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ABSTRACT

This study compared the diagnostic performance of 612 second-, third-, fourth-, fifth-, and sixth-year students from three Dutch medical schools who were educated in either a problem-based, an integrative, or a conventional curriculum. The students were presented with 30 carefully selected clinical cases to diagnose. The study found that, overall, the students trained within the problem-based and integrated frameworks displayed better diagnostic performance than students trained within a conventional curriculum. No overall differences were found between the problem-based and the integrated curriculum, although second- and third-year students from the latter excelled the comparable year groups in the other curricula formats. The study concludes that integration between basic and clinical sciences and an emphasis on patient problems may be the critical factors determining superior diagnostic performance rather than whether a curriculum is self- or teacher-directed. (Contains 16 references.) (MDM)

# The Development of Diagnostic Competence: A Comparison Between a Problem-Based, an Integrated, and a Conventional Medical Curriculum

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Abstract

**Purpose.** To compare diagnostic performance of students of five different levels of training, educated in either a problem-based, an integrative, or a conventional curriculum. **Method.** Data were analyzed from 612 students diagnosing 30 cases which were epidemiologically representative for Dutch society and covered all organ systems. Number of accurate diagnostic hypotheses were tallied for each of the groups involved. The data were analyzed using analysis of variance (ANOVA) and post-hoc Newman-Keuls tests. **Results.** Overall, students trained within the problem-based framework and students trained within the context of an integrated curriculum displayed better diagnostic performance than students trained within a conventional curriculum. No overall differences were found between the problem-based and the integrated curriculum, although second- and third-year students from the latter excelled the comparable year groups in the two other schools involved. **Conclusion.** It was concluded that integration between basic and clinical sciences and an emphasis on patient problems may be the critical factors determining superior diagnostic performance rather than whether a curriculum is self- or teacher-directed. Problem-based learning seems to live up to its expectancies, but so does the integrated approach to medical education. It was also concluded that the procedure for measuring diagnostic performance appears to be valid and provides a simple means of measuring curriculum effects. It remains to be seen whether the response patterns found would be replicated when subjects are allowed to freely explore the problem situation.

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] one of the early proponents of PBL, assumes that, through continuous exposure to real-life problems, and 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 his 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 conventional medical education.

Others are more skeptical.[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 independent 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 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 (p. 282)." 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 dysfunctions. 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 generally see more case-histories than students in conventional medical education (simply because cases are the stimuli for most of their learning), this may produce superior diagnostic performance on similar case-histories. Hmelo,[8] for instance, found a positive effect of previous cases discussed in a problem-based curriculum on subsequent diagnostic performance on similar ones. This implies that Barrows may be right, but for a different reason.

What is the evidence in favor for each of these positions? To what extent do students from PBL schools perform better – or in other ways differently – on diagnostic tasks as compared to students from more traditional denominations? Three studies address this issue in some detail.

Patel, Groen, and Norman[9] asked subjects from a conventional and a problem-based curriculum to solve a clinical problem and integrate three passages of relevant basic science knowledge into their explanation 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 her colleagues[10] compared the performances of students from two medical schools; one problem-based and one conventional. These (preclinical) 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 pyrovate kinase lead to haemolytic anemia?" In answering this question, knowledge about biochemistry and about internal medicine must be applied and integrated. Students from the problem-based curriculum appeared to take an analytical approach to the problem by first exploring the biochemical aspects of the problem, later linking them to clinical aspects. 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 less accurate answers and more failures by the students from the conventional program.

A third study was recently completed by Cindy Hmelo.[8] At three points in time, she compared diagnostic performance of about 40 Rush medical students, who were either participating in a conventional track or a PBL track. Over the course of a year, the preclinical subjects were presented with three times two cases. 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. Accuracy of diagnostic hypotheses produced by 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, students from the PBL track were able to apply the biomedical knowledge acquired to the clinical cases whereas the other students failed to do so. As indicated above, prior encounters of similar cases by the PBL group influenced the results, but the data indicated that case recognition did not account entirely for the difference between both groups. There was also a beneficial effect of PBL beyond the experience it provides with specific 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 studies PBL students produced more causal explanations, in only two of these studies these causal pathophysiological explanations were also of better quality. In Hmelo's study, the PBL students came up with more accurate diagnoses whereas in the Patel et al. study, the PBL students performed poorer than those from a traditional curriculum.

There may be several reasons for these inconsistencies. The first is that the number of students used in these three studies was fairly limited. The Boshuizen et al.[10] study employed for instance no more than eight students, four from each school. Patel et al.[9] 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 are 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 US have taken a more molar approach by comparing performance of larger groups of students from traditional and problem-based curricula on the clinical examinations of the National Board of Medical Examiners.[11-12] These studies have, generally, shown students from problem-based schools to do somewhat better on the clinical part of the NBME, and somewhat poorer on the basic science part. It can, however, be argued to what extent these examinations measure problem-solving skill or diagnostic performance.)

A second reason may be that different programs may employ different admission criteria which make groups dissimilar to begin with. Although the Rush students were similar on a number of characteristics such as MCAT scores, it is hard to believe that their 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 of the students involved. The McMaster and McGill students, compared by Patel and her 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 on one or a few cases does poorly predict their performance on 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 of cases.

In the present study, diagnostic performance of 612 students from three Dutch medical schools was compared: A problem-based school, a school with an integrated, but teacher-driven curriculum, and a school with a conventional, discipline- and lecture-based curriculum. The subjects were presented with 30 carefully selected clinical cases, in an attempt to avoid possible bias caused by case specificity. In addition, the study profited from a unique feature of the Dutch allotment system: Students are admitted to the different medical schools through a lottery procedure in which academic achievement plays an important role, whereas aptitude for a particular instructional approach does not. This feature enhances the opportunity for meaningful comparisons to be made.

## Method

### Subjects

Subjects were 612 second-, third-, fourth-, fifth-, and sixth-year medical students of three Dutch medical schools, approximately 40 per curriculum year and per medical school. The subjects received a small enumeration for their participation.

### The curricula compared

The University of Limburg medical school in Maastricht has an established problem-based curriculum since the early seventies. It was, in fact, the second school in the world that adopted 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, lab activities and -- more extended -- training in interpersonal and physical examination skills. The rest of the time is scheduled for self-directed learning activities. The University of Amsterdam experiments with an integrated curriculum, in which small-group teaching plays a role. It has, however, more structuring elements in the form of lectures, labs, et cetera, than the Maastricht curriculum. In addition, students are not considered to be self-directed; chapters, books and articles are prescribed. The University of Groningen medical school curriculum can be characterized as conventional, discipline-oriented and teacher-centered. The study was completed just before the latter institution embarked upon a new, largely patient-oriented and integrated curriculum.[13] Medical curricula in the Netherlands take six years and consist of four years of preclinical and two years of clinical training.

### Materials

The materials consisted of 30 short case-histories, each approximately half-a-page long, that covered all organ systems and were epidemiologically representative for the kind of diseases prevalent in Dutch society. 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 (lab) values was included. The cases were bundled in a 17-page booklet. The following case is a representative example : "A 65-year old lady visits her family physician. She enters your surgery room with red eyes suggesting that she has been crying. She tells you that she worries a lot because she looses so much weight. After you have calmed her down, she tells you in a cascade of words that she has lost 12 kilogram, 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 a sweaty, warm skin. The thyroid gland is diffusely enlarged. Blood pressure 150/89; pulse rate 140/min irregular/unequal. The legs show pitting edema. The heart is enlarged and a souffle suggesting mitral insufficiency is heard. Lab data: T4 300 nmol/l, T3 10nmol/l, TSH 0.05 mU/l. ECG: atrium fibrillation accompanied by a high ventricle frequency."

Table 1 contains the diagnoses of the 30 cases included.

Table 1. Diagnoses underlying the cases presented

| | |
|---|---|
| Case 1. | Hyperthyroidism |
| Case 2. | Subdural hematoma |
| Case 3. | Paralysis agitans (= Parkinson's disease) |
| Case 4. | Polyneuropathy<br>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)<br>- with an allergic component *<br>- with a hyperreactive component * |
| Case 15. | Pneumococcal pneumonia |
| Case 16. | Congestive heart failure right- and left-sided |
| Case 17. | Cardiac asthma with atrial fibrillation<br>- with mitral regurgitation *<br>- with tricuspidalis regurgitation * |
| Case 18. | Myocardial infarction |
| Case 19. | Hepatitis B |
| Case 20. | (Acute) Pancreatitis<br>- due to gall stones *<br>- due to biliary obstruction * |
| Case 21. | Reflux (esophagitis) |
| Case 22. | Melanoma |
| Case 23. | Psoriasis (vulgaris) |
| Case 24. | (Seborrheic) dermatitis |
| Case 25. | Otoscelerosis |
| Case 26. | Salpingitis |
| Case 27. | Endometriosis (externa) |
| Case 28. | Ovary cysts |
| Case 29. | Laryngeal carcinoma |
| Case 30. | Appendicitis |

Additional credit points were awarded for information indicated with an asterisk; omission of information between brackets did not influence the accuracy rating of the diagnosis.

## Procedure

Subjects were run in small groups of varying magnitude. They 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 (system) seemed to be affected or which pathophysiological mechanism seemed to be involved. They were encouraged not to spend too much time to each of the cases. Subjects were 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 2 credit points. If the correct diagnosis appeared as part of a differential diagnosis, but not in first position, the answer was awarded 1 credit point. The accurate diagnoses for cases 4, 14, 17 and 20 could contain one or two additional elements which were each credited with one additional point. The maximum score for the test as a whole, therefore, was equal to 67. Interrater agreement exceeded 90%. The resulting data were analyzed using ANOVA.

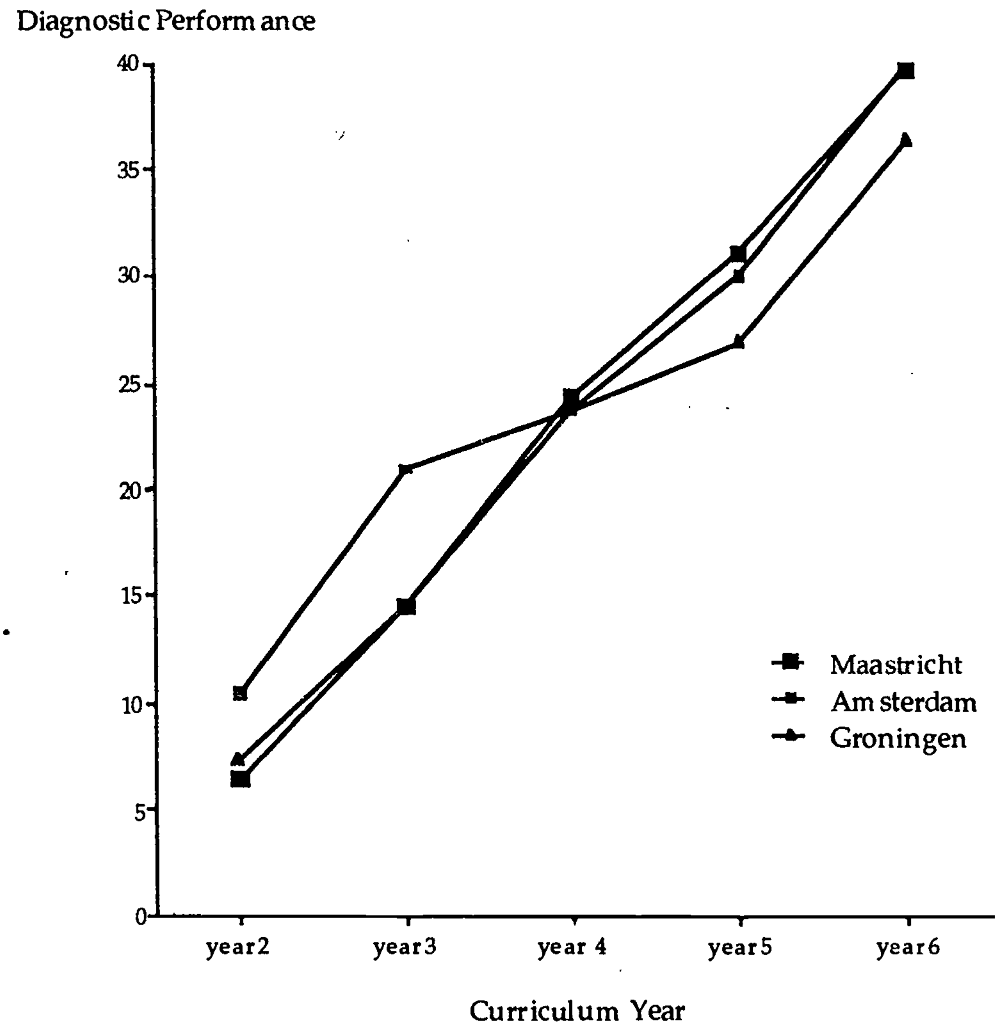
## Results

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, $F\ (4, 597) = 457.49, p < .0001, MS_e = 17007.16$. Finally, both variables interacted with each other, $F\ (8, 597) = 3.795, p < .001, MS_e = 141.09$. Table 2 contains average diagnostic scores and standard deviations for each of the schools and all levels of training involved. Figure 1 displays the diagnostic scores visually.

Table 2. Average diagnostic scores by five levels of expertise in three Dutch medical schools

| Level of Expertise | Maastricht (Problem-based) | | Amsterdam (Integrative) | | Groningen (Conventional) | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Year 2 | 6.33 | 3.86 | 10.37 | 4.18 | 7.30 | 3.74 |
| Year 3 | 14.49 | 7.25 | 20.95 | 5.63 | 14.49 | 5.90 |
| Year 4 | 24.29 | 6.49 | 23.69 | 6.88 | 23.73 | 6.75 |
| Year 5 | 31.13 | 6.95 | 30.09 | 8.16 | 26.93 | 6.66 |
| Year 6 | 39.66 | 6.87 | 39.83 | 5.84 | 36.25 | 4.97 |

Figure 1. Average diagnostic performance as a function of school and curriculum year.




Post-hoc Student-Newman-Keuls tests revealed that, overall, students from the conventional Groningen medical school performed poorer than those of the other two schools. Comparing means in each year group shows that students from the integrated Amsterdam curriculum performed significantly better than the other two groups in the second and third curriculum year, whereas students from the problem-based Maastricht curriculum performed better than the students from the conventional curriculum in year 5, but not better than the students from the integrated curriculum. Students from the integrated curriculum did also perform better than those of the conventional curriculum. Differences between adjacent curriculum years within each of the schools were all statistically significant.

## Discussion

The findings presented in this article constitute, to our knowledge, the first large-scale study that compares performance of medical students from different curricula under controlled conditions. The cases presented were epidemiologically representative for Dutch society 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 represent a departure from existing practices.

We will first discuss differences between the problem-based and the conventional program. Subsequently we will deal with the data comparing the problem-based and the integrated curriculum 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 almost 9% better than the Groningen comparison group. The question is, of course, whether these 9% represent a meaningful portion. Expressed in terms of accuracy of diagnostic performance this percentage means that the Maastricht students on average diagnosed 1.5 out of 30 cases more accurately than the students from the conventional curriculum. Assuming that these students will actually see about thirty patients each day in the coming years and assuming that our findings signify a difference in actual diagnostic expertise between 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 occurring 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. Nevertheless, it shows that even relatively small effects of curriculum type, when extrapolated, may affect the quality of every-day diagnostic performance in non-trivial ways. Interestingly, although the findings represent a curriculum main effect, the differences become only apparent in the clerkship years. It is not clear why this is so. This may imply that effects of problem-based learning 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 is 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 and the student-centered curriculum. The students in the Amsterdam curriculum performed better in the second and third year. That the study was cross-sectional rather than longitudinal blurs this finding because the integrated curriculum studied was implemented only in 1990. Hence, year 5 and 6 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's assume, however, for the time being, that the lack of difference overall represents a "true" curriculum effect.[Note 1] The question, then, is, what do the problem-based and the integrated curriculum have in common such, that their effects on students are similar, and what distinguishes them from the third, conventional curriculum? A tentative answer would be the fact that the problem-based and the integrated curriculum 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-directness of 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 life-long, self-driven learning.[2])

Where to go from here?

Some claim that presenting students with pre-packaged clinical information, as we have done, is insufficient to study their clinical reasoning skills.[14] The hallmark of diagnostic reasoning is *free inquiry;* subjects should be put in a position in which they should gather the information in open interaction with the patient. 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

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Note 1 As the first author 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 the subjects of unknown background are submitted to treatments of which the effective elements are ungathering has been studied 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 patients may unravel patterns not observed before.[15]

A second issue to be clarified, is to what extent the present procedure used for comparing students from different curricula is sufficiently sensitive to smaller-scale course effects. It is clear that the procedure has more than acceptable discriminant validity; the set of 30 case-histories produced significant differences between all levels of expertise within each of the schools. But would the procedure enable measuring effects of, say, a course on the cardiovascular system? Do students better on cases relevant to that system after they have completed the particular course? If so, the approach would not only be useful to measure student progress over the years but would also be a useful instrument for program evaluation. A third issue, finally, is to what extent 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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known and may vary over the years. There is no way, other than speculation, to attribute effects or their absence to elements of the educational treatment.

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