA, the OECD's Programme for International Student Assessment, measures 15-year-olds' ability to use their reading, mathematics, and science knowledge and skills to meet real-life challenges. Its surveys are carried out every three years. The Trends in International Mathematics and Science Study (TIMSS) provides data on the achievement of U.S. students compared to that of students in other countries. TIMSS data have been collected from students at grades 4 and 8 every four years since 1995.

18. Aditomo and Klieme (2020) conducted an analysis using data from the 2015 PISA survey. These researchers distinguished two types of investigation pedagogy, one where investigation is "independent," the other where investigation is "guided." The latter pedagogy implies that the teacher directly provides the students with con-

Boyer, Bissonnette, Baillargeon and Morneau-Guérin (2023) ISBN : 978-2-923805-73-3

ceptual and other explanations, and explicitly conducts modeling of problem-solving or technique application, etc., actions which go to the core of explicit teaching. It comes as no surprise that Aditomo and Klieme (2020) concluded, based on the results of the data analysis, that using guided investigation pedagogy was more effective than independent investigation pedagogy (where students have to take the teaching load on themselves, fully or nearly fully, in the joy of discovery).

19. The first applications of problem-based learning in the medical field go back to 1969 (Schmidt et al., 2009).

7.0
Brief description of RCPSC CBE applied to residency

20. The goal here is not to provide a comprehensive description of the overall conceptual structure of the application of CBE to residency, but to identify its broad lines in order to have an overview of the pedagogy being used.

21. Reminder: in conventional residency, some specialties require 6-7 years of residency.

22. CanMEDS is a Physician Competency Framework. It is also a consortium of medical bodies, including the following: Royal College of Physicians and Surgeons of Canada, College of Family Physicians of Canada, Association of Faculties of Medicine of Canada, Canadian Federation of Medical Students, Canadian Medical Association, Canadian Medical Protective Association, Canadian Patient Safety Institute, *Collège des médecins du Québec*, *Fédération médicale étudiante du Québec*, Federation of Medical Regulatory Authorities of Canada, *Fédération des médecins résidents du Québec*, Medical Council of Canada, and Resident Doctors of Canada.

8.0
Entrustable professional activities (EPAs)

23. The use and definition of the concepts of milestones and EPAs vary considerably by training program, country, and medical specialty. For instance, in Emergency Medicine in the United States, a document (https://www.aliem.com/users-guide-assessment-with-epas) explains that EPAs are used to demonstrate the acquisition of certain milestones and adds the concept of "observable professional" activities (OPAs), possibly originating in Internal Medicine (Warm et al., 2014) and identifying some observable sub-elements of a milestone or EPA. One U.S. Pediatrics program uses the term "developmental milestones" exclusively, never referring to EPAs or OPAs (Hicks et al., 2010). In Canada and Québec, *Triple-C* CBE, in Family Medicine, uses the concept of *key competencies*. This lack of consistency makes the study of research in the field somewhat more complex.

24. OSATS is a grid used to measure technical competencies in surgery. It purports to be a reliable, valid tool (Vaidya et al., 2020). This grid uses a global rating scale for technical competencies (e.g., A. Respect for Tissue; B. Time and Motion; C. Instrument Handling; D. Knowledge of Instruments; E. Flow of Operation; F. Use of Assistants; G. Knowledge of Specific Procedure—see Niitsu et al., 2013), using a 5-point Likert assessment scale for each item. Nevertheless, some research results appear to show that OSATS is possibly too general to identify correctly the specific quality of the execution of each type of procedure or operation (Myers et al., 2022). Moreover, Anderson et al. (2016) consider, following their study in Orthopedic Surgery, that assessment metrics need to be incorporated into OSATS that reflect the specific nature of the surgical outcome, such as direct physical measurement of the quality of the reduction and the integrity of the mechanical fixation in cases of intra-articular fracture reduction and extra-articular fracture fixation.

9.0
Overview of research on EPAs, milestones

25. The usefulness of certain EPAs in internal medicine was challenged in Québec. How to act in that regard varied from one university faculty to another (for instance, at least one faculty is said to have organized an intensive weekend to put the resident doctors concerned quickly through the EPAs that were considered not particularly useful).

 ISBN : 978-2-923805-73-3

26. It is ironic to note that followers of Foucault or of some of his influence in the current social debate, involving postmodernist postures, adopt a discourse of infallibility and attempt to stifle dissenting voices, and reincarnate, as it were, in the costume of a *monster* that Foucault was analyzing and denouncing.

10.0
Some salient features of CBE as applied to medical residency

27. Some authors in medical pedagogy mistakenly believe that the ineffectiveness of explicit and operational objectives has already been demonstrated in general pedagogy (Norman, Norcini and Bordage, 2014). Starting from that point, they deduce that the same ineffectiveness should be seen in medical pedagogy.

11.0
Technology-enhanced simulation (TES)

12.0
Overview of research on use of TES

28. Chernikova et al. (2020b) also pointed out that the presence of examples, scaffolding of the learning to be achieved (for a definition of scaffolding, see note 72, p. 80), and reflective phases can influence the effect on TES, depending on participants' level of prior knowledge (for the effect of scaffolding, see also the meta-analysis by Chernikova et al., 2020a).

29. All these elements represent considerable weaknesses in terms of measurement of the effects of a pedagogical approach on learning (Cheung and Slavin, 2016; Wang et al., 2021).

30. The meta-analysis on cardiac auscultation by Osborne, Brown and Mostafa (2022) indicated that there was no significant difference in knowledge or skills among learners when comparing high-fidelity to low-fidelity simulation.

31. CBP involves meticulous analysis of the target task, determination of progression in the difficulty of the task and subtasks until the target task is carried out comprehensively, identification of assessment criteria and measurements for professional behaviours at each step in the progression, frequent, precise feedback, and intense, repetitive practice. CBP has obvious affinities with *deliberate practice* and *mastery learning*. Research on CBP shows positive effects on the development and mastery of certain procedures (Angelo et al., 2015; Breen et al., 2019; Thomsen et al., 2017).

13.0
Standardized patients (SPs)

14.0
Overview of research on use of SPs

15.0
In brief, then, SPs and TES

16.0
Deliberate practice

17.0
Overview of research on deliberate practice

32. It is true that constructivist pedagogies also use learning by observation and a form of learning by modeling. The modeling used in constructivist pedagogies is usually characterized by the desire that the learner build his

 ISBN : 978-2-923805-73-3

own procedures (Guilmois et al., 2020), while in explicit teaching the procedure is prescribed and directed, as in RCPSC CBE (see the following section: 18.0 Procedurization). Also, in constructivist pedagogies, systematic exercises are usually seen as a harmful learning activity to be avoided, among other things, because they are non-significant and inauthentic (Guilmois and Popa-Roch, 2021).

18.0
Procedurization

19.0
Overview of research on procedurization

33. A number of empirical applications from the first author (of this text) with young children indicate that procedurization does not have an automatic positive effect and can sometimes even become an obstacle to learning. A procedure that is excessively or insufficiently detailed, and broken down too much or not enough, too far from the flow of real actions (cognitive, motor, etc.), is detrimental to learning and can even make it more complex. If this is true with children, it may be just as valid with adults and complex learning.

20.0
Feedback and formative assessment

21.0
Mastery learning (ML)

22.0
Overview of research on ML in general pedagogy

34. https://www.nytimes.com/1983/01/09/education/mastery-learning-on-a-grand-scale-chicago.html and https://www.washingtonpost.com/archive/1985/04/21/prescriptions-for-learning/29ec0651-1659-4069-a436-6eae9d50f5a8/

35. Thompson (2014) did not report the quantity of internal and external suspensions before Chicago introduced ML, but there were enough internal suspensions at May Elementary School for a space to be dedicated to them (Room 317). This room became deserted (there were only five suspensions over the entire year of implementation of ML). In an underprivileged school with no effective behaviour management system, it is not unusual to find an internal and external suspension rate of 100 pupils per month (Grasley-Boy, Gage and Lombardo, 2019).

The teaching staff at May Elementary School mentioned that following the implementation of Chicago's ML program, the atmosphere in the school became much calmer and more conducive to learning; more pupils focussed on learning, and avoided misbehaving (e.g., throwing food, etc.); more pupils now borrowed paperbacks to read at breakfast or lunch; teaching staff were more enthusiastic and felt more effective than before the ML program; there were better relations with parents, who expressed their appreciation of the changes made and the impact they observed. While all these comments are interesting, they remain purely anecdotal, with no points of comparison and objective measurements.

36. Slavin (1989, 1990) in the same period criticized the methodology used in the research conducted on ML (see Guskey, 1987, for a reaction to Slavin's criticisms).

23.0
Overview of research on ML in medical education

 ISBN : 978-2-923805-73-3

24.0
ePortfolio

37. It was in Strasbourg in 1779 that Johann Friedrich Oberlin and Louise Scheppler created the first kindergartens for workers' children aged under 6. In 1860, in Boston, Elizabeth Palmer Peabody opened the first kindergarten in the USA, in a perspective virtually identical to the educational orientation of today's preschools (e.g., indirect, minimalist intervention, as opposed to direct, explicit teaching).

25.0
Overview of research on the ePortfolio in general pedagogy

38. The use of the portfolio or ePortfolio has nevertheless not completely disappeared in Kentucky nor in elementary schools in the West. In general pedagogy, constructivist ideas and conceptions, like zombies, never die, even when they are not supported by facts and even when they are completely invalidated by evidence (Phelps, 2005, see Holland, 2007; Boyer and Bissonnette, 2019).

26.0
Overview of research on the ePortfolio in medical education

39. Longitudinal studies are clearly also needed.

27.0
In brief, then, the ePortfolio

28.0
Self-regulation of learning

29.0
Overview of research on self-regulation of learning in general pedagogy

40. Reminder: a correlation does not signify a causal relationship, but the fact that two variables vary more or less together. Having blond hair in Norway strongly correlates with the ability to speak Norwegian, but one is not the cause of the other

30.0
Overview of research on self-regulation of learning in medical education

31.0
So, the concept of self-regulation?

32.0
Which type of pedagogy underpins RCPSC CBE, and does it work?

33.0
Impact of CBE as applied in fields other than medicine

34.0
Overview of research on CBE in general pedagogy

41. Some say that all criticisms of CBE stem from conservative groups from the political right, who militate against progressive, helpful pedagogical innovations such as CBE, Whole Language, and multicultural education (Watt, 1999). This somewhat confused discourse, aimed at neutralizing criticism, has been present in education faculties and the university world for the past 40 years, an unhealthy, specious outgrowth of radical constructivism and postmodernism. Being in favour of a scientific process, demonstration through experimental research, rigour, and reason is not a stance of the *Right* or the *Left*, but a belief in the possibility for humanity of understanding and improving

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the world, beyond perceptions, beliefs, and ideologies.

42. The cost of implementing CBE-remote learning may still be quite substantial at the outset: conversion of traditional programs to competency development-based programs, revamping of assessments in terms of competencies, purchase of technological devices, and adjustment of technology already in use, development of applications appropriate to the program, etc

35.0
Enthusiasm for CBE in non-medical vocational education

43. University faculty support is not unanimous, some professors fearing the change in roles that CBE entails and the decrease in their duties and possibly salaries (Ford, 2014; Gravina, 2017). Others professors fear that vocational training, being strictly limited to the needs of the labour market, might lead to limiting the development of important skills, such as a critical thinking (Ford, 2014; Gravina, 2017).

36.0
Overview of research on CBE in non-medical vocational training

37.0
CBE was definitely used in other fields before being used in medicine, but . . .

38.0
Foreword on evaluation of CBE applied to medical education

44. Research on a form of CBE applied to medical education was carried out before the 21st century. For instance, Martin et al. (1998) conducted a study in the USA in surgery, with eight resident doctors, on a competency development approach in the spirit of 2010s CBE. The acquisition of three procedures was studied: chest tube insertion; endotracheal tube insertion; and venous cutdown. The results showed that resident physicians substantially increased the speed of execution of the procedures while reducing possible complications. This experimental research looked at *before and after*, with no control group, thus limiting the range of possible conclusions. Since no other approach was compared with CBE, the authors could only conclude that the resident doctors learned, and not that CBE is superior to anything else.

In the 1990s, trials of CBE were also carried out in China (Stillman et al., 1997).

39.0
Overview of research on RCPSC CBE

45. In family medicine, residency uses the *Triple-C* program, and not the program we call in this text RCPSC CBE. The *Triple-C* program is nevertheless a form of CBE, but is different from RCPSC CBE.

46. Jason R. Frank, Director of Specialty Education at the RCPSC, told us in an email dated May 24, 2022 that he knew of no other quantitative studies of this nature carried out in Canada. After numerous investigations using search engines from the medical world and scientific research in general, we can confirm this observation.

47. There are thousands of articles dealing with RCPSC CBE, but they are generally restricted to measuring the perceptions of resident doctors, supervisors, and those responsible for CBE implementation. Several articles are also dedicated to theoretical analysis of certain aspects of CBE or the anticipated effects and the challenges to be met resulting from implementation of CBE.

48. The possibility of completing residency more quickly is visible in *Table 2* (49%), but in Québec our checks in no way confirmed that this possibility actually exists. For instance, of the 32 resident doctors completing their residency in 2022 under RCPSC CBE in ENT and Anesthesiology in Québec, *not one will have finished before the end of 5-year residency* (administrative barriers?).

 ISBN : 978-2-923805-73-3

49. Nousiainen et al. (2018) mentioned 11 resident doctors in their article, whereas from the information we were given, we believe there were 12 of them.

50. It is curious that the RCPSC sometimes implies (RCPSC, 2014) and sometimes explicitly claims (RCPSC, 2020) that development of a competency is not time-based, even though CBE is built, among other things, on more intensive exercising of skills. In a document dedicated to presenting CBE to residents, it is written, word for word (Slide #6): *Competence ≠ time spent* (https://www.royalcollege.ca/rcsite/documents/cbd/resident-developoment-orientation-cbd-f.pptx). The work of Ericsson (2004, 2015; Ericsson, Krampe and Tesch-Römer, 1993; see 16.0 Deliberate practice, p. 28) showed rather the contrary. Similarly, numerous studies on ML in both general and medical education (23.0 Overview of research on ML in medical education, p. 32) tend to indicate the opposite of this RCPSC position, i.e., developing high-level mastery of skills requires a considerable investment of time.

51. van Rossum et al. (2018) performed an economic analysis in the Netherlands of the potential costs and benefits of non-hybrid CBE (variable duration, depending on resident doctors' progression) in Gynecology. The researchers concluded, with two different scenarios, that the potential reduction in time with non-hybrid CBE led to overall higher costs for the hospitals, regardless of the scenario.

52. Ferguson et al. (2013) stated that resident doctors undergoing CBE in 2009-2010 and 2010-2011 had better technical skills than those in traditional residency, but without sharing the results or providing any details. Alman et al. (2013) claimed that the three residents from the 2009-2010 CBE cohort had higher satisfaction levels with regard to their training and better performance on five technical skills than the nine residents in conventional residency. These claims would have needed a more open sharing of the methodology and data in the articles in order for their basis to be gauged (e.g., Hawthorne effect? Selection bias in favour of CBE? Significant difference?).

40.0

In short, research conducted specifically on RCPSC CBE

53. Various faculties tried out RCPSC CBE before its widespread implementation (University of Ottawa, Queen's University, University of Toronto, Dalhousie University) in different specialties (Orthopedics, Psychiatry, and Anesthesiology). Aside from the articles on Orthopedics by Ferguson et al. (2013), Nousiainen et al. (2018), Sonnadara et al. (2012), and Alman et al. (2013; which does not provide new data), there have been no other publications of relevant quantified data in the other medical specialties. The articles available on applications of Canadian CBE in Psychiatry and Anesthesiology looked only at the perceptions of resident doctors or their supervisors and theoretical analyses of the benefits and challenges of Canadian CBE.

41.0

CBE applied to medical education around the world

54. The summary proposed in the article by Morcke, Dornan and Eika (2013) is misleading.

55. Weller, Naik and San Diego (2020) pointed out, in their narrative review, that they "found no studies reporting improved overall competence of graduates or improved patient outcomes." (Weller et al., 2020, p. 749). Two Canadian studies were included in this narrative review. The first measured the perception of CBD by *three* resident doctors in Anesthesiology by means of interviews (Boet, Pigford and Naik, 2016). The second study (Chiu et al., 2016), also in Anesthesiology, analysed the validity of several TES scenarios (using dummies) based, among other things, on the opinion of resident physicians as to the relevance of those scenarios, all gauged by means of a questionnaire.

56. The *learning curve* corresponds to the graphic representation of the relationship between level of performance in a task and level of experience. Generally speaking, performance (measured on the Y-axis) increases with experience (X-axis), i.e., the more often someone carries out a task, the better their performance in that task is (Hopper, Jamison and Lewis, 2007). Mean learning curves for medical procedures can, among other things, be used to assess and locate the learner in the learning under way. These curves also offer parameters that specify the average time needed to attain a high level of mastery of a task, and make it possible to allow for learning times and usual speeds of deterioration of

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the performance concerned after a decrease in or cessation of practice.

57. Our estimates are based on information presented in the article by Brydges et al. (2021) and that displayed in a horizontal tally chart whose scale is divided into 5-point segments, with no further details provided.

42.0
Is CBE in medical residency evidence-based?

58. We repeat, once again there is a geyser of medical pedagogy literature concerning CBE, but mostly descriptive studies and theoretical and argumentative texts. This literature is highly irrelevant to the primary question of the effectiveness of CBE in medical residency. It could even state that this literature drown the field with soft and irrelevant information that ends up interfering with and obscuring the fact that the primary question has yet to be answered ...

43.0
Perception of RCPSC CBE by Québec's resident doctors

59. Reminder: the term used by the RCPSC to designate their program is *Competence by Design* (CBD).

60. Sixteen of the 21 Anesthesiology residents and 10 of the 11 residents in Otolaryngology/Head and Neck Surgery (ENT/HNS) came from four Québec universities (University of Montréal, McGill University, Laval University, University of Sherbrooke).

61. In the FMRQ reports, CBD (Competence by Design) is used, but in order to avoid confusion, we have standardized the terminology with the rest of this text, and have substituted "CBE" and "RCPSC CBE" for CBD.

62. The Internal Medicine Core Curriculum was added to the list of programs newly under CBE in 2019. This program alone had more resident doctors than all the programs that began under RCPSC CBE during the first three years of its implementation. That explains the larger number of participants surveyed.

63. "As early as 2016, the promoters of [CBE] at the [RCPSC], in meetings attended by FMRQ representatives, openly resorted to the allegory of the ocean liner which, once it has left port, is virtually impossible to stop. This allegory was used when faculty representatives questioned whether the model was really ready to be implemented in July 2017, and also when others asked for introduction of the model to be slowed down in view of the observation that training sites were sadly lacking in the financial resources they need to manage all the collateral effects of implementation. These were the types of strategies used by the supporters of an ideology they wanted to impose regardless of the cost." (FMRQ, 2022a, p. 19)

44.0
What we should learn from the implementation of RCPSC CBE in relation to Québec's resident doctors

64. Paradigm shifts in science are generally based on evidence or end up being supported by evidence that confirms their validity. The current weakness of the scientific demonstration of CBE in general and vocational education and in medical education should have limited the dissemination of this pedagogy, this paradigm shift, but it did not.

The current generalization of this pedagogy and its maintenance in all spheres of education is not a reflection of rationality and evidence but, at least in part, is attributable to the adoption of purely ideological paths which do not get bogged down in providing an empirical demonstration of what they say, being satisfied simply with the enthusiasm they elicit.

45.0
Conclusions and questions

65. With respect to *Triple-C* CBE in family medicine, although we did not investigate this CBE variant specif-

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ically, the article by Danilovich et al. (2021) on *Triple-C* does not present any particularly eloquent findings as to its effectiveness. It is therefore probable that the effectiveness of this CBE variant has yet to be demonstrated.

66. According to an email received on June 8, 2022 from the *Direction des études médicales* of the *Collège des médecins du Québec* (CMQ), the CMQ has no publications concerning Competence by Design.

67. The RCPSC has nevertheless referred publicly to some of the FMRQ's criticisms (RCPSC, 2019b).

68. According to the FMRQ, a resident's average work week, including call duty, is around 72 hours, but in some specialties and in certain periods of the training, more than 100 hours a week is reported.

69. *Technology-enhanced simulation* and the use of *standardized patients*, which can be blended with ML, *deliberate practice*, and CBP, also offer possibilities for effectiveness in medical education, but these have yet to be demonstrated.

Appendix A
Problem-solving applied to medical education

70. The median is the measurement indicating the score in a series of ordered data that divides the overall data into two equal groups (containing the same amount of data on each side).

71. Scaffolding is a technique used to facilitate learning of a concept, behaviour, skill, or procedure. It involves splitting the learning, skill, or procedure concerned into subtasks adapted to the learner's performance level. These subtasks are placed in a sequence ranging from simple to complex, the most complex being the complete task whose learning is being targeted. The support is materialized by, among other things, precise instructions for each subtask, by the shared or joint accomplishment of the subtasks by the novice and the teacher, and through the ultimately autonomous accomplishment by the learner. Master modeling is also planned. The support offered comprising the scaffolding may be simultaneously verbal, visual, motor, graphic, or written, in person or virtual. Scaffolding includes frequent, precise, functional feedback that leads to a fine adjustment of the behaviours to be acquired. Verbal or other encouragement is provided to clarify certain topographical aspects of the learning to be developed. Feedback and encouragement can have a reinforcing effect on the learning being pursued. Scaffolding is therefore a pedagogical technique that is gradually withdrawn (fading technique) as the learner masters his learning and becomes autonomous.

Several authors attribute the birth of the concept of scaffolding and its fading to Bruner (1983) and, partly, Vygotski (1997; https://www.verbotonale-phonetique.com/geste-pedagogique-etayage-enseignant/ and https://wiki.teluq.ca/wikitedia/index.php/etayage). Those who present the history of these concepts in this way are forgetting that the functional (and not theoretical) techniques of scaffolding (shaping), and its fading, are in fact the work of Skinner (1953) and the behaviourists. Similarly, the concept of modeling (*vicarious learning*) was introduced by Bandura (1977) and the behaviourists in the 1950s and 1960s, very likely several years before the rediscovery of the concepts in certain pedagogical circles.

 ISBN : 978-2-923805-73-3

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