Problem-based learning at McMaster's Michael G. DeGroote School of Medicine: Looking back on 50 years

***Jonathan Sherbino,** Department of Medicine and McMaster Education Research, Innovation and Theory (MERIT) program, McMaster University.

Geoffrey Norman, McMaster Education Research, Innovation and Theory (MERIT) program, McMaster University.

Robert Whyte, Department of Anesthesia, McMaster University.

Virginie Servant-Miklos, Department of Economics & Business, Erasmus University.

Contact: sherbino@mcmaster.ca

ABSTRACT

This chapter describes how problem-based learning (PBL) was developed and implemented at the McMaster Michael G. DeGroote School of Medicine. Key leaders in its development, the basic educational design and philosophy of PBL, the dissemination and adoption of PBL outside of McMaster, and the four curricular models of PBL over the ensuing 5 decades at McMaster are explored. The chapter ends by considering the evidence of effectiveness of PBL, which is mixed. Despite several program evaluations, the impact of PBL on clinical performance is equivocal. While self-assessment of the utility of PBL suggests a benefit, this finding is not supported by supervisor assessments or objective assessments such as licensing examinations. The complexity of PBL, as an educational intervention, requires program evaluations that measure what works, where, and how.

KEYWORDS

problem-based learning, curriculum, teaching, medical education

Any discussion of educational innovation at McMaster University would be remiss if it did not acknowledge what is undoubtedly the most far-reaching innovation—problem-based learning (PBL)—which was adopted by the then new medical school in the late 1960s. Mention of McMaster at almost any medical meeting elicits the automatic response, "McMaster—PBL."[1] Since its inception, PBL has been widely adopted by over 100 medical schools worldwide, as well as by allied health-professions and other disciplines as diverse as engineering and law (Servant, 2016). While evidence for the effectiveness of PBL is mixed, the impact of this educational innovation is considerable. PBL challenged conventional medical education

curricula of structured lectures and high stakes knowledge-retrieval exams. PBL introduced small groups, self-directed learning, and abolished (for a while) examinations. In effect, PBL introduced a discourse in medical education and in health-professions education, more broadly, about educational design and curriculum development.

In this chapter, the following elements are briefly described: (a) the origin of PBL, (b) the basic educational design and philosophy of PBL, (c) the dissemination and adoption of PBL outside of McMaster, (d) the four curricular models of PBL at McMaster over the past 5 decades, and (e) the evidence of PBL's effectiveness.

The authors approach this scholarship acknowledging their own positionality with PBL. Sherbino is a physician trained in a PBL system outside of McMaster. As an education designer and researcher, he incorporated PBL into curricula he designed. Norman is an education designer and researcher. He co-developed the third iteration of PBL at McMaster and is the co-principal investigator of a systematic review of the educational impact of PBL. Whyte is the former associate dean of undergraduate medical education at McMaster who co-developed the fourth iteration of PBL. Servant-Miklos completed her PhD thesis on the origins of PBL; her scholarship strongly influences this chapter. All authors have championed, to varying degrees, PBL as an educational method. This perspective underlies their interpretation and articulation of the supporting literature.

THE ORIGINS OF PBL

The actors

In 1965, in response to an Ontario government mandate to develop new medical schools, the president of McMaster, Henry Thode, recruited the young, charismatic Toronto cardiologist John Evans as the new dean of the Faculty of Health Sciences. Evans was a truly exceptional individual who, after his tenure as dean from 1965 to 1975, went on to a number of leadership positions, including president of the University of Toronto, a director of the World Bank, and chair of the Rockefeller Foundation.

Evans rapidly gathered an eclectic group of clinicians around him. Acknowledged as the founders of McMaster's medical school, they included Bill Spaulding (internist), Bill Walsh (internist), Fraser Mustard (pathologist), and Jim Anderson (anatomist). They were soon joined by a second wave of clinician educators, Dave Sackett (internist), Moran Campbell (respirologist), Barber (Barb) Mueller (surgeon), and Howard Barrows (neurologist), all of whom actively participated in the development of the undergraduate medical program, which enrolled its first cohort of students in the Fall of 1969.

The curricular design of the new medical school was not pre-determined. PBL did not exist. By accident, the founders formed the nexus of one of the most significant changes in medical education in the past century. None had any formal training in education, and none, except for Barrows, went on to pursue academic inquiry in medical education. There are no published manifestos of PBL in medical education, except for one paper on "The McMaster Philosophy" written by Neufeld and Barrows (1974), published after three classes had already graduated. There was one book, written by Spaulding and published in 1991 that describes the

early history but leaves many questions unanswered. Perhaps the best explanation for "Why then? Why there?" is, as Servant (2016) says, "that the personalities that would have been drowned out in a large bureaucratic institution were allowed to shape the program in their own image" (p. 30). It did help, though, that the common denominator of the founders is that all were personalities writ large, each with a commanding presence and many followers. It is undoubtedly the case that PBL derived from the collective wisdom and charisma of the founders, not from any logical application of best practice, evidence, or theory in education. As such, PBL reflects "an eclectic collection of thoughts and ideas" (Servant, 2016, p. 30).

The context

Any attempt to piece together the various, causal aspects that led to the development of PBL is vulnerable to multiple interpretations. However, it is plausible that the genesis of PBL is, in part, a consequence of the time in which it occurred. Evans came on board in 1965, just at the outset of the 1960s. Society was emerging from the early postwar period of social conservatism and institutional compliance into a time of revolution, frequently violent, with the civil rights movement and the Vietnam War as rallying points. Many of the revolutionaries were students.

The founders of McMaster medical school were not revolutionaries going on peace marches, but they could not be removed from the current social turmoil. Manifestos like *Teaching as a Subversive Activity* (Postman & Weingartner, 1969) and *Medical Nemesis* (Illich, 1975) offered direct challenges to traditional systems in education and health care. In this environment, the design and implementation of a revolutionary approach to medical education was possible. Mueller said in an interview,

> The [unorthodox design of the McMaster medical school] could probably only happen during the 1960s, a decade dominated by a youth culture that had endured neither the deprivation of a Depression or the excesses and brutality of a World War but knew the prosperity and unbridled enthusiasm of the postwar years. . . The youth of the sixties saw the educational system as stultifying, and an undisguised desire for student liberation permeated campus life. (Servant, 2016, p. 114)

Servant and Schmidt (2016) state:

> Indeed, the intellectual and practical influences that fed into PBL would not have transpired if the historical context of the 1960s had not supported radical innovation in education; the foundations of PBL are grounded, more than anything, in a time of social change and economic prosperity. (p. 701)

Influential educational philosophies

Many writers have attempted to establish the philosophical roots of PBL. There is some influence from contemporary psychology, which was rooted in behaviourism at the time and translated to education through Mager's (1962) *Preparing Instructional Objectives*. Servant

(2016) demonstrated that faculty invested considerable time in writing curricular learning objectives but that these were found to conflict with the self-directed learning environment that was fostered in the medical school. The faculty objectives were never implemented.

There is speculation that the founders of PBL were influenced by other educational philosophers. Schmidt (1993) traced the roots of PBL to John Dewey, Jean Piaget, Jerome Bruner, and Karl Popper. However, Servant (2016) was unable to identify any evidence that these writers had any influence on the early deliberations of the founders, who appeared to be "blithely unaware of such influences" (p. 78). Linkages between aspects of PBL and philosophical or evidentiary bases remains unclear. Servant (2016) highlights that any identified associations are not evidence that the McMaster-based designers were influenced by these antecedents.

THE INITIAL FORMULATION OF MCMASTER PBL

The initial operational design of the McMaster PBL curriculum involved a small group meeting early in the week where a clinical problem was presented. Via tutor facilitation, the medical students would determine learning objectives and a group process for achieving them. Over the intervening days, each student would seek out and collate resources to meet their learning objectives. The group would re-congregate near the end of the week to present learnings and discuss and debate interpretation of conflicting evidence to achieve consensus. The tutor was ideally selected to provide facilitation rather than to directly guide or provide expert consultation. There was no common solution or answer key to the clinical problem. Structured large-group learning activities, such as lectures, were rare. Medical students were integrated as observers and participants into the clinical environment early in the curriculum so that learning from PBL cases could be informed by clinical context.

What is PBL? There have been many post hoc attempts to define pure problem-based learning as distinct from hybrid models (i.e., part lecture-based, part-PBL models) (Maudsley, 1999). Unsurprisingly, there is no consensus categorization of the types of PBL (Barrows, 1986). In fact, categorizations of PBL rarely address the educational theory underlying PBL; these categorizations rest on processes and not philosophies. Other medical education curricular designs, such as competency-based medical education, share this issue with PBL, where categorization does not address the underlying education theory (Sherbino et al., 2021).

If PBL cannot be defined by its supporting theory, neither can it be readily defined by common processes. For example, some argue it is not PBL if there are lectures. A distinction also arises between PBL as an entire curriculum, as used at McMaster, and PBL for a single course, which is more widespread. Four curricular versions of PBL, each different in their approach yet still sharing commonalities, have been employed at McMaster (as elaborated in the Evolution section below). Thus, it is very difficult to pinpoint the active ingredients in PBL. Recognizing this challenge, we identify three possibly defining processes of McMaster PBL: (a) the content is organized using clinical problems, (b) the primary instructional method is small-group discussion with a faculty facilitator, and (c) learning is self-directed. Each of these processes is elaborated below, followed by description of how student learning through PBL has been assessed and of the dissemination and proliferation of PBL beyond McMaster.

Problem-based learning

As the name implies, one critical ingredient of PBL is the use of clinical (i.e., patient) problems to organize curricular content. There is, nevertheless, a critical distinction between a problem introduced at the beginning of the curriculum to anchor and structure learning and a problem introduced near the end of a curriculum as an exercise. In PBL, students begin each session (i.e., class meeting) with a problem situation. As they proceed through the problem, they identify learning issues that underlie the resolution or understanding of the problem. This approach to structuring learning is different from the use of a concluding problem, common in curricula, that serves to tie together disparate material presented in the curriculum. Almost universally, PBL problems in medical education are organized around physiology (e.g., inflammation) or anatomy (e.g., renal, or in the first McMaster curriculum, "blood and guts"). This organizing principle derives from an earlier reform in undergraduate medical education, the organ-system approach of Case Western Reserve University in the 1950s (Ham, 1962).

Interestingly, the origin of the term *problem-based learning* is lost in the oral history of McMaster's medical school. An informal inquiry of members from the first generation of faculty conducted by Norman in the 1990s was unable to obtain any attribution. Barrows did publish a book with Robyn Tamblyn (1980) called *Problem-Based Learning*, but he discounted any claim of coining the term. However, the use of educational problems as a stimulus for learning was known to the McMaster medical school founders. Spaulding discovered the case-study method through a friend who was on faculty at Harvard Business School, which used the case-study method (personal communication with GN circa 1980). This method built on the problem-solving method of John Dewey from the 1920s. Ironically, the case-study method was used by the Harvard medical school some 20 years before the inaugural McMaster medical school class but failed due to its reliance on analogical reasoning rather than problems (Servant, 2016). It may be more precise to say that McMaster re-invented PBL years after this similar case-study method had been used at Harvard.

Small-group discussion

The origin of the use of a small group in PBL is also unclear. One account, likely the correct one, is that the McMaster medical school faculty wanted to make space for and encourage discussion and debate as part of the learning experience. Many faculty members were brought up in the "Oxbridge" tradition, where the Oxford/Cambridge tutorial allowed structured discussion between one or two students and one instructor. However, maintaining this ratio was economically and operationally unfeasible, which resulted in compromising with a small group of five to six students. An alternative explanation is that small-group discussion was a common approach of grassroots political organizations during the cultural age when PBL was established at McMaster. This cultural influence was imprinted on the medical school despite the dominance of instructional designs in established medical schools that favoured lecture theatres and lab demonstrations in the preclinical years.

Self-directed learning

The provenance of self-directed learning is much clearer. At the time of the establishment of the McMaster medical school, Malcolm Knowles was an educational populist and had two bestsellers—*The Adult Learner: A Neglected Species* (1973) and *Self-Directed Learning* (1975). Both dealt with an iconic self-directed learner who can identify personal deficiencies, defining learning objectives, and seeking resources to remediate. Self-directed learning, therefore, empowers the student within the PBL system to establish a learning agenda that builds from the problem. This process, introduced at the start of medical training, aligns with anticipated future practice as a physician, where novel problems encountered in the clinical setting and not covered by previous medical training necessitate self-directed research and learning.

While self-directed learning seems a laudable and obvious organizing educational design for medical training, the supporting evidence and theoretical underpinning has subsequently been challenged. Many studies have shown, both within the health-professions and in other domains, that people are notoriously unreliable at self-assessment (Eva & Regehr, 2005). Thus, in the absence of valid identification of personal weaknesses, appropriate identification and prioritization of personal learning needs is impaired. Guided, self-directed learning, where an external, expert facilitator assists a learner in the assessment and establishment of learning priorities, is effective (Eva & Regehr, 2005). However, this line of research challenges the positioning of the learner as autonomous in determining their learning agenda.

Assessment

One issue that involved considerable discussion in the early days is the place of assessment in the curriculum. During the establishment of the McMaster program, contemporary medical schools were dominated by grueling knowledge-based multiple-choice examinations, which are the antithesis of the type of learning environment that the McMaster founders were seeking to create. As a result, at McMaster, assessment was achieved using self-, peer, and tutor assessments drawn from observations of participation and performance in small-group sessions. This approach was the sole assessment strategy for nearly 20 years.

It eventually emerged that this kind of assessment did not provide meaningful information about performance or learning trajectory to either the learner or the school. In 1990, the failure rate of the class was five times the national average on the Medical Council of Canada Qualifying Exam (Part 1). Consequently, in 1991, a structured progress test of basic and applied medical knowledge, called the Personal Progress Index, comprising repeated multiple-choice tests at 4-month intervals, was introduced (Blake et al., 1996). Within one year, performance on the licensing examination was comparable to other Canadian medical schools (Neville, 2009).

Dissemination and proliferation of PBL

McMaster's PBL curriculum would have been forgotten if it were only admired. But within a few years, many medical schools began to adopt PBL. The first, and perhaps the most important adoption for advancing PBL, was Maastricht University Faculty of Health, Medicine,

and Life Sciences, in the Netherlands. While the founding dean of the McMaster Faculty of Health Sciences was a charismatic physician, most of the architects of Maastricht were psychologists—Peter Bouhuijs, Henk Schmidt, Cees van Boven, and Wijnunt Wijnen (and later Cees van der Vleuten). There was considerable communication between the two institutions, but Maastricht adopted its own approach to PBL.

While the McMaster curriculum clearly exposed students to the core content of medicine and took pains to ensure that the curriculum content was balanced appropriately, at some point the process of self-directed learning inhibited a uniform, common learning experience across the student population. As one particularly poignant example, one problem described a middle-aged female executive who had occasional episodes of mild depression and then progressed to describe abnormal results from a random cholesterol check. The goal of the problem was to look at the predictive value of diagnostic tests, but the students in one group decided to focus on social aspects of overdiagnosis of depression in women, completely ignoring the intent of the problem (and the last 10 pages of the case). This direction was deemed acceptable, as their learning was viewed as acquisition of content in the service of enhancing problem-solving skills. The most ardent proselytizer of this perspective was Barrows, who never found reason to change his position.

By contrast, the Maastricht approach viewed PBL as an effective way to mobilize relevant knowledge to solve a new problem; what might now be viewed as an application of the cognitive psychology principle of transfer (Day & Goldstone, 2012). The McMaster curriculum was structured around clinical problems that required a solution—a diagnosis and management plan, for example. At Maastricht, the focus was more on understanding, so that some of the problems in the curriculum, like “Why does a red blood cell expand in salt water and shrink in tap water?” require an understanding of physics and physiology (e.g., entropy and osmosis) for application to issues of clinical presentations of abnormal electrolytes, but not a solution to a clinical scenario (Norman & Schmidt, 1992).

The two perspectives mirrored concurrent developments in the new discipline of cognitive psychology. On the one hand, there were attempts to develop general, context-free problem-solving abilities; on the other, researchers were preoccupied with issues like knowledge acquisition, retrieval, transfer, and expertise.

In the end, the Maastricht position won over the McMaster approach, and more recent versions of McMaster PBL adopt the knowledge-mobilization approach. However, there remain many aspects of medical education that assume, explicitly or implicitly, that the central aspect of expertise is general problem-solving skills (Monteiro et al., 2020). Education research has demonstrated that general problem-solving skills do not exist; rather, problem-solving is a function of experience and is specific to the context in which the experience is acquired (Monteiro et al., 2020).

Other notable adopters of McMaster’s PBL were the University of New Mexico, Wake Forest University, and Harvard University in the United States and the University of Linköping in Sweden. Harvard’s medical school was divided into four societies, and one of these, the Oliver Wendall Holmes Society, adopted PBL around 1984. In an ironic twist a few years later, *NOVA*, the American documentary program, did a story on Harvard’s PBL where they claimed that

Harvard invented PBL (WGBH Boston, 1988), causing considerable rancor at McMaster. As argued earlier, Harvard's legitimate claim to the invention of PBL occurred via the business school, and not the medical school.

EVOLUTION: THE FOUR PBL CURRICULAR VERSIONS AT MCMASTER

In the 5 decades since the first class entered the McMaster medical school, there have been four substantive PBL curriculum renewals at McMaster, each emphasizing and operationalizing the design features (identified above) of organizing content using clinical problems, facilitating small-group discussion, and encouraging self-directed learning. These four renewals, each described in turn below, include (a) biomedical problem solving (1969–1980), (b) priority health problems (1980–2001), (c) essential health concepts (2001–2019), and (d) learning for transfer (2019–present). The success of these curricula has varied depending on the outcomes considered, including national medical licensing examinations scores (Neville & Norman, 2007).

Curriculum 1: Biomedical problem-solving (1969–1980)

While the rhetoric surrounding the new PBL curriculum was focused on individual learning goals, individual experiences, and tailored curriculum, a review of the course materials suggests a prescriptive approach with book chapters, audiovisual resources, and self-assessment multiple-choice questions accompanying each problem. The focus was explicitly on biological mechanisms. Problems were biomedical problems illustrating aspects of human biology and physiology; curriculum units were organ systems (e.g., renal) or mechanisms (e.g., inflammation). In contrast to conventional curricula, basic and clinical science were integrated in the context of the problems as opposed to being taught in stand-alone discipline-based courses (e.g neuroanatomy). As Evans (1967) stated in an internal document, "The aim of the medical school to provide an education in human biology takes precedence over all other aims, whether of the medical school itself or any of its components" (p. 1).

Curriculum 2: Priority health problems (1980–2001)

In the early 1980s, a new generation of medical educators—Neufeld, Barrows, Sackett, and Jack Sibley, among others—took over leadership of the curriculum. The change in leadership also transformed the teaching philosophy to emphasize population health, social determinants of health, and the essential knowledge and skills of a practicing physician. To that end, the second curriculum was structured around priority health problems, identified based on prevalence, severity, treatability, threat to life, and pedagogical value. These problems were then assembled into instructional units. Emphasis shifted from an understanding of basic mechanisms of disease to prerequisite abilities to manage commonly encountered clinical problems. Students were encouraged to query biomedical bibliographic databases (e.g., *Medline*) to identify cutting-edge literature. Each problem was designed to address biological, psychosocial, and population perspectives.

Curriculum 3: Concept-based learning (2001–2019)

The use of realistic, multidimensional, unstructured problems in Curriculum 2 resulted in a plethora of learning objectives, and tutorials were spent more in defining objectives for learning than in learning. Around the turn of the millennium, a task force was established to take a fresh look. While the three essential learning processes (i.e., problem-based, small-group, self-directed) would be retained, everything else was negotiable. In contrast to the first and second curricula, which were not based on learning theories, the third curriculum was explicitly based on current theory of the psychology of learning. It particularly recognized the centrality of knowledge and that learning fundamentally amounts to integrating new concepts with previously learned concepts. As Bjork et al. (2013) say,

> we do not store information in our long-term memories by making any kind of literal recording of that information, but, instead, we do so by relating new information to what we already know. We store new information in terms of its meaning to us, as defined by its relationships and semantic associations to information that already exists in our memories. (p. 419)

Thus, the sequence of exposure to new content is critical to learning. Concepts build on other concepts; random sequences inhibit learning. In the new concept-based curriculum, the design was turned on its head (Neville & Norman, 2007). Instead of a distribution of equally important problems to be learned in parallel, the curriculum sequenced problems to reveal the underlying concepts in appropriate order. Each concept built on previous concepts and led to subsequent concepts. As a final step, clusters of concept sequences were identified to be contained in a single problem, and then problems were assembled. Problems were much shorter, more structured, and more focused. Other changes included increased didactic sessions and the introduction of a specific professional competencies curriculum that addressed issues of ethics and communication.

Curriculum 4: Learning for transfer (2019–present)

The shaping of a fourth iteration of PBL at McMaster followed in the pedagogical progression that had arisen over the prior 4 decades. Emerging gaps and deficiencies from the prior curriculum iteration needed to be addressed. Well-resourced nations like Canada were witnessing an increasing prevalence of patients living with complex and chronic illnesses over the preceding 2 decades with insufficient coverage of these issues in medical school curricula (Touchie, 2013). Importantly, the previous iteration employed an intricate networking of concepts that relied on sophisticated curriculum oversight that can rarely be achieved or maintained when relying on many volunteer and community-based faculty members acting as tutors in the curriculum. The need for a larger faculty tutor cohort was a consequence of the rapid growth of the medical school from a class size of around 100 for many years to a current size of about 250 since the turn of the millennium, which led to a move away from full-time faculty as tutors. These issues led to several important modifications of the fourth generation of PBL at McMaster.

Complex presentations, including multi-organ disease and chronic illness, were moved

from earlier units to the final unit before students entered clinical training, a new pre-clinical culminating Integration Foundation unit. Learners could initially focus on core concepts that were easier for novices to master, working towards more complex concepts later. The Integration Foundation unit facilitated the reinsertion of missing clinical complexity.

The Integration Foundation unit also served as a structural placeholder in the curriculum to revisit core concepts from earlier units and to practice transfer of previously covered concepts to new presentations. Previously, each curriculum domain was only covered once. In other words, the responsibility of concept scaffolding and transfer was shifted from discipline-specific leads of organ-based sub-units to the faculty overseeing the design of the Integration Foundation, which had as a key purpose to integrate concepts from the first year of the program.

Finally, to leverage the educational impact of assessments (i.e., assessment for learning), a more explicit blueprint was created of the concept domains and disciplines to be iteratively assessed and the proportionate representation of each on individual assessments and across all assessments. This assessment blueprinting was more rigorously attended to in the design of the individual assessments and was prospectively audited across assessments, thus ensuring that content was systematically sampled and continuously tested in an iterative fashion (Roedinger & Butler, 2011).

DOES PBL WORK?

In view of the widespread adoption of variations of PBL, it is reasonable to ask whether PBL leads to improved educational outcomes or more efficient curricular delivery. As of this writing, about 30 systematic reviews of PBL in a variety of health disciplines have been conducted looking at various educational outcomes in diverse health-professions. Acknowledging that this chapter is not focused on meta-research of PBL—a synthesis of syntheses—there are several, weak conclusions that arise from these reviews. For knowledge outcomes (the most frequent outcome reported), two reviews concluded that PBL was an inferior strategy compared to traditional curricula that organized learning around basic sciences and delivered information in lecture format. Few studies report clinical performance outcomes (Dochy et al., 2003; Newman, 2003). Albanese and Mitchell (1992) specifically examined the question of clinical performance. While the authors found a trend in favour of PBL over other teaching methods, they stated that the results were inconclusive. One review specifically examined performance in practice, based on self- and supervisor-based assessments (Koh et al., 2008). Self-assessments demonstrated the value of PBL, but this was not supported by supervisor-based assessments. One massive study involving all North American medical schools predicted licensing examination outcomes for graduates of 116 schools over 11 years. PBL curriculum accounted for about 1% of the variability in student performance (Hecker & Violato, 2009). In summary, the evidence for the educational effectiveness of PBL—its impact on acquisition or retention of knowledge or performance as a physician—is equivocal.

Perhaps it is unrealistic to expect that curriculum manipulations will be reflected in student performance on outcomes that are simple to measure, like written licensing examinations. Education innovations like competency-based medical education that have been

implemented at a national level in Canada and the US are directed, in part, to improve aspects of competence like communication, empathy, and teamwork that do not easily reduce to simply measured outcomes (Holmboe et al., 2010). Indeed, one systematic review (Koh et al., 2008) found that the benefit of PBL was strongest in social domains such as population health.

THE IMPLICATIONS OF PBL FOR THE FUTURE OF MCMASTER HEALTH-PROFESSIONS EDUCATION

The impact of PBL on health-professions education at McMaster is demonstrated in three key domains. First, PBL was a response to traditional curricular structures of medical education, likely unconsciously influenced in design by the culture and context of its origin. As the health needs of society change and health sciences become more complex, the education of health-professions must adapt to meet these contextual needs. Future McMaster health professional education must intentionally examine both the established, local education traditions and the contextual needs and culture to be served by future health professionals. PBL does not necessarily require preservation. Rather, the spirit of innovation and contextual responsiveness that imbued this innovation must continue.

Second, as PBL evolved at McMaster via subsequent curricular iterations, greater attention to education theory and the psychology of learning informed the design. With each iteration of PBL, the learnings of previous versions facilitated an evidenced-informed next version that enhanced the effectiveness of the curriculum. McMaster continues to produce education scholarship that informs the teaching and learning of future health professionals. Renewal of current and implementation of new health-professions training programs require incorporation of learning theory and education research into the foundation of the curricular design.

Finally, program evaluations of PBL demonstrate mixed results of efficacy. This overall signal may reflect the challenges of evaluating an entire curriculum composed of numerous instructional methods with longitudinal implementation using a fragile, single measure of effect. Evaluations of PBL suggest that more complex, programmatic approaches are required to interrogate, what works, where, and how.

CONCLUSIONS

A paradox surfaces after reviewing the greater than half century of PBL at McMaster's medical school. On the one hand, PBL was adopted with enthusiasm by the medical education community and has rapidly proliferated around the world. It also became a stimulus for research, leading to hundreds of publications. Moreover, many of the original PBL programs continue to the present day. Yet the initial promise of a new approach to educating a physician—endowed with critical thinking and equipped with self-directed learning skills to meet the challenges of a dynamic career—does not appear to be supported by the evidence. Perhaps, too much is expected from a curriculum.

Nevertheless, the efforts to develop and implement PBL around the world have led to positive, unintended consequences by directing the attention of educators and administrators toward a critical examination of learning and curricula in medical schools. That may be sufficient.

NOTES

1. Or another three-letter acronym, EBM, evidence-based medicine. EBM was developed at McMaster and has been globally influential in the adjudication of diagnostic and therapeutic medical evidence (Guyatt, 1992). But EBM is not an educational innovation.

NOTES ON CONTRIBUTORS

Jonathan Sherbino, *MD, MEd, is the assistant dean of health-professions education research and a professor of medicine, McMaster University. He is an award-winning educator, receiving the top Canadian award for university teaching and educational leadership. As a researcher he has published more than 175 papers and given numerous plenary and keynote addresses.*

Geoffrey Norman, *PhD, is an emeritus professor of epidemiology and biostatistics at McMaster University. He is a highly regarded researcher in medical education, with over 300 publications and 10 books. He held a Canada Research Chair from 2001 to 2014 and is a member of the Royal Society of Canada. He has won numerous awards, including the prestigious Karolinska Institute Prize for Research in Medical Education.*

Robert Whyte, *MD, MEd, is an associate professor in the Department of Anesthesia and is the vice-dean of education in the Faculty of Health Sciences at McMaster University. He was the associate dean of undergraduate medical education during the implementation of the fourth and current iteration of McMaster's medical curriculum. His academic interests include professionalism education and equity in health-professions training.*

Virginie Servant-Miklos, *PhD, is an assistant professor of superdiverse education at the Erasmus School of Social and Behavioural Sciences, specialising in experimental pedagogics, sustainable education, and diversity, equity, and inclusion in education. She is a Comenius fellow at National Directorate of Education Research in The Netherlands.*

REFERENCES

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*(1), 52–81.

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education, 20(6)*, 481–486. https://doi.org/10.1111/j.1365-2923.1986.tb01386.x

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. Springer Publishing Company, Inc.

Blake, J. M., Norman, G. R., Keane, D. R., & Mueller, C. B. (1996). Introducing progress testing in McMaster University's problem-based medical curriculum: Psychometric properties and effect on learning. *Academic Medicine, 71*(9), 1002–1007.

https://doi.org/10.1097/00001888-199609000-00016

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology*, *64*, 417–444. http://doi.org/10.1146/annurev-psych-113011-143823

Day, S. B., & Goldstone, R. L. (2012). The import of knowledge export: Connecting findings and theories of transfer of learning. *Educational Psychologist*, *47*(3), 153–176. https://doi.org/10.1080/00461520.2012.696438

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction*, *13*(5), 533–568. https://doi.org/10.1016/S0959-4752(02)00025-7

Eva, K. W., & Regehr, G. (2005). Self-assessment in the health-professions: A reformulation and research agenda. *Academic Medicine*, *80*(10), S46–S54. https://doi.org/10.1097/00001888-200510001-00015

Evans, J. (1967). *Objectives of the Faculty of Medicine, 1966-1972*. Faculty of Health Sciences Library Archives (Dr. John R. Evans Subfonds, Box 145.8, F.1), McMaster University, Hamilton, Ontario, Canada.

Guyatt, G., Cairns, J., Churchill, D., Cook, D., Haynes, B., Hirsh, J., Irvine, J., Levine, M., Levine, M., Nishikawa, J., Sackett, D., Brill-Edwards, P., Gerstein, H., Gibson, J., Jaeschke, R., Kerigan, A., Neville, A., Panju, A., Detsky, A., . . . Tugwell, P. (1992). Evidence-based medicine: A new approach to teaching the practice of medicine. *JAMA*, *268*(17), 2420–2425. https://doi.org/10.1001/jama.1992.03490170092032

Ham, T. H. (1962). Medical education at Western Reserve University: A progress report for the sixteen years, 1946–1962. *New England Journal of Medicine, 267*(17), 868–874. http://doi.org/10.1056/NEJM196210252671707

Hecker, K., & Violato, C. (2009). Medical school curricula: Do curricular approaches affect competence in medicine? *Family Medicine*, *41*(6), 420–426. https://www.stfm.org/familymedicine/vol41issue6/Hecker420

Holmboe, E. S., Sherbino, J., Long, D. M., Swing, S. R., Frank, J. R., & International CBME Collaborators. (2010). The role of assessment in competency-based medical education. *Medical Teacher*, *32*(8), 676–682. https://doi.org/10.3109/0142159X.2010.500704

Illich, I. (1975). *Medical nemesis: The expropriation of health*. London: Calder & Boyars, Ltd.

Knowles, M. (1973). *The adult learner: A neglected species.* Gulf Publishing Company.

Knowles, M. S. (1975). *Self-directed learning: A guide for learners and teachers*. Association Press.

Koh, G. C. H., Khoo, H. E., Wong, M. L., & Koh, D. (2008). The effects of problem-based learning during medical school on physician competency: A systematic review. *Canadian Medical Association Journal*, *178*(1), 34–41. https://doi.org/10.1503/cmaj.070565

Mager, R. F. (1962). *Preparing instructional objectives*. Fearon Publishers.

Maudsley, G. (1999). Do we all mean the same thing by "problem-based learning"? A review of the concepts and a formulation of the ground rules. *Academic Medicine: Journal of the Association of American Medical Colleges*, *74*(2), 178–185. http://doi.org/10.1097/00001888-199902000-00016

Monteiro, S., Sherbino, J., Sibbald, M., & Norman, G. (2020). Critical thinking, biases and dual processing: The enduring myth of generalisable skills. *Medical Education*, *54*(1), 66–73. https://doi.org/10.1111/medu.13872

Neufeld, V. R., & Barrows, H. S. (1974). The "McMaster Philosophy": An approach to medical education. *Journal of Medical Education*, *49*(11), 1040–1050. https://journals.lww.com/academicmedicine/Abstract/1974/11000/The__McMaster_Philosophy___an_approach_to_medical.4.aspx

Neville, A. J. (2009). Problem-based learning and medical education forty years on. *Medical Principles and Practice*, *18*(1), 1–9. https://doi.org/10.1159/000163038

Neville, A. J., & Norman, G. R. (2007). PBL in the undergraduate MD program at McMaster University: Three iterations in three decades. *Academic Medicine*, *82*(4), 370–374. http://doi.org/10.1097/ACM.0b013e318033385d

Newman, M. (2003). A pilot systematic review and meta-analysis on the effectiveness of problem based learning. Economic and Social Research Council. https://eric.ed.gov/?id=ED476146

Norman, G. R., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine*, *67*(9), 557–565. https://doi.org/10.1097/00001888-199209000-00002

Postman, N., & Weingartner, C. (1969). *Teaching as a subversive activity*. Dell Publishing Co., Inc.

Roedinger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Schmidt, H. G. (1993). Foundations of problem-based learning: Some explanatory notes. *Medical Education*, *27*(5), 422–432. https://doi.org/10.1111/j.1365-2923.1993.tb00296.x

Servant, V. F. C. (2016). *Revolutions and re-iterations: An intellectual history of problem-based learning*. [Doctoral dissertation, Erasmus University]. http://hdl.handle.net/1765/94113

Servant, V. F. C., & Schmidt, H. G. (2016). Revisiting 'Foundations of problem-based learning: Some explanatory notes.' *Medical Education*, *50*(7), 698–701. https://doi.org/10.1111/medu.12803

Sherbino, J., Regehr, G., Dore, K., & Ginsburg, S. (2021). Tensions in describing competency-based medical education: A study of Canadian key opinion leaders. *Advances in Health Sciences Education, 26*, 1277–1289. https://doi.org/10.1007/s10459-021-10049-8

Spaulding, W. B. (1991). *Revitalizing medical education: McMaster Medical School's early years, 1965–1974*. B. C. Decker.

Touchie, C. (2013). *Report of the incidence and prevalence of diseases and other health related issues in Canada: A study for the MCC Blueprint Project*. Medical Council of Canada. https://www.mcc.ca/media/Touchie-Incidence-Prevalence-Report-1.pdf

WGBH Boston (Television station). (1988, December 13). Can we make a better doctor? [Television episode]. *NOVA.* Public Broadcasting Service.