The Development of Diagnostic Competence: Comparison of a Problem-based, an Integrated, and a Conventional Medical Curriculum

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ABSTRACT

Purpose. To compare the diagnostic performances of students in five curriculum years educated at schools with problem-based, integrative, or conventional medical curricula.

Method. Data were analyzed in 1994 for 612 students in their second, third, or fourth (preclinical) or fifth or sixth (clinical) years at three Dutch medical schools with problem-based, integrative, or conventional curricula. The students gave differential diagnoses for 30 case histories that were epidemiologically representative of Dutch society and covered all organ systems. The numbers of accurate diagnostic hypotheses were tallied for each of the groups involved. The data were analyzed using analysis of variance and post-hoc Newman–Keuls tests.

Results. Overall, the students trained within the problem-based framework and the students trained within the integrated curriculum made more accurate diagnoses than the students trained within the conventional curriculum. No overall differences were found between the students in the problem-based and integrated curricula, although the second- and third-year students from the latter performed better than the second- and third-year students from both other schools.

Conclusion. Integration between basic and clinical sciences and an emphasis on patient problems may be the critical factors that determine superior diagnostic performance rather than whether a curriculum is self- or teacher-directed. Problem-based learning seems to live up to its expectations, but so does the integrated approach to medical education. In addition, the procedure for measuring diagnostic performance appears to be valid and to provide a simple means of measuring curriculum effects. It remains to be seen whether the findings would be replicated when students are allowed to freely gather data in open interaction with patients rather than respond to written presentations of cases.

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One of the original reasons for promoting problem-based learning (PBL) as an approach to medical education was that students would be in a better position to learn how to solve medical problems. Barrows[1-2] and Tamblyn,[2] early proponents of PBL, assume that through continuous exposure to real-life problems and problem solving as modeled by their tutor, students would acquire the craft of evaluating a patient's problem, deciding what's wrong, and making decisions about appropriate actions to treat or manage the problem. In their view, fostering clinical-reasoning or problem-solving skills is a primary goal of PBL, a goal not sufficiently emphasized in more traditional approaches to medical education. The assumption here is that PBL facilitates the acquisition of diagnostic-reasoning skills to a larger extent than does conventional medical education.

Other researchers are more skeptical about the possible effects of PBL on the diagnostic performance of students.[3-6] Schmidt and colleagues,[5] for instance, argue that most of the medical-expertise literature suggests that medical problem solving is case-specific to an extent that the existence of knowledge-independent clinical-reasoning skills can be seriously questioned (see also Elstein and colleagues[7]). If clinical-reasoning skills do not exist independently of knowledge, they cannot be taught in a direct fashion. What, then, is the role of PBL in this respect? Norman[3] puts it this way: "If the game is not to teach the problem-solving process, how does

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one justify the use of clinical problems as the central feature of a curriculum? The answer is straightforward. PBL is simply a case of learning 'stuff' as students work their way through a clinical problem. In general, the 'stuff' is unspecified. Some of it is the usual stuff of medicine—Krebs cycles and Starling laws. However, the problem is unbounded, and the stuff also encompasses epidemiology, psychology, pharmacology, and just about any other -ology available in medical, behavioral or social science." Boshuizen and Schmidt[6] argue that the ability to solve a patient's problem may emerge as a by-product of the attempt at comprehending the multiple ways in which the human body functions and fails to function. Therefore, whether PBL would lead to better diagnostic performance would depend to a large extent on the quality, comprehensiveness, and thoroughness of the knowledge-acquisition process. These authors do not exclude the possibility, however, that mere exposure to case histories may affect recognition of particular diseases in similar case histories. Since students in PBL programs generally see more case histories than do students in conventional medical education (simply because cases are the stimuli for most of the learning in PBL), this may produce superior diagnostic performance on similar case histories. Hmelo,[8] for instance, found that cases previously discussed in a problem-based curriculum had a positive effect on subsequent diagnostic performance in similar cases. This implies that Barrows may be right, but for a different reason.

What is the evidence in favor of each of these positions? To what extent do students from PBL schools perform better—or in other ways differently—on diagnostic tasks compared with students from more traditional approaches?

Three studies address this issue in some detail. Patel and colleagues[9] asked subjects from conventional and problem-based curricula to solve a clinical problem and integrate three passages of relevant basic science knowledge into their explanations of the problem. The students from the problem-based curriculum advanced many more causal explanations than the students from the conventional curriculum. However, although the students from the problem-based curriculum did produce a large number of causal explanations, many were incorrect.

In a study of the effects of curriculum type on knowledge integration, Boshuizen and colleagues[10] compared the performances of preclinical students from two medical schools, one problem-based and one conventional. The students were asked to explain how a specific metabolic deficiency and a specific disease could be related: e.g., "How does a genetic deficiency of pyruvate kinase lead to hemolytic anemia?" In answering this question, knowledge about biochemistry and about internal medicine must be applied and integrated. The students from the problem-based curriculum appeared to take an analytical approach to the problem by first exploring its biochemical aspects and later linking them to clinical aspects. The students in the conventional curriculum tended toward a more memory-based approach. They searched their memories to find a direct answer to the question. This strategy, however, resulted in significantly fewer accurate answers and more failures by the students from the conventional program.

A third study was recently completed by Hmelo.[8] At three points in time, she compared the diagnostic performances of about 40 preclinical students who were either participating in a conventional track or a PBL track at Rush Medical College of Rush University. Over the course of a year, the students were presented with two cases at each of three points in time. They were requested to produce a diagnosis and an explanation of the signs and symptoms provided in each case in terms of their underlying pathophysiology. The accuracy of diagnostic hypotheses produced by the PBL students increased linearly over time, whereas the students from the conventional track did not show different performances at the three measurement points. Hmelo concludes that, in the course of the year, the students from the PBL track were able to apply the biomedical knowledge they had acquired to the clinical cases, whereas the other students failed to do so. As indicated above, prior encounters with similar cases by the PBL group influenced the results, but the data indicated that case recognition did not account entirely for the difference between the groups. There was also a beneficial effect of PBL beyond the experience it provided with specific types of cases. In addition, the PBL students showed more coherence in their pathophysiological explanations as measured by the length of their reasoning chains.

To say that these three studies point in the same direction would be an overstatement. Although in all the studies PBL students produced more causal explanations, in only two of the studies were the causal pathophysiological explanations of better quality. In Hmelo's study, the PBL students came up with more accurate diagnoses, whereas in Patel and colleagues' study, the PBL students performed poorer than students from a traditional curriculum.

There may be several reasons for these inconsistencies. The first is that the number of students used in the three studies was fairly limited. Boshuizen and colleagues employed no more than eight students, four from each school. Patel and colleagues employed 72 students, who were, however, assigned to six different experimental conditions. Although statistical tests take into account small numbers (the smaller the number of subjects, the stronger the experimental effect must be), and the use of small samples is fairly common practice in cognitive-psychology research, the fairly global nature of the treatment (PBL versus non-PBL) in combination with sampling errors may account for the inconsistencies. A number of studies conducted in the United States have taken a different (more molar) approach by comparing the performances of larger groups of students from traditional and problem-based curricula on the comprehensive examination of the National Board of Medical Examiners (NBME).[11–12] These studies have, generally, shown that students from problem-based schools do somewhat better on the clinical parts of the NBME examination and somewhat poorer on the basic science part. It can, however, be argued as to what extent these tests measure problem-solving skill or diagnostic performance.

A second reason may be that different programs may employ different admission criteria, making the groups dissimilar to begin with. Although the Rush students were similar in a number of characteristics, such as Medical College Admission Test (MCAT) scores, it is hard to believe that a student's preference for either the PBL or the conventional track is the result of pure chance and has nothing to do with differences in personality or other characteristics. The McMaster University School of Medicine and McGill University Faculty of Medicine students, compared by Patel and colleagues, are known to have different background characteristics due to different admission criteria.

A third, more important, reason why the findings are difficult to interpret may be the small number of clinical cases employed. As stated before, one of the most consistent findings in the medical-expertise arena has been that diagnostic performance is to a large extent case-specific. Performance by physicians or students in one or a few cases poorly predicts their performance in other cases. Therefore, performance as observed in the experiments discussed may have depended to a large extent on the particular cases selected, which may have favored one group or the other. A remedy would be to increase the number and extend the nature of cases used.

In the present study, we compared the diagnostic performances of 612 students from three Dutch medical schools: a problem-based school; a school with a systems-based, integrated, but teacher-driven curriculum; and a school with a conventional discipline- and lecture-based curriculum. The students were presented with 30 carefully selected clinical cases, which covered all organ systems and were epidemiologically representative, in an attempt to avoid possible bias caused by case specificity. In addition, the study profited from the Dutch allotment system, whereby academically qualified students are admitted to the different medical schools through a lottery procedure in which preference for a particular instructional approach plays only a minor role. This feature enhances the opportunity for making meaningful comparisons.

METHOD

Subjects

The subjects were 612 second-, third-, fourth-, fifth-, and sixth-year students at three Dutch medical schools in 1994, approximately 40 students per curriculum year per school. (Medical students in The Netherlands go to school for six years: four years of preclinical and two years of clinical training.) The students volunteered to participate and received a small remuneration in return. In the absence of relevant data, no check could be made as to how similar the students were when they enrolled in medical school. It has been shown, however, that no entrance differences exist among the students of the eight Dutch medical schools, probably due to the lottery procedure used to admit students. There is no reason, therefore, to assume a priori differences among the groups involved other than differences caused by the particular curricula studied. These 612 students constituted approximately 5% of the total population of medical students in The Netherlands.

The Curricula Compared

The University of Limburg medical school in Maastricht has had an established problem-based curriculum since the early 1970s. It was, in fact, the second school in the world to adopt the problem-based approach. Students meet twice a week for small-group discussion of problems. In addition, they participate in a limited number of lectures, laboratory activities, and more extended training in interpersonal and physical examination skills. The rest of their time is scheduled for self-directed learning activities.

The academic medical center of the University of Amsterdam has a curriculum that integrates the biomedical and clinical sciences around major organ systems. Students engage in patient demonstrations and small-group training sessions in which knowledge previously acquired is applied to relevant clinical cases. Although it employs some small-group learning, the Amsterdam curriculum contains more structured elements, such as lectures, laboratory work, and so on, than does the Maastricht curriculum. In addition, students are not considered to be self-directed; chapters, books; and articles are all prescribed.

At the time of this study the University of Groningen medical school curriculum could have been characterized as conventional: i.e., discipline-oriented and teacher-centered. The study was completed just before the University of Groningen embarked upon a new, largely patient-oriented and integrated curriculum.[13]

Materials

The materials consisted of 30 short case histories, each approximately half a page long, that covered all organ systems and were epidemiologically representative of the kinds of diseases prevalent in Dutch society. The cases were particularly selected based on the pattern of diseases seen in family practice. The test consisted of a combination of more prototypical, textbook-like cases and cases drawn from actual practice. Each of the cases included the presentation of a patient and his or her complaints, physical examination findings, and laboratory results whenever appropriate. A list of normal laboratory values was included. The cases were bundled into a 17-page booklet. The following case is a representative example:

> A 65-year-old woman visits you, her family physician. She enters your office with red eyes, suggesting that she has been crying. She tells you that she is worried because she has lost so much weight. After you have calmed her down, she tells you in a cascade of words that she has lost 12 kilograms, although she eats well. She worries about this state of affairs very much, sleeps poorly, and is restless and agitated. She does not take any drugs. Her family history displays nothing unusual. Upon physical examination you find a sick, restless woman with sweaty, warm skin. The thyroid gland is diffusely enlarged. Blood pressure is 150/89 mmHg; pulse rate is 140/min, irregular/unequal. The legs show pitting edema. The heart is enlarged, and a souffle suggesting mitral insufficiency is heard. Laboratory data: T_4, 300 nmol/l; T_3, 10 nmol/l; TSH, 0.05 mU/l. ECG shows atrium fibrillation accompanied by a high ventricle frequency.

List 1 shows the diagnoses of the 30 cases. The cases were difficult for the groups involved; the group with the highest level of expertise attained an average score of 38.6 out of 67, equaling a 58% score.

List 1

Diagnoses for the Cases Presented in a Comparison of the Diagnostic Competence of 612 Students at Three Dutch Medical Schools with Problem-based, Integrated, or Conventional Curricula, 1994

Case 1	Hyperthyroidism
Case 2	Subdural hematoma
Case 3	Paralysis agitans (Parkinson's disease)*
Case 4	Polyneuropathy
	—due to diabetes mellitus†
Case 5	Myasthenia gravis
Case 6	Ankylosing spondylitis
Case 7	Tenosynovitis
Case 8	Polymyalgia rheumatica
Case 9	Pyelitis
Case 10	Renal cell carcinoma
Case 11	Bladder carcinoma
Case 12	Acute glomerulonephritis
Case 13	Pneumothorax
Case 14	COPD (chronic obstructive pulmonary disease)†
	—with an allergic component†
	—with a hyperreactive component†
Case 15	Pneumococcal pneumonia
Case 16	Congestive heart failure, right- and left-sided
Case 17	Cardiac asthma with atrial fibrillation
	—with mitral regurgitation†
	—with tricuspidalis regurgitation†
Case 18	Myocardial infarction
Case 19	Hepatitis B
Case 20	(Acute) pancreatitis*
	—due to gall stones†
	—due to biliary obstruction†
Case 21	Reflux (esophagitis)*
Case 22	Melanoma
Case 23	Psoriasis (vulgaris)*
Case 24	(Seborrheic) dermatitis*
Case 25	Otosclerosis
Case 26	Salpingitis
Case 27	Endometriosis (externa)*
Case 28	Ovarian cysts
Case 29	Laryngeal carcinoma
Case 30	Appendicitis

*Omission of the information between parentheses did not influence the accuracy rating of the diagnosis.

†An additional credit point was awarded for this information.

Procedure

The students were put in small groups of varying sizes within a time frame of two months. There were no systematic differences among the schools in terms of when the tests were taken. The students were requested to read each case and provide a differential diagnosis if they could. If they were unable to come up with a specific diagnosis, they were allowed to state which organ (or system) seemed to be affected or which pathophysiological mechanism seemed

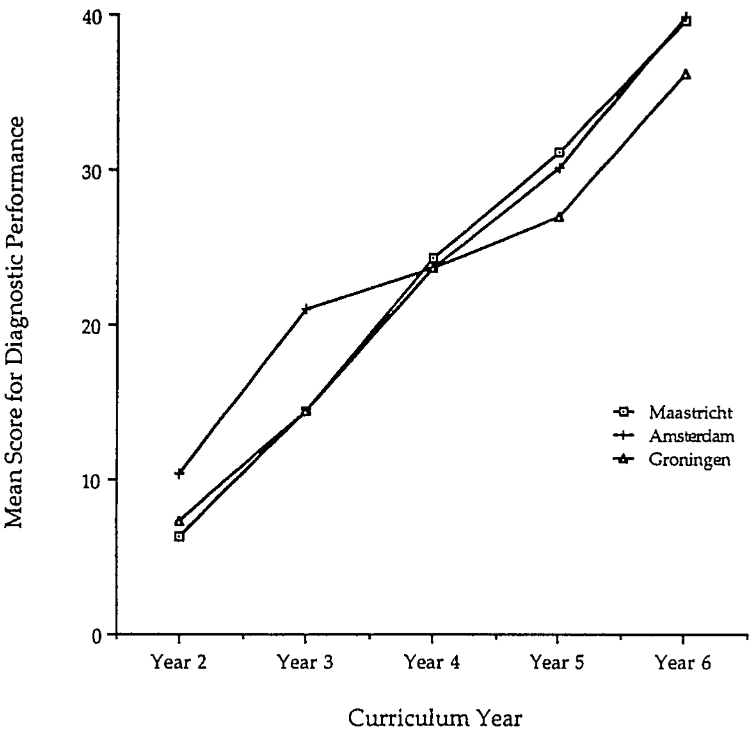

Figure 1. Average diagnostic performance as a function of school and curriculum year, 612 students at three Dutch medical schools, 1994. The University of Limburg medical school in Maastricht has a problem-based curriculum; the academic medical center of the University of Amsterdam has a curriculum that integrates the biomedical and clinical sciences around major organ systems; and the University of Groningen medical school had, at the time of the study, a discipline- and teacher-oriented curriculum. There were approximately 40 students per curriculum year per school. The students were tested on 30 cases (see List 1) over a two-month period. The maximum score was 67. Statistically significant effects were found for curriculum year, curriculum type, and the interaction between the two. (See text for details about the scoring system and statistical analysis.)

to be involved. They were encouraged not to spend too much time on each of the cases. All students were, however, given sufficient time to complete the test. The following scoring system was used: If the correct diagnosis appeared as the most likely one in the differential diagnosis, the answer was awarded two credit points. If the correct diagnosis appeared as part of a differential diagnosis but not in first position, the answer was awarded one credit point. The accurate diagnoses for cases 4, 14, 17, and 20 could contain one or two additional elements, each credited with one additional point. The maximum score for the test as a whole, therefore, was equal to 67. Interrater agreement between two independent judges exceeded 90%; differences of opinion were resolved through discussion. The resulting data were analyzed using a 3 × 5 analysis of variance, involving three levels of curricular treatment and five levels of expertise.

Results

A statistically significant effect of curriculum type on diagnostic performance was found, $F_{(2,597)} = 14.40$, $p < .0001$, $MS_e = 535.42$. In addition, an effect of curriculum year on performance was demonstrated, $F_{(4,597)} = 457.49$, $p < .0001$, $MS_e = 17{,}007.16$. Finally, both variables interacted with each other, $F_{(8,597)} = 3.795$, $p < .001$, $MS_e = 141.09$. Figure 1 shows the average diagnostic scores for each of the schools and all levels of training involved.

Post-hoc Student–Newman–Keuls tests revealed that, overall, the students from the conventional Groningen medical school performed poorer than those from the other two schools. Comparing means among the groups by curriculum year shows that the students from the integrated Amsterdam curriculum performed significantly better than the other two groups in the second and third curriculum years, whereas the students from the problem-based Maastricht curriculum performed better than the students from the conventional curriculum in the fifth and sixth years, but not better than the students from the integrated curriculum in those years. The students from the integrated curriculum also performed better than the students from the conventional curriculum in the fifth and sixth years. Differences between adjacent curriculum years within each of the schools were all statistically significant at the .05 level.

Discussion

The findings presented in this article represent, to our knowledge, the first large-scale study that compares the diagnostic performances of medical students from different curricula under semicontrolled conditions. The cases presented were epidemiologically representative of diseases seen by Dutch family physicians and covered the major organ systems. The number of cases to be diagnosed was much larger than those included in similar studies, in an attempt to avoid outcomes biased by case specificity. In addition, the number of students involved and the five levels of training included also depart from existing practices.

We will first discuss differences between the problem-based and the conventional programs. Subsequently, we will deal with the data comparing the problem-based and the integrated curricula and their implications.

The students trained within the context of a problem-based curriculum showed better diagnostic performance than the students from the conventional curriculum. A significant overall effect of curriculum type was found. At the end of the six years, the Maastricht students performed about 5% better than the Groningen comparison group. The question is, of course, whether this 5% represents a meaningful portion. Expressed in terms of accuracy of diagnostic performance, this percentage means that the Maastricht students on average diagnosed 1.5 of 30 cases more accurately than the students from the conventional curriculum. Assuming that these students will actually see about 30 patients each day in the coming years, and assuming that our findings signify a difference in actual diagnostic expertise between the students from both schools (rather than just an effect on a written test), the difference soon becomes sizable. After only one month, a Groningen graduate would have missed, on average, 37.5 diagnoses not missed by a Maastricht graduate. Of course, this kind of reasoning ignores possible compensation effects that may occur during further training and practice. In addition, it assumes—perhaps uncritically—that performance on a paper-and-pencil test can be generalized to performance in professional practice without much ado. Third, it is highly unlikely that the 30 cases used in this study would be presented in professional practice with equal frequency. Nevertheless, this study shows that even relatively small effects of curriculum type, when extrapolated, may affect the quality of everyday diagnostic performance in non-trivial ways.

Although the findings represent a curriculum main effect, the differences became apparent only in the clerkship years. It is not clear why this is so. This may imply that the effects of PBL are the result of an incubation-type of process; they appear only when students begin to deal with real patients in the academic hospital or outside. Alternatively, it may simply imply that the Maastricht clerkship was more effective than the Groningen one. The latter explanation is, however, less likely, because the first measurement on which significant differences between curricula appeared was taken early in the clerkship phase.

No overall differences were found between the integrated, teacher-directed curriculum and the problem-based, student-centered curriculum. That the study was cross-sectional rather than longitudinal blurs this finding because the integrated curriculum studied was implemented only in 1990. Hence, the fifth- and sixth-year students were trained under the old, traditional regimen. This makes it difficult to draw substantive conclusions about differences between the integrated, yet fairly teacher-centered, approach and the problem-based approach. Let us assume, however, for the time being, that the lack of difference overall represents a "true" curriculum effect.* The questions, then, are: What do the problem-based and the integrated curricula have in common that makes their effects on students similar, and what distinguishes them from the third, conventional, curriculum? A tentative answer would be that the problem-based and the integrated curricula both offer subject matter to students in an integrated fashion and that students are encouraged to process the information in an active way through small-group discussion. Thus, subject-matter integration and active processing seem more important factors in attaining proficiency in diagnostic reasoning than the amount of self-directedness in a curriculum. (Self-directed learning, to be fair, has never been claimed to facilitate the acquisition of diagnostic skills. It is primarily advocated to help students acquire the skills for lifelong, self-driven learning.[2]) In addition, seeing paper patients or their real-life equivalents seems to be important. In fact, teachers involved in the various curricula attributed the fact that the students in the Amsterdam curriculum performed better in the second and third years to this phenomenon, hence explaining the interaction between curriculum and level of expertise. In the first three years, Amsterdam students are confronted more extensively with patients than even the PBL students, whose curriculum has a somewhat basic-science–oriented slant in those years.

Where to go from here? Some teachers claim that presenting students with prepackaged clinical information, as we have done, is insufficient for studying their clinical-reasoning skills.[14] The hallmark of diagnostic reasoning is *free inquiry*; subjects should be put in a position in which they can gather information in open interaction with patients. Although previous experiments with free data gathering have generally shown that this approach does not contribute to the validity of distinctions between expert and less-expert diagnosticians, it may be worthwhile to pursue this issue once again. In the past, data gathering has been studied by focusing mainly on formal characteristics of the process. This was in line with the spirit of that time.[7] An approach more geared toward the *contents* of the interaction between a diagnostician and his or her patients may reveal patterns not observed before.[15]

A second issue to be clarified is the extent to which the present procedure

*As Schmidt has argued elsewhere,[16] trying to attribute a curricular effect to particular elements of the curricula compared is extremely complicated. Curriculum-effect studies can be compared to clinical trials spanning several years in which patients with generally unknown characteristics are subjected to treatments whose effective elements are unknown and that may vary over the years. There is simply no way, other than speculation, to attribute effects, or their absence, to elements of the educational treatment.

used for comparing students from different curricula is sensitive to smaller scale course effects. It is clear that the procedure has a more-than-acceptable discriminant validity; the set of 30 case histories produced significant differences among all levels of expertise within each of the schools. But would the procedure make it possible to measure the effects of, say, a course on the cardiovascular system? Do students perform better in cases relevant to that system after they have completed the particular course? If so, the approach would be useful not only in measuring student progress over the years but also as on instrument for program evaluation. A third issue, finally, is the extent to which performance on the diagnostic tasks is related to basic-science and clinical knowledge related to these tasks. Research is in progress to answer these questions.

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