

Teaching for Expertise:

Problem-Based Methods in Medicine and Other Professional Domains

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The daily train trip between my small hometown and the university city where I used to work has always provided me with lots of unexpected opportunities to receive feedback about students' perceptions of their education. In all those years I have overheard them talking about their studies, teachers, lectures, peers, but also about parties and village gossip. One conversation, between three students of a beauty care course in one of the community colleges, struck me because of the sensible things they were saying about their curriculum. One of the girls was trying to read a chapter in a book about health for their assignment of that week. The book was meant for all the care and wellness courses, and so was their course, taught by a young physician who - as they grumbled - "was not even handsome". Apart from the appearance of their teacher, which might have compensated a lot, their main complaint was that they did not have a clue about the use of this kind of knowledge for their future practice as a beautician.

The girls' complaint is very similar to the situation students in discipline-organized and teacher-centered academic curricula find themselves in. This kind of curricula has many problems; among them are lack of horizontal and vertical integration of the subjects taught, lack of apparent practical relevance, a constant overload, and emphasis on the principles and practices of the separate disciplines instead of the practices of the profession. As a consequence the students themselves have to find out what and how they can ultimately use the knowledge they are building up during a specific course, if they do so. More importantly, they have to fill in the gaps between the discipline knowledge and the professional application and

practice themselves. Like our future beauticians; can we expect from them that they can apply what they have learned about tumors or immune processes to anti-aging or acne therapy? No wonder that many students learn for the exam and never again think about the topic, let alone that they integrate it with other learning matter.

These problems were recognized by Barrows in the 1960s when he started to work with simulated patients integrated in his neurology courses (Barrows, 1968); later this developed into a complete method (Barrows, 1971). From this work the famous McMaster Problem-Based Learning (PBL) method was developed (Barrows & Tamblyn, 1980). Another, simultaneous movement was the call for community-based education. This was so important because much of the work of a physician is done in the community and not in the hospital. Though countries differ a great deal in this respect (so no generally applicable recipe can be given), the necessity for a community view on the curriculum is generally recognized. Especially the developing countries have strongly advocated and developed this approach. Although PBL and CBL (Community-based learning) can be implemented one without the other, in practice we see that new medical curricula include both. Harden, Sowden and Dunn (1984) have positioned developments in medical education on six axes: Student-centered vs. teacher-centered, integrated vs. discipline-based, systematic vs. apprenticeship-based, problem-based vs. information-gathering, community-based vs. hospital-based, and elective vs. uniform. Four of these continua have already been described here but the third might need some clarification. Underneath the dimension Systematic – Apprenticeship-based one can recognize the discussion whether the problems students are trained with must be selected and developed for them by well-informed teachers, or have to be found in the practice situation students are confronted with. Or, stated otherwise, what provides a better learning

environment, the ward and community with its rich supply of patients and situations students can learn from, or the well-planned curriculum of cases and problems that have been carefully selected to provide good coverage in terms of diseases, patient groups, severity, epidemiology, treatments, and approaches? Harden et al. concluded that the established schools tended to be more on the right hand side of these dimensions, while the newer ones were more often on the left side, although theoretically speaking all kinds of combinations are possible.

These curriculum reforms can be redefined at a more abstract level. They are integrated, planned, geared toward the problems of the field involved, focusing the competencies required for professional life defined by the needs of the community to be served and the perspective of a lifelong career in that profession.

This is in a nutshell the development of PBL in medicine. In this chapter I'll further elaborate several steps in this process. I'll start with a description of the problems with traditional education for the learned professions. Next "traditional" PBL will be described at an instructional and curriculum level, and some new developments will be presented. Finally the question will be raised whether it works or not? To answer this question, attention will be given to the measurement of performance in the professions. Medicine will be used as a prototype for PBL. Where necessary and available I'll give examples from other domains to illustrate the diversity in implementations and to show the reader that the cognitive and practical characteristics of the different professional fields have their implications for educational design.

Traditional Professional Academic Education

Academic professional education is as old as universities are. An example is the university of Bologna (Italy), which is the oldest, still existing European

university dating back to the 11th century. At that time it taught the liberal arts and law. In the 14th century other academic professions were included as well: medicine and the clergy whose education and training so far had been the privilege of the monasteries. The most famous medical faculty at that time was Padua, also in Italy, where famous scientists as Vesalius and Falloppio taught. The curriculum structure that was developed at that time has remained the norm for many centuries. Basic sciences such as anatomy, herbology, and later physiology and pathology were taught in the first years, while in the clinical phase bedside teaching was the dominating work-form. Da Monte may be considered as the founder of the clinical sciences in the 16th century. He introduced ward rounds with the medical staff and students, followed by discussions on diagnosis and treatment. Boerhaave brought this system to perfection in Leiden, the Netherlands, in the early decades of the 18th century. He emphasized the connection between biomedical knowledge and clinical observations, and systematically used post-mortems to check the analyses and conclusions based on history and physical examination (Kidd & Modlin, 1999).

Other curricula for professional education share the emphasis on a thorough introduction into the basic sciences of the field, but deviate from this approach in the sense that a systematic introduction to the practical sciences is missing. Instead graduates work as trainees or volunteers to build up practical experience and skill.

An exception is legal education in the USA. By the end of the 19th century it was recognized that neither a systematic, lecture-based introduction nor the apprenticeship method were very effective. To solve this problem, Christopher Langdell of Harvard Law School introduced the case method in 1870, a method that still dominates legal education in the USA (see Williams, 1992).

Returning to the basic sciences curricula. Problems with this kind of curricula do not only have to do with problems of “not-seeing-the-use-of-it” as expressed by our future beauticians and with lack of integration, also issues concerning changed opinions in society about professional accountability and risk avoidance, curriculum overload, changed opinions about task and role of the professional play a role (see Dornan, Scherpbier, & Spencer, 2008).

Horizontal and Vertical Integration

Horizontal and vertical integration regard the links between basic science knowledge (horizontal) and between basic and clinical or other applied sciences (vertical). Integration as a cognitive process is not automatic. Connections between parts of the knowledge bases will only be constructed when they are activated at the same time. This can be due to simple reminding processes, when reading or hearing about one concept or principle in one context is reminiscent of something else studied earlier. For instance, studying the production of bile and storage and transport through the gall bladder may remind one of anatomic knowledge of the gall bladder and upper abdomen. Later both knowledge parts can again be activated when studying a patient case about bile stones. More intensive cognitive operations such as elaboration, critically processing or application will result in more and stronger links between the knowledge parts.

The utility of knowledge integration is not self-evident for students. Especially during secondary education they may have been confronted with teachers who ridicule them when asking questions about the link between topics in history and economics, or about the difference between how different disciplines use a term as “capital” or “elasticity”. Integration in medicine is not self-evident either. Some experiments with co-teaching by a clinician and a bioscientist have only been

successful when organized bottom-up by colleagues who know and trust each other and value each others' work.

Another reason why organizing a curriculum that promotes integration can be difficult is that the different groups not always agree about the level of detail that should be reached. Koens, Custers, and Ten Cate (2006) found that basic scientists and clinicians agreed on the inclusion of concepts at the clinical, organ and cellular level. However, they strongly disagreed about the importance of knowledge at the molecular level. Together with the cellular level this is, however, the area where tremendous scientific progress is being made at this moment.

Curriculum Overload

The diverse sciences and academic disciplines that inform professional knowledge and practice have their own dynamics and their own development. For instance, recently the nanotechnology, genetics, and proteomics have made quantum leaps affecting the fields of pharmacology and medicine, but also engineering. Also the legal field is subject to change. It has to do with international changes, and treaties overruling national legislature. For instance, the establishment and growth of the European Union has resulted in an abundance of articles and analyses in most legal domains about the consequences for the national – now 25 nations – legislation and jurisdiction. The dynamics in economics and business administration is strongly related to economic change. Uncritically incorporating all these developments in a curriculum will inevitably lead to overload. However, in most such situations new scientific knowledge does not replace old knowledge.

Overload is a problem that especially afflicts the traditional professional curricula. The disciplines in such curricula have their own independent place and make their own independent decisions about content. Teachers who find themselves

in a situation where they have a semester of two lecture hours and two hours of practical training and lab available to teach their discipline do not have many selection criteria. One is time. The other is based on the systematic approach to their discipline, its basic findings, systems, theories, and methods, and recent developments. The third is their own appreciation of their domain, the things that make them tick and that they want to convey to their students. Every year new methods, theories, and findings require an addendum to the syllabus. No need to say that the connection with practice and other disciplines is not guaranteed this way.

Accountability and Risk Avoidance

Professions differ in the inherent risks and dangers. Lawyers may lose their court cases, surgeons' operations may result in unforeseen complications, investment decisions may lead to substantial losses, an architectural construction may not be resistant to strong winds or collapse under its own weight, etc. But also less costly errors, sometimes made in a split second, can have long-lasting effects on clients' health, or physical or financial wellbeing. There is a big difference between Europe and the USA in the way professional mistakes are legally dealt with. The number of lawsuits against professionals is much larger in the USA. Yet, also for Europeans the tendency toward a greater transparency of professional services and accountability of professionals is unmistakable where professional bodies or the state require that they are competent and certified. This affects both the content of undergraduate training as well as the position of the student or the apprentice on the work floor. It also affects the perception of practice as a learning situation.

Task and Role of the Professional

In the recent years many professional bodies have tackled the question how the profile of the future professional would look like. Their explorations of future

developments and scenario studies were based on trends in the profession and in society. These studies have resulted in advice regarding both work and education of the professional-to-be.

For instance, the General Medical Council (1993, 2002) has published several books and articles on the changing roles and duties of physicians in the UK. Similarly, the Royal College of Physicians and Surgeons of Canada has published its “The CanMEDS 2005 Physicians Competence Framework” in which it has inventoried and analyzed the roles of the physician with the intent to improve the practice standards, train better physicians and provide better care (Frank, 2005). It describes the roles that only partly overlapped with the prototype of the medical doctor many generations grew up with, and that still underlies many undergraduate, graduate, and specialist training programs. It discerns the Medical Expert – being the central role, integrating and forming the basis for the other roles -, the Communicator, the Collaborator, the Manager, the Health Advocate, the Scholar, and the Professional role. Some of these roles are relatively new such as communication, collaboration and management; other roles date back till Hippocrates but have accumulated new content.

Implications

The combination of the tendency toward more accountability and risk reduction on the one hand, and renewed descriptions and prescriptions of the role of the professional in society on the other, has led to a trend to train undergraduates in such a way that they are well prepared for practice, or at least have the key competencies at the level of independent though supervised practice as a new entrant. Yet, professions vary along this dimension. It is the danger of harm being done to the clients or to the professional him- or herself in the practical situation a new entrant

has to work in that defines how 'complete' the graduate must be on entering the workplace.

For instance, a newly trained pilot must be able to do all procedures on all occasions under all circumstances with all aircraft one is certified for. There is no second chance for wrong solutions, and skills cannot be trained while in the air. Medical graduates, nurses, operators in process industry, or teachers are much like pilots. Their jobs have a real-time character; routinized, unreflective actions are based on instant responses to immediate recognition; errors made can have very negative or long-lasting effects on the people in their care. At the other end of the spectrum we find professions such as engineering design or law trainees who can do much of their work off-line and have the possibility to discuss their proposals with their supervisors before bringing things into effect. Eraut (1994) analyzed the time characteristics of different workplaces and professions. He characterized the latter type as deliberative analysis and decisions, and actions following a period of deliberation. These characteristics of the workplace graduates are prepared for affects the amount of practical training that has to be included in these curricula in real or simulated settings.

As a consequence of these developments many professional academic curricula adopted problem-based learning as their instructional and curriculum format. Well-chosen, authentic problems provide the context in which basic and applied sciences are studied integrated. The same problems also provide the key for selection of relevant subject matter. They are a means for integrating relevant skills training.

Problem-Based Learning as an Instructional Method and as a Curriculum Strategy

Problems

As an instructional method, PBL departs from authentic problems, which students analyze in small groups. These groups are chaired by a student and supported and supervised by a tutor. By doing so, students suggest explanations and solutions of the problem, but more importantly, they recognize gaps and inconsistencies in their knowledge. This leads to the identification of a set of learning goals that in turn spark the students' learning. Many PBL implementations require that students themselves identify the learning resources and materials that best fit their goals and their own preferences. This does not mean that students do not have lists of selected handbooks or web-portals, but a one-to-one relation between learning goals and resources (up to the precise page numbers) will not be provided. Typically, two or three PBL sessions per week are being held, chaining activities of problem analysis and learning goal identification one day, and discussion of what has been learned and problem solution a few days later; independent learning activities take place in between. After having completed one problem, the analysis of a new one immediately starts off (Footnote 1). Table 1 gives typical examples of PBL problems from different faculties of Maastricht University.

Problems are chosen to serve specific goals. Schmidt and Moust (2000) have developed a classification system that is based on these different cognitive goals, that is, the kind of knowledge to be built. They discerned three kinds of academic and professional knowledge (descriptive, explanatory, and procedural), and personal, normative knowledge. Each cognitive goal can be tackled with a dedicated kind of problem: descriptive knowledge is often addressed with fact-finding problems,

explanatory knowledge with explanation problems, and procedural knowledge with strategy problems. Personal, normative knowledge is mostly acquired through moral dilemma problems. Problems can be presented in a pure form, but mixes are possible too. Also students can choose learning goals that emphasize something else than the planning group intended, depending on their own interests and on the gaps and inconsistencies they may have identified.

For instance, ‘What a mess’ in Table 1 is typically an explanation problem meant to build explanatory knowledge, bringing together theories on expertise development, neuropsychology, and work psychology. These theories and the supporting evidence may partly contradict. The key problem in this vignette underlies Lidy’s worries: Does older age or alternatively overtraining of one’s skills set prevent or impede learning a new, similar but different skills set? If so, how? If not, how? To find answers to these questions students first discuss their pre-existing knowledge and identify strategies to find and evaluate additional information, both in terms of validity and reliability of the source and the content of the information, and in terms of the case they are dealing with. In this case, students must weigh two phenomena described in the literature: On the one hand, high levels of expertise enable learning new knowledge and skills in the same domain, also at old age; on the other hand, experience concentration may result in very rugged skills profiles with combinations of very well trained and neglected areas, with skills obsolescence lurking in the future if the content and context of work may change. Especially these neglected areas may hinder new learning. The students’ learning in this specific case does not only require learning theories plus supporting evidence but also critically evaluating information according to scientific rules, and weighing and combining the results in order to formulate an answer for Lidy’s problem.

‘Melena’ also regards explanatory knowledge, but probably the planning group also intended procedural knowledge goals. It is very well possible that the students take this task as an opportunity to revise descriptive knowledge and find out all about specific kinds of lab values, what normal and abnormal values are and what they indicate. Students often formulate a problem like this in a general way: “What is the diagnosis? And explain the findings.” In this case they have to explain how black stools, high pulse rate, low Hb, elevated thrombocytes, and epigastric tenderness are related. A further evaluation of the case does not only entail the diagnosis (plus possible alternatives plus their plausibility, and how they can be differentiated) but also an evaluation of the severity of the situation and possible progression. Based on this analysis they may also discuss what a doctor should do.

‘The Company’ is a strategy problem meant to build descriptive and procedural knowledge in the domain of business administration. Theory learning is not on the foreground here. One of the skills students must learn and apply here is a thorough analysis of the company itself, as an example of a specific kind of company as opposed to other companies (e.g., manufacturing and marketing cosmetics vs. a fast food chain), and as a player in a dynamic environment. Finally ‘Will you defend me?’ is a moral resolution problem, aimed at building personal, normative knowledge. The issue here is the alignment of personal emotions, norms and value, and professional standards.

There is some debate about the role and required competencies of the tutor. In the early years of PBL it was thought that everyone with good social and group skills could be a tutor. So even secretaries and lab personnel acted as tutors. Most of them were not very successful and students had a clear preference for domain experts, that is, for doctors in case of a medical faculty. Moust (1993) tested a model of tutor

functioning in a law school, using several instruments including a tutor observation scale, a group functioning questionnaire, and some outcome variables: hours spent on self-directed learning, grade, and interest in the course topic at the end of the module. Outcomes were accumulated at the group (N=38) level; tutor expertise varied from master students to domain experts. A path-analysis showed that a combination of (use of) domain expertise and social congruence (active and personal involvement with students) leading to cognitive congruence of the tutor (this is the skill of tutors to put themselves in the place of a student, and to express themselves in terms understandable for students) is the key to successful tutoring. This had a direct positive effect on group functioning and, through that, on both student grades and interest in the topic. Tutors also play a role helping students to determine whether they have covered the intended material, have gone deep enough into that material and applied scientific reasoning skills the right way.

Courses and Curricula

Apart from a description at the problem level, PBL can also be depicted at the course and at the curriculum level. To reach the ultimate goals described above, more is needed than working with authentic problems. Apart from these problems, such a course can consist of a set of lectures, skills training and integrated knowledge application, and learning in real or simulated practice sessions. The resulting course is the product of a careful analysis of the knowledge, attitude, and skills goals and the required mastery level to be reached, combined with an analysis of the most suitable workforms. Course planning groups must take care that teachers are not left to their old reflexes but are well prepared for their new role. Lectures are a telling example. Many teachers love to lecture. Left to themselves they could fill the whole course with lectures on their topics disrupting all careful planning done. Lectures should be

used only for those things that students cannot easily read in the standard books: new developments, topics that are known to be difficult for students and that easily lead to misconceptions, introductions to disciplines that students have not yet become acquainted with (examples are sociology or ethics for medical or law students), and demonstrations (e.g., patient demonstrations for medical students) (Footnote 2).

Finally, student evaluation and assessment must fit the type and level of the goals of the course and the curriculum. Saying this is in itself almost a platitude. Yet, practical PBL implementations have shown a myriad of exams that contradict this basic principle of educational testing. Reasons of efficiency, but also perceptions of validity, reliability, and of what is good educational testing, may underlie these choices. For instance, it is easier to secure good content coverage using multiple-choice questions, but the disadvantage is that such exams tend to be superficial and fact oriented. However, the most important reason is probably that exam construction comes always last and suffers from the planning group's tailing energy. Under optimal conditions the design of student evaluations should be an integrated part of course and curriculum design. Early planning of the content and format of assessments will contribute to the relevance and representativeness of the assessments in relation to the domain being taught. Good exams require students to show their mastery of the domain in terms of factual knowledge, critical analysis and evaluation, as well as application in relevant contexts at the level that can be expected of students in this stage of expertise development.

At the curriculum level decisions must be made about the organizing principles within and over years. An example of such an organizing principle – again from medicine – is organ systems: gastrointestinal, neurological, respiration, sexual, etc. For the structure within modules similar decisions must be made. One may

choose to work starting from the relevant biomedical structures and processes and its growth and regulation, followed by disease and malfunction as expressed in different cases. Again principles for choosing these cases must be agreed upon: e.g. will we prefer frequent problems over severe, will typical cases be chosen or atypical and do we use authentic or pre-processed cases? Furthermore, decisions must be made about integration between courses, practical experience, etc. This is also the level in the organizations where gaps in the curriculum and duplicates of topics that return in several courses should be identified and rectified.

Different Goals and Different Implementations of PBL

PBL has seen from its inception many different implementations, at different levels. For instance, PBL in McMaster has traditionally consisted of long patient cases. The goal was that apart from knowledge students develop good problem solving and management skills. At this moment a profound curriculum reform (Norman, et al., 2004) is taking place in which information-seeking skills of the students are de-emphasized and information-processing skills are prioritized. The curriculum will be reorganized around critical concepts, problems in a course will be ordered in such a way that it can help students to further refine their knowledge base and differentiate between diseases and clinical manifestations. Finally, the role of ICT is redefined. Also in the clinical rotations new formats will be developed, in which mobile ICT will play a prominent role to capture individual experience in the clinical rotations. The reasons for this reform are very diverse, ranging from the normal wear and tear of the curriculum to the new needs due to changes in the role of the physician (see above), while both the present emphasis on evidence-based practices and the ever increasing availability of relevant information require different information skills than before.

PBL in the medical school of Maastricht University has always paid much attention to the integrated study of the basic and clinical sciences aiming a well-developed and -integrated knowledge base. More recently it concluded that academic competencies should receive more attention and that the strict divide between the four-year pre-clinical and the clinical period should be diminished. This change that had immediate effects on knowledge acquisition, which was shown in the analyses of the progress test results of different batches of students before, during and after the curriculum change. A progress test is a periodical test pitched at the end of curriculum level. Each student takes parallel forms of the test 24 times before graduation. The results of these students were compared with the results of students in two other medical schools on the same tests in which such a curriculum change had not taken place (Muijtjens, Schuwirth, Cohen-Schotanus, & Van der Vleuten, 2008).

Manchester University Faculty of Medicine more recently changed into PBL, at first in the two-year preclinical phase only, later also in the clinical period. Reason for the latter change was mainly curriculum coverage (see Patel, David, Boshuizen, & Wolfhagen, 1998). To integrate PBL and experiential learning, self-directed learning in between the two discussion sessions should not only include printed and e-materials, but also practical learning resources that are available in the clinical context. Examples are clerking a relevant patient, observation in a specific clinic, or participating in community activities. It was soon recognized that students needed a lot of support to identify relevant activities. They had problems finding out what was going on in the clinic but even more so to recognize what could be important for their learning goals and to get access to these activities. Hence a sign up system was developed that included a database that contained all activities where students were welcome to participate, the number of students allowed and –most importantly- the

learning goals that could be achieved through that activity. Part of the requirements for participation was that students evaluated the activity and reported on their learning before they could sign up for a new activity (Dornan, Hadfield, Brown, Boshuizen, & Scherpbier, 2005).

Bringing the concept of PBL to other professional areas requires a careful analysis of the structure of practice in that field and of the relation between basic and applied sciences. For instance the typical PBL structure in medical faculties largely resembles the situation in the outpatient clinic in which several patients presenting different complaints and having different backgrounds enter the office within an hour and cooperation with other physicians or other health professionals is not very prominent. The tempo and structure of work in software engineering, law or marketing do not fit this very well. Tasks and projects do not only take longer but teamwork of cooperating specialists may be an essential quality of the work. Adaptation of PBL tasks to such features may greatly improve students' learning and knowledge application as was shown by Arts, and colleagues (Arts, Gijssels, & Segers, 2004, 2006) when they redesigned the Company case and course, shown in Table 1. This task was expanded to several weeks, and restructured to facilitate the different levels of system analysis described above. An analysis of what makes learning in that domain difficult can also be of help, and should actually be part of all educational design (see Nieveelstein, Van Gog, & Prins, 2008, and Williams, 1992, for the domain of law).

PBL and Expertise Research

For many years education and educational psychology had no relation whatsoever with expertise research, not even with knowledge. Only in the last decade

could the first break with this long tradition be witnessed, when “How people learn,” the book by Bransford, Brown, and Cocking (1999), was published. The professional fields were faster with their recognition of the importance of expertise development research for the design of their curricula. Examples of domains where curriculum change was not only inspired by changes in the profession and the society but also by expertise development research are law (due to the work by Crombag, de Wijckersloot, & Cohen, 1977), economics (see Gijsselaers, Tempelaar, & Keizer, 1994), and medicine (see below). Bédard

Medical Expertise Development Research

Medicine is the professional field most intensively researched when expertise development is concerned. The first studies were by Elstein, Shulman and Sprafka (1978) who investigated clinical reasoning by students, subexperts, and experts. It was generally expected at that time that there would be a big difference between these groups in their diagnostic accuracy and in their processes of clinical reasoning. However, research showed no significant differences, neither could these authors find differences between top experts nominated by their peers and mediocre physicians. I myself started my research in this domain about the time their book had just been published, and I could only conclude that it was a period of strong convictions about differences in expertise that could not be supported by empirical evidence. For instance, when trying to find experts who were willing to participate in my studies, I was more than once informed that there was no need at all for an experiment like this, because everyone already knew how clinical reasoning worked, and how it should be done and taught. Another telling example was a family physician who participated in my first think aloud study (reported in Boshuizen & Schmidt, 1992). He carefully read all presented information aloud as requested but showed no thinking. My

standard question “Please keep thinking aloud” resulted in the remark: “Well, I don’t think yet, I try to postpone thinking to keep my mind open, but actually I thought that he might have ... [and several hypotheses were formulated].” This physician showed strong adherence to the ideology that good clinical reasoning is characterized by an open mind, and postponement of hypothesis generation until all information has been gathered to prevent premature closure. The outcome that groups differing in expertise level did not differ in reasoning style or strategy was very disappointing though we found that the more expert groups (experienced family physicians compared to 5th, 4th and 2nd year medical students) had better diagnoses and better diagnostic hypotheses. And it was recognized that these non-findings were in fact very telling and that the outcomes so far showed great resemblance to De Groot’s 1946/1968 chess findings.

To quote Elstein Shulman, and Sprafka (1978, p 276):

“Thus investigations of problem solving in chess, in logic, and in medicine are converging on the same conclusion. The difference between experts and weaker problem solvers are more to be found in the repertory of their experiences, organized in long-term memory, than in differences in the planning and problem-solving heuristics involved.”

Once it was recognized that findings in medical expertise research were so similar to De Groot’s (1946/1965) findings, many researchers followed in his footsteps to find out whether De Groot’s measurements would also lead to interpretable results in medicine. De Groot’s keyfindings were that experts did not think better but thought better things, and that experts could better remember elaborate, midgame board positions than less expert players. In medicine the latter findings could only be partially replicated. Boshuizen (1989, later extended by Van de

Wiel, 1997) could demonstrate that many articles showed a positive, monotonic relation between levels of expertise and recall measures. However, researchers constructed these results by reporting amount recall divided by the total amount of time spent on reading a case or by dividing it by amount of time taken for reproduction. At the basic level the relation consistently turned out to be an inverted U-shaped relation. That means that when given ample time intermediates remember more of a case than novices and than experts. However, when time is seriously constrained (from 3 minutes 30 seconds down to 30 seconds) experts perform better than medical students, in recall and again in diagnostic accuracy (Schmidt & Boshuizen, 1993).

This outcome and other phenomena in the recall (e.g., interpreted vs uninterpreted recall) was taken as an indication that experts' knowledge structure allows that they process information in a different way than intermediates (advanced medical students) and novices (beginning medical students). Other, more direct methods such as priming (Rikers, Schmidt, & Boshuizen, 2001) could corroborate these conclusions. Also think-aloud, self-explanation, and post-hoc explanation studies showed how the quality and organization of basic and applied science knowledge changed with increasing expertise levels. Table 2 summarizes the conclusions derived from these studies.

Does It Work?

Though theory and practice of PBL are scaffolded by the outcomes of expertise research, it does not relieve PBL-schools of the task to show that their approach indeed has the desired effects. That is, can the following questions be answered with "Yes"? Do students learn better? Have they learned better? Do graduates have better fitting jobs? And Do they do a better job? Before we try to

answer these questions some caveats are needed. Assessing the effects of PBL can be done in two ways: Historical comparison within one school or one course (before and after the innovation) and comparison between schools or courses. Both approaches have inherent design flaws related to the general quality of faculty and content of the curriculum, and to selection and self-selection of students. Rarely do we see studies in which students have been randomly allocated to a PBL or a traditional version of one course or a whole curriculum. The aspect of selection and self-selection is less problematic in PBL-studies in the domain of medicine that have been done in the Netherlands where a national committee selects students on basis of their grades on the national exams at the end of secondary education and allocates them to one of the medical schools on basis of availability and student preference (Footnote 3). Some researchers doubt whether comparisons between institutions are worth the effort. They have reservations regarding the value from the perspective of curriculum improvement. The huge amount of bias and error in these studies make them ineffective in that respect, they say (Footnote 4). They expect more from process-oriented research especially dedicated to the affective and learning processes and the related instructional measures.

Comparisons made between PBL and non-PBL schools and courses in medicine mostly regard the first two questions. In the final part of this chapter I'll review research that can answer these questions.

Do Students Learn Better?

The question whether students learn better, regards effects on instructional and educational parameters as well as cognitive and affective processes and content; e.g., do students learn better in terms of process and outcomes? Are they better motivated? Are the attrition rates lower? Hmelo, Goterer, and Bransford (1997) have argued that

to assess the effect of PBL not just knowledge should be taken into consideration, but also the theoretical goals of PBL (clinical reasoning, integration of clinical and biomedical knowledge, lifelong learning skills) and that cognitive measures derived from expertise research should be used.

Many of such investigations have been done since the early 1970s. A couple of review studies have summarized the outcomes. The first burst of reviews was in 1993 (Albanese & Mitchell, 1993; Berkson, 1993; Vernon & Blake, 1993), followed by a new burst about ten years later (Colliver, 2000; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Gijbels, Dochy, Van den Bossche, & Segers, 2005; Hmelo-Silver, 2004; Schmidt, 2006). The first and most famous (narrative) review was by Albanese and Mitchell (1993). They concluded the following (p. 52): “Compared with conventional instruction, PBL, . . . , is more nurturing and enjoyable; PBL graduates perform as well, and sometimes better, on clinical examinations and faculty evaluations; and they are more likely to enter family medicine. Further, faculty members tend to enjoy teaching using PBL. However, PBL students in a few instances scored lower on basic sciences examinations and viewed themselves as less well prepared in the basic sciences than were their conventionally trained counterparts.” Vernon and Blake (1993) reviewed the same studies but used a statistical meta-analysis. They found that PBL was superior regarding students’ appreciation of their program and regarding clinical performance. No differences could be detected regarding knowledge outcomes. However, PBL students did slightly worse on the NBME Step 1 test (National Board of Medical Examiners). Berkson’s (1993) study in the same year was again a narrative synthesis of almost the same set of studies. Her conclusion was that there were no differences between graduates of the two kinds of curricula, but that the costs in terms of stress and money were too high.

Colliver's (2000) conclusion, several years and several studies later, contradicted this. He found no convincing evidence – or evidence of a practically relevant magnitude - regarding knowledge and clinical performance, but concluded that PBL was more challenging, motivating and enjoyable for the students.

Later, methodologically more rigorous analyses by both Dochy et al. (2003) and Gijbels et al. (2005) built again on these previous reviews, extending the database and doing more dedicated analyses. Hmelo-Silver (2004) did a narrative, theory driven analysis. Dochy et al. (2003) extended the database with other articles from refereed journals or book chapters of health related curricula, written in English. Their statistical meta-analyses searched for main effects of curriculum on knowledge and skills, and for moderating effects for possible differences between curricula, such as the empirical design of the study and the kind of assessment instrument used. These instruments were very diverse: MCQ, modified essay questions, long and short essay questions, progress tests, free recall, performance-based testing (ratings), standardized simulated patients, long and short cases, etc. Dochy et al. concluded that there was a robust and positive effect of PBL on cognitive and sensorimotor skills, and a tendency to negative results on knowledge, which was mainly due to two outliers. They also concluded that the trustworthier research designs were associated with less negative results regarding knowledge acquisition, i.e. the most negative outcomes were found in studies using historical comparisons. Furthermore students' expertise levels were related with effect size and direction of knowledge outcomes, but these differences disappeared when knowledge application is tested in the context of diagnostic tasks. Effects of retention period suggested that PBL students might have acquired slightly less knowledge but retained that knowledge better, while their skills were superior at immediate tests and were also better retained. Finally, the assessment method used in

the studies affected the outcomes. The more an instrument required the integrated use of knowledge in representative contexts, the larger the positive effect of PBL was.

Gijbels et al. (2005) investigated the effect of assessment methods identified by Dochy et al. (2003) more deeply. They did not only include studies in medicine and the health field but also a few other domains. They differentiated between knowledge tests regarding concepts, principles, and application. Results showed that the more complex knowledge that was tested performance favored PBL students, while the simple test items on concepts did not yield overall significant differences between PBL and traditional curricula.

Hmelo-Silver (2004) reviewed the PBL research literature trying to formulate lessons for other educational fields than medicine. Her conclusion about knowledge and skills are similar to Dochy et al. (2003). She also concluded that self-directed and self regulated learning is not learned automatically in PBL. In the beginning all students struggled in directing their own learning to attain success with PBL. However, students lacking solid skills in self-directed learning had problems with PBL. Current PBL programs do not provide instructional means to help students to develop these skills. At the other part of the spectrum a similar problem can negatively influence learning of highly competent and experienced self-directed learners. PBL-theory and practice does not provide guidelines for reduced teacher control (Vermunt, 2000). Hmelo-Silver also concluded that only few studies have been done that focus the effect of one distinctive feature of PBL, i.e., cooperative learning. Similarly, effect of on motivation of cooperation and of PBL as a whole has been hardly investigated.

Finally, Schmidt (2006) reviewed 16 studies in which PBL and other medical curricula in the Netherlands were compared. He also included studies published in the

Dutch language. Again it was found that different curricula did not yield positive effects on knowledge outcomes, but that PBL students scored higher on skills and skills-related tasks. Schmidt (2006) also reported consistently lower attrition rates for PBL curricula. When we take the outcomes of expertise research into account, we may indeed conclude that PBL curricula lead to better learning.

Have students learned better?

The question whether students have learned better regards effects on outcome at the graduate level. Outcome criteria can be formulated in terms of key competencies reached, but many professions judge their new entrants in terms of knowledge only. An example of such an entrance test is the NBME step 3 examination of the US Medical Licensing Examination. This test takes two days. One and a half day is spent of multiple-choice questions; the rest is taken by solving computer simulated patient management problems.

The analyses made by Dochy et al. (2003) reveal that only 8 of the 43 studies that had been done, included this level of competence. No comparisons were based on NBME step 3 results. Five studies included comparisons based on knowledge tests using students in their final year; three studies did the same using skill related tests. Only 6 of these studies reported information about the numbers of participants involved and/or the basis for comparison of their findings (see Table 3). The findings of graduates are not much different from those of students. PBL graduates do better than those of traditional school on skills, but not on knowledge tests.

Do Graduates Have Better Fitting Jobs?

Not many PBL schools will claim that their graduates will get better jobs. Yet, assuming that PBL graduates are better prepared for the job implies that they should

end up at least having better fitting jobs, or have built competencies that better fit the jobs they have.

Studies that directly address this question could not be found. However, Meng (2005) investigated how well problem- and project-based education had prepared graduates for the generic and domain-specific competencies required in their jobs, about three or four years after graduation. His research deviates in many ways from the usual PBL-evaluations presented above. He compared about 25,000 graduates of higher education institutes in nine countries in different parts of the world and with different educational systems and labor market dynamics, using graduates' self-ratings and estimates of the necessity of the rated competencies in their job. Furthermore, he distinguished between activating (problem- and project-based) curricula and not activating (laissez-faire or teacher-centered) schools. Meng found that in general students in activating study environments ended up with an academically oriented competence mix, maybe a bit deficient in domain-related specific competencies. He also found that students who spent more time on the acquisition of discipline specific competencies through self-study or by study-related employment did that successfully. Since his study dealt with graduates from a huge variety of studies and schools, it is hard to say whether this specific finding would also be found when the professional schools are analyzed as a separate group. His finding that dedicated training on discipline-related specific competencies yields positive outcomes can be taken as an indicator for that. Another indication might be that the same analyses done for tertiary vocational education again shows that the activating environments result in better general academic competencies while these groups of students did not show negative effects on domain specific competencies.

Do Graduates Do a Better Job?

Another consequence of the claim that PBL graduates are better prepared for their jobs is that they should also make a difference in the practice they become part of. For instance, medical graduates of a school that promotes integrated care for the elderly should show more collaboration with other allied health workers and more preventive actions. After a couple of years their actions and the results of their actions should be detectable in the health statistics. From the viewpoint of the public served, thus the most important question is whether PBL graduates perform better.

This question is only rarely investigated. An exception is a study by Tamblyn, Abrahamowicz, Dauphinee, Girard, Bartlett, Grand'Maison, and Brailovsky (2005). These authors could use four health administrative databases to derive indicators for the graduates' preventive care, continuity of care, precision of the diagnoses (this was derived from the prescription rate of dedicated medicines versus symptom relieving medicines), and quality of patient management (which was derived from the prescription rate of contra-indicated drugs for a specific age group). These criteria reflect the changed tasks of the physician; they mainly concern the Medical Expert role. Tamblyn et al. compared health care effects of graduates before and after a curriculum reform of Sherbrooke medical school (historic controls). They also compared them with graduates in the same years of three other Canadian medical schools where no curriculum reform had taken place. The findings showed that introducing PBL resulted in improvements on preventive care, continuity of care, and precision of the diagnoses as expressed by the improved prescription rate of disease specific drugs. No improvement was found on the prescription rate of age contra-indicated drugs. These health care indicators of graduates from traditional schools were stable over the same period. Despite the improvement on three indicators, the

PBL graduates only performed best at the preventive and continuity of care indicators and was second best on the two medication indicators.

Conclusion

Can we conclude that PBL is indeed a good way of teaching for expertise? This overview suggests that it is, though a couple of remarks have to be made. The first is the use of measures that can capture expert performance. We have seen that most knowledge tests used in the comparisons do not meet that requirement. Only some of the skills measures used can be characterized as addressing the core competence of the medical profession but even these can be criticized. For instance, the short cases tests used by Schmidt, Machiels-Bongaerts, Hermans, Ten Cate, Venekamp, and Boshuizen (1996) and by Schuwirth, Verhoeven, Scherpbier, Mom, Cohen-Schotanus, Van Rossum, et al. (1996) were rather prototypical in nature and preprocessed in the sense that they were formulated in encapsulating terms. Both features facilitate relevant knowledge activation. Furthermore, the tasks did only ask for diagnosis; patient management and treatment were not included. Research by Harasym, Papa, and Schumacker (1997) suggests that the higher expertise levels are able to make finer discriminations exactly on these dimensions. Research into expert performance and effects of education and training misses such an instrument that is sensitive to these differences. Second, PBL in its present format needs better concepts regarding support and development of self-directed and self-regulated learning. The attention given in the new McMaster curriculum to information skills may help students to monitor more complex kinds of learning. Third, careful course and curriculum planning is needed based on knowledge of stages and characteristic difficulties in expertise development in the specific field. Similarly, monitoring the

curriculum in action is the best way to prevent wear and tear. A well-designed and maintained PBL learning environment is the best way to prepare for professional practice we have at this moment. Improvement of the triad Learning task – learning process – learning outcome and its evolvement over a period of several years requires attention to all aspects alike. Implementations that neglect parts of it will be affected in all respects. The first three conclusions formulated here require further research. Especially a better alignment of measurement instruments and procedures and expertise level might have both theoretical and practical value.

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Footnotes

1. Actually, implementations of PBL in community colleges will often deviate from this format by giving the students more structural and content support and working in a different timeframe. In this case a day may start with a problem analysis and be closed with discussion of what has been learned, while the learning resources may be pre-selected or even transformed to a more digestible format.

2. Remarkably even very well planned courses from the problem and training perspective, can be very sloppy regarding lecture planning and communication. H. A. M. Snellen-Balendong, personal communication January 29, 2007, Maastricht, NL.

3. This situation has changed lately when medical schools were allowed by the ministry of education to admit students on basis of specific experience or motivation. Only a few schools use this option.

4. Cees van der Vleuten, Maastricht, January 8, 2007. Also see Visschers-Pleyers (2007).

#. All problems have been translated and adapted from UM course material. The Company is an abbreviated and anonymized description of a real PBL problem, based on descriptions in Arts, Gijsselaers and Segers (2002). Will you defend me? is from Schmidt and Moust (2000). What a mess! and Melena by courtesy of Faculty of Health, Medicine and Life Science.

##. Table 2 has been reprinted from Boshuizen & Schmidt (2008). Reprinted with permission from Elsevier.

Table 1. Four PBL problems (footnote #)

<p>What a mess!</p> <p>The ladies at the university's switch board, Lidy, Elly, Carla and Ingrid, are having a terrible time at their work. This week a new telephone system has been put into operation and everything goes wrong. Before, it had been explained to them in depth how the new system worked, and they also had the opportunity to practice with it. Everybody felt well prepared. But things are not running as smoothly as they had thought. The ladies have to keep their mind closely on what they are doing. This is hard to manage because other employees also run into problems and start to phone them: the telephone is ringing all the time. Especially Lidy, the oldest and most experienced of them all, is having a hard time. Normally she could always do something extra, such as knitting, but not today. They all hope and expect that it will be going better in a few weeks and consider the problems of today as typical starting problems. Only Lidy is worried and wonders whether she is getting too old and slow to adapt herself to new situations, and whether she will ever be able to work with this new telephone system. Of course, she does not show it, but she has her doubts.</p>	<p>Faculty of Health Science, 1999-2000</p>
<p>The Company</p> <p><i>Context: The Company problem consists of a description of the firm, and links to different pages with information about the consumers, production, research, market position, etc.</i></p> <p>The Company's strategy can be characterized as fast paced globalization of their business. It aims for total coverage of international markets.</p> <p>The Company group now generates 96% of sales in four segments its covers for over 50 years, and has concentrated its efforts on ten major global brands, which are responsible for 87% of its sales. Kelly Kreuger, Chair and CEO of The Company, is planning a strategic meeting with the management committee to discuss implications of potential strategic alliances with current competitors.</p>	<p>Faculty of Economics and Business Administration, 1999-2000 Arts, Gijselaers and Segers (2002)</p>
<p>Melena</p> <p>A 64-year old accountant presents to his GP's office with weakness and epigastric pain. He has a 20-year history of mild dyspepsia. He has a long history of cigarette smoking, drinks alcohol moderately and has been taking aspirin since two weeks for lower back pain. Since two days he noticed "jet-black, sticky stools that looked like tar."</p> <p>On physical examination he looks pale, blood pressure is 130/70 mmHg, the pulse frequency is regular (110/min). There is tenderness in the epigastrium to the right of the midline. Further physical examination reveals no abnormalities except for the presence of tar-like stool by rectal examination.</p> <p>Laboratory: Hb 6.5 mmol/l Thrombocytes 421 *10⁹/l Alkaline phosphatase 98 U/l Gamma-GT 40U/l Urea 12.2 mmol/l Creatinine 84 µmol/l</p>	<p>Faculty of Medicine, 1996-1997</p>
<p>Will You Defend Me?</p> <p>"You are staring aimlessly into the fire of your cigarette. Your client has just told you about the crimes he has committed. His story was awkward. Numerous serious sexual assaults were described in detail. He described incidents of drug trafficking and severe physical abuse. In the same breath, he told you about his bitter childhood experiences: his stepfather, who mistreated him; his mother, who neglected him; his brothers and sisters, who made life miserable for him. He concluded his story with a desperate gesture and asked, "Please, will you defend me?" "</p>	<p>Faculty of Law, 1985-1986 Schmidt and Moust (2000, p 60)</p>

Table 2. Knowledge restructuring, clinical reasoning and levels of expertise level (Footnote ##).

<i>Expertise level</i>	<i>Knowledge representation</i>	<i>Knowledge acquisition and (re)structuring</i>	<i>Clinical reasoning</i>	<i>Control required in clinical reasoning</i>	<i>Demand on cognitive capacity</i>	<i>Clinical reasoning in action</i>
novice	networks	knowledge accretion and validation	long chains of detailed reasoning steps through pre-encapsulated networks	active monitoring of each reasoning step	high	difficulty to combine data collection and evaluation and clinical reasoning
intermediate	networks	encapsulation	reasoning through encapsulated network	active monitoring of each reasoning step	medium	...
expert	illness scripts	illness script formation	illness script activation and instantiation	monitoring of the level of script instantiation	low	adjust data collection to time available and to verification/falsification level of hypotheses

Table 3. Results of final year students and graduates from PBL and more traditional schools on knowledge and skills test.

	<i>N subjects</i>	<i>Measurement</i>	<i>Results</i>	
	<i>Pbl comp</i>		<i>Effect Size</i>	<i>p-value</i>
<u><i>Studies of Knowledge</i></u>				
Saunders et al., 1990	45 243	MCQ	- 0.716	<0.0001
Van Hessen & Verwijnen, 1990	179 *	MCQ	-	<0.05
Albano et al., 1996	120 181	MCQ	=	
Verhoeven et al., 1998	135 122	MCQ	- 0.385	<0.01
<u><i>Studies of Skills</i></u>				
Schmidt et al., 1996	100 est.	30 cases	+ or =	
Schuwirth et al., 1996	32 25	60 cases	+ 1.254	<0.001

Based on Dochy et al. (2003). Reported information per study if available: Number of subjects in the PBL and comparison groups (* is compared with a national standard); kind of measurement used; direction and size of the effect (+ means that the PBL group did better, - did worse, = no difference); and p-value.