Preparing medical students for future learning using basic science instruction

Maria Mylopoulos[1] & Nicole Woods[2]

OBJECTIVES The construct of 'preparation for future learning' (PFL) is understood as the ability to learn new information from available resources, relate new learning to past experiences and demonstrate innovation and flexibility in problem solving. Preparation for future learning has been proposed as a key competence of adaptive expertise. There is a need for educators to ensure that opportunities are provided for students to develop PFL ability and that assessments accurately measure the development of this form of competence. The objective of this research was to compare the relative impacts of basic science instruction and clinically focused instruction on performance on a PFL assessment (PFLA).

METHODS This study employed a 'double transfer' design. Fifty-one pre-clerkship students were randomly assigned to either basic science instruction or clinically focused instruction to learn four categories of disease. After completing an initial assessment on the learned material, all participants received clinically focused instruction for four novel diseases and completed a PFLA. The data from the initial assessment and the PFLA were submitted to independent-sample t-tests.

RESULTS Mean ± standard deviation [SD] scores on the diagnostic cases in the initial assessment were similar for participants in the basic science (0.65 ± 0.11) and clinical learning (0.62 ± 0.11) conditions. The difference was not significant ($t[42] = 0.90$, $p = 0.37$, $d = 0.27$). Analysis of the diagnostic cases on the PFLA revealed significantly higher mean ± SD scores for participants in the basic science learning condition (0.72 ± 0.14) compared with those in the clinical learning condition (0.63 ± 0.15) ($t[42] = 2.02$, $p = 0.05$, $d = 0.62$).

CONCLUSIONS Our results show that the inclusion of basic science instruction enhanced the learning of novel related content. We discuss this finding within the broader context of research on basic science instruction, development of adaptive expertise and assessment in medical education.

Medical Education 2014; 48: 667–673
doi: 10.1111/medu.12426

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[1]SickKids Learning Institute, The Hospital for Sick Children and The Wilson Centre, University of Toronto, Toronto, Ontario, Canada
[2]The Wilson Centre, University of Toronto, Toronto, Ontario, Canada

Correspondence: Maria Mylopoulos, SickKids Learning Institute, The Hospital for Sick Children, 555 University Ave, Toronto, Ontario M5G 2L3, Canada. Tel: 416 813 7654 ext. 303126; E-mail: maria.mylopoulos@utoronto.ca

INTRODUCTION

The construct of 'preparation for future learning' (PFL) is understood as the ability to learn new information from available resources, relate new learning to past experiences and demonstrate innovation and flexibility in problem solving.[1] This ability has been proposed as a key competence of adaptive expertise.[1] Adaptive expertise is understood to represent excellence in clinical practice[2,3] and, critically, to be the product of a learned skill set that must be developed throughout training.[4,5] Thus, to foster the development of adaptive expertise, educators must ensure both that opportunities are provided for students to develop PFL ability and that assessments accurately measure the development of this form of competence.

Preparation for future learning has emerged in the education literature through studies in the area of learning transfer, which explore the extent to which students are able to transfer their knowledge from one problem-solving situation to the next.[1] Traditionally, studies of learning transfer have focused on knowledge acquisition and have used assessments that require the unassisted, direct replication or application of acquired knowledge. However, more recently researchers have focused on the fact that even the finest problem-solving instruction is unlikely to prepare students for every situation they might come across in practice. For example, despite the efforts of medical educators to ensure that students experience as many problem-solving contexts as possible,[6] it is inevitable that physicians will encounter new problems and contexts they have never seen before. Thus the ability to apply and replicate acquired knowledge is insufficient to enable physicians to perform effectively. Moreover, adaptive experts are expected to be both able to use their acquired knowledge effectively and efficiently, and able to construct new solutions when faced with novel problems.[7] Therefore, education researchers have argued for the inclusion of PFL instruction and testing cycles focused on supporting and assessing the ability of students to learn new knowledge. The challenge lies in developing instructional strategies and materials that best support this form of learning, and designing tests that can make visible developing PFL ability. Early research aimed at developing and assessing PFL has demonstrated that perhaps the most important feature of a PFL approach to instruction and assessment is its potential to make visible the value of those learning activities which have impacts untapped by traditional assessments. That is, two methods of instruction may initially seem to produce the same testing outcomes, but differences in performance may appear when the learners' PFL ability is assessed.[1,8]

In medical education, instruction in the basic sciences may be an example of a learning activity to which PFL principles readily apply. To date, in attempting to evaluate the potential value of basic science instruction, researchers have relied on a traditional approach to assessment, exploring the extent to which students are able to replicate and apply the learning materials.[9–11] Yet, the most powerful argument for the inclusion of basic science in the curriculum is that it serves as a preparatory tool for future learning. Woods[12] argues that the value of basic science training is its ability to assist students with the development of a coherent framework for the understanding of clinical knowledge. Students trained using basic science instruction might therefore be better able to incorporate novel clinical information into their existing mental representations and more quickly solve new diagnostic problems in comparison with students trained without an understanding of the basic science mechanisms of disease. Therefore, basic science instruction can be considered to be a form of PFL instruction and thus a PFL approach to assessment might provide a more appropriate measure for the assessment of basic science instruction. Accordingly, this study represents a first step in addressing the challenge of identifying the instructional strategies and materials that best support the development of PFL ability. The objective of this research was to compare the impact of basic science instruction with that of clinically focused instruction on performance on a PFL assessment (PFLA). If basic science instruction suitably prepares students for future learning, we anticipate that students who learn basic science mechanisms for disease will be better able to learn novel, related disease conditions than students who receive clinically focused instruction.

METHODS

Design

This study employed a 'double transfer' design, adapted from Bransford and Schwartz,[1,8] to determine whether a PFLA can reveal differences in performance between students trained using one of two instructional methods (clinically focused instruction and basic science instruction, respectively) that are undetected in an initial assessment

(Fig. 1). Students first studied the same clinical disorders using one of the two instructional methods in the initial instruction phase. For the remainder of the study, participants learned and were tested on the same material. The double-test design required all students to then complete an initial assessment of learning, demonstrating the knowledge acquired from the initial instruction phase and applying that knowledge in the solution of clinical problems. Students then completed a PFL instruction phase that required them to learn new material. Finally, in the PFLA, students were required to demonstrate and apply the knowledge acquired from the PFL instruction phase in the solution of clinical problems. We expected that students across instructional methods would perform similarly in the initial assessment, but that the PFLA would reveal significant differences in how the two instructional approaches prepare students to learn new material.

Material development

Two faculty neurologists from the Department of Medicine at the University of Toronto were recruited as clinician consultants to develop the instruction and assessment materials for the study.

Instruction materials

Along with the clinical consultants, members of the research team created a list of signs and symptoms and passages describing the underlying basic science mechanisms for eight categories of neurological disease adapted from previous experiments.[13,14] Four of the categories represented general classifications of neurological disease (upper motor neuron lesions, lower motor neuron lesions, neuromuscular junction disorders and muscle disease). The other four categories were more specific examples of these classifications (brainstem stroke, myasthenia gravis, spinal cord compression and polyneuropathy). For the initial instruction phase of the study, we created two sets of learning materials each consisting of four separate narrative passages describing each of the general classifications. One set of instructional materials described only the clinical signs and symptoms; the second set included the signs and symptoms plus underlying basic science mechanisms. As an example, the basic science description of upper motor neuron (UMN) lesions stated: 'In normal functioning, UMNs are responsible for regulating activity lower in the pathway. When they are damaged, the other cells become overactive. This hyperactivity causes the muscle to stiffen, leading to increased muscle tone.' By contrast, the clinically focused narrative passage for the same disease stated: 'It is common for the patient to have increased muscle tone.' For the PFL instruction phase of the study, the instructional narratives described the four specific examples of the classifications and included only the clinical signs and symptoms.

Assessment materials

Memory quizzes

Assessment after initial learning and after the PFL instruction phase consisted of two components: memory quizzes, and diagnostic assessments. First, a series of multiple-choice questions (MCQs) to be answered from memory were used to independently assess participants' basic acquisition of the learning material. These short quizzes were considered as distinct from the initial assessment and the PFLA as they were designed to assess the recognition of facts rather than problem solving. This was necessary to ensure that any differences between the two learning conditions could not be attributed to differential understanding of the basic material. Critically, memory items did not assess basic science knowledge.

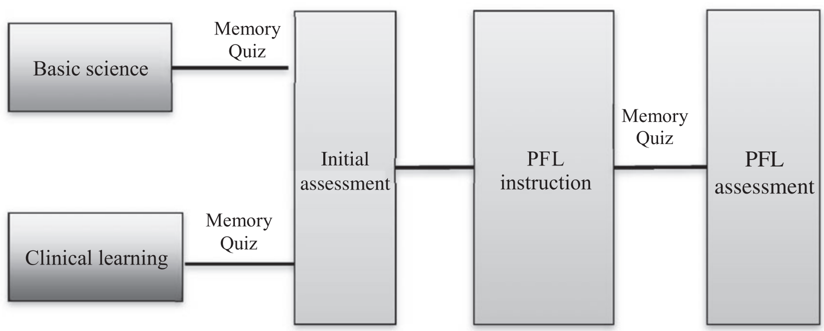

Figure 1 Study design. PFL = preparation for future learning

Initial assessment and PFLA diagnostic tests

By contrast with the memory quizzes, the initial assessment and the PFLA required that students solve clinical cases and not simply recall clinical facts. To create these assessments, the two clinical consultants were asked to independently review and provide feedback on a set of cases drawn from an existing case bank (four broader categories to be used in the initial assessment and four specific diseases to be used in the PFLA). For each case, the consultants were asked to comment on the clarity of the narrative and to indicate what they believed to be the correct diagnosis. Members of the research team modified the cases according to feedback from the consultants and looked for instances of diagnostic disagreement between the consultants and the diagnosis listed in the case databank. For all 32 cases, there was complete consensus between the consultants regarding the correct diagnosis. The end result of this process was the initial assessment, which consisted of 16 cases drawn from the four broader categories, and the PFLA, which consisted of 16 cases referring to the four specific diseases.

Participants and data collection

With institutional ethics approval, pre-clerkship students (Years 1 and 2) at the University of Toronto were recruited to the study cohort via e-mail. This resulted in the enrolment of 51 study participants. Data for three participants were found to include outliers and were excluded from the analysis. Participants were randomly assigned to either of the basic science (BS) or clinical learning (CL) conditions. The experiment was conducted on personal computers with participants in groups of up to four students. All phases of the study occurred within a single experimental session lasting approximately 2 hours.

Participants first completed the initial instruction phase in which they were asked to learn four broad classification categories (upper motor neuron lesions, lower motor neuron lesions, neuromuscular junction disorders and muscle disease) via a custom-designed computer program. Participants in the BS condition reviewed four basic science disease descriptions, which included the clinical features of the respective diseases and basic science mechanisms explaining why each feature occurred. Participants in the CL condition reviewed four corresponding clinical disease descriptions, which included clinical features with accompanying epidemiological factors. To mimic the experience of a classroom lecture, the computer program presented the material in the form of slides to be viewed on the computer screen with accompanying audio-recordings presented through headphones. No time limits were imposed on the duration of study time. Following the initial instruction phase, participants in both conditions were asked to complete a memory test of the clinical aspects of the initial learning material. Students then completed the initial assessment designed to assess diagnostic skill. Participants were required to read a total of 16 patient cases and to select the most appropriate diagnosis. The student's response and the length of time taken to respond were recorded.

Participants were then asked to complete the PFL instruction phase. Having already learned the general classifications of neurological diseases, students were now required to learn four specific examples of those categories. Students read four novel disease passages that had not been presented in the initial instruction phase. Critically, for students in both conditions, the content of the new material was exclusively clinical (i.e. it included no mention of basic science mechanisms). This manipulation ensured that any differences in performance on the subsequent PFLA could not be attributed to differential familiarity with the learning materials. Students were allowed as much time as they liked to read each passage, but were not allowed to return to the passage once they had moved on. Students were then presented with 20 new memory test items assessing their knowledge of the clinical features of the novel diseases. Finally, participants completed the PFLA, which required them to diagnose 16 new patient cases based on the novel disease conditions.

Data analysis

For each participant the proportions of correct responses on the initial assessment and the PFLA were calculated. Performances on memory items and diagnostic cases were analysed separately. To determine whether the two forms of assessment (initial assessment and PFLA) revealed different aspects of performance between the two types of learning (BS and CL), the data were submitted to independent-sample *t*-tests.

RESULTS

Mean ± standard deviation (SD) scores on the diagnostic cases in the initial assessment were similar for participants in the BS (0.65 ± 0.11) and CL

(0.62 ± 0.11) conditions. The difference was not significant ($t[42]= 0.90$, $p = 0.37$, $d = 0.27$). Analysis of responses to the diagnostic cases on the PFLA revealed significantly higher mean ± SD scores for participants in the BS learning condition (0.72 ± 0.14) compared with those in the CL condition (0.63 ± 0.15) ($t[42] = 2.02$, $p = 0.05$, $d = 0.62$) (Fig. 2). There were no significant differences between the two learning conditions in scores on the MCQ memory items administered after initial instruction ($t[42] = 1.23$, $p = 0.22$) or after PFL instruction ($t[42] = 1.06$, $p = 0.296$).

DISCUSSION

Although the two groups of participants showed similar patterns of performance on basic recall and initial assessments, our results indicate that participants who received basic science instruction demonstrated better learning of novel related content than did those who received only clinically focused instruction. These findings are consistent with those of previous studies and support the argument that basic science instruction allows students to develop a coherent framework for the understanding of clinical knowledge, which, in turn, prepares students for future learning.[12] Similarly, researchers exploring adaptive expertise have suggested that the ability of adaptive experts to flexibly use knowledge in new problem-solving contexts is learned through instruction and assessment that focus on interpretive knowing (knowing with), rather than replicative (knowing that) or applicative (knowing how) knowing.[1,15] The inclusion of basic science instruction appears to support this form of learning and thus the development of adaptive expertise more broadly.

This finding is particularly interesting within the broader context of research on basic science instruction. A study in which students were provided with basic science texts and asked to explicitly apply the concepts to solve a clinical problem found that participants were unable to transfer their understanding of basic science to the clinical problem.[9] Some researchers have concluded that the failure of this and other similar studies to uncover the positive impact of basic science supports the claim that no such impact exists.[9–11] Moreover, clinical teachers and students often struggle to see the value of basic science training.[16] Our results imply a different interpretation of this body of research, demonstrating that the use of a PFL assessment of learners' ability to learn novel content makes visible the impact of basic science instruction in ways that traditional assessments (like our initial assessment) do not. Considering these implications more broadly, whereas assessment in medical education traditionally evaluates students' ability to replicate and apply learning material, PFL assessments that explore the extent to which students are able to use their knowledge to learn new content can be used to determine which educational practices in medicine (e.g. basic science instruction, test-enhanced learning[17,18]) are best able to prepare students to be innovative and flexible in their future problem solving. The task for education researchers is to find ways to optimise instruction in order to best support this form of learning and problem solving, and to create assessments that can make PFL ability observable as it develops.

In particular, an emphasis on learning novel content rather than demonstrating the application or replication of prior knowledge has significant implications for our understanding of assessment in medical education, particularly if our aim is to develop

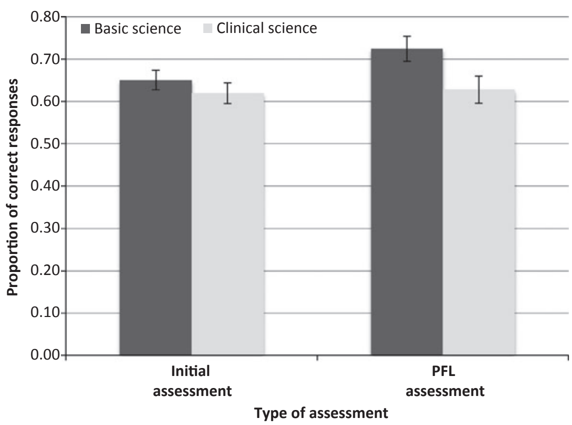

Figure 2 Mean ± standard deviation performance on the initial assessment and preparation for future learning (PFL) assessment by participants after basic science or clinical science instruction

adaptive expertise in our students. Adaptive experts work within what has been described as the 'optimal adaptability corridor', balancing efficient and innovative problem solving in their work. Developing adaptive expertise requires that the same balance be maintained throughout development, thus requiring instruction that is focused on both the efficiency- and the innovation-related dimensions of practice.[7] It can be argued therefore that there is a place for both traditional and PFL instruction and assessments in the development of adaptive expertise.[19,20] Therefore, medical educators must consider exactly how they expect learners to use the knowledge they acquire during different learning activities and subsequently align assessments with the type of knowing they are aiming to foster. Blanket statements about learning based solely on assessments of replication and application are limited indicators of the success of our programmes and our students.

The study has a few notable limitations that may impact the translation of its findings to classroom teaching. Firstly, students in both groups (BS and CL) reviewed the same clinically focused material during the PFL instruction phase. Future studies will incorporate a PFL instruction phase that includes basic science information. This will allow us to determine whether initial clinical instruction can prepare students to later acquire basic science knowledge. Secondly, the tightly controlled laboratory setting of the study (personal computers, audio-recordings) allowed for the standardisation of teaching in a manner that may not be replicable in a real-world setting. Finally, the ability of students to transfer knowledge from the initial learning to the PFL material was likely to have been enhanced by the complementary nature of the materials and the immediacy of the transfer task. However, it is important to note that a large body of research attempting to find instances of spontaneous transfer of knowledge under similar conditions has revealed that successful transfer is notoriously difficult to observe.[21,22] Unlike traditional investigations of transfer, which require the direct application of the solution of one problem to a novel problem, PFL defines successful transfer as the use of the prior experience as a platform for the solution of novel problems. The fact that we shifted our focus from assessing how learners' transfer a specific solution to giving them a foundation for the acquisition of new knowledge probably explains our finding of successful transfer where others have failed.

The implications of a PFL perspective on instruction and testing presented in this paper go beyond our understanding of basic science education. For example, although there are forms of instruction (e.g. problem-based learning, case-based learning) that require students to make explicit links between clinical features and the underlying basic science, traditional assessments do not allow us to explore the extent to which these forms of instruction support the development of PFL ability. Thus, although we began with an examination of basic science knowledge as a platform for adaptive expertise, the general concept of PFL challenges current notions of instruction and assessment in other areas of medical education practice and research.

Contributors: MM and NW both made substantial contributions to the conception and design of this research and to the collection, analysis and interpretation of data. MM drafted the article. Both authors conducted the critical revision of the article and approved the final manuscript for publication.

Acknowledgements: we would like to acknowledge our colleagues, Dr. Ryan Brydges, Dr. Tina Martimianakis, Dr. Mahan Kuselagaram and Dr. Geoff Norman for their critical feedback during all stages of this research.
Funding: funding was received from the Medical Council of Canada Research in Clinical Assessment.
Conflicts of interest: none.
Ethical approval: this study was approved by the Health Sciences Research Ethics Board, University of Toronto.

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Received 22 July 2013; editorial comments to author 16 September 2013; accepted for publication 19 December 2013