DOCUMENT RESUME

ED 396 640 HE 029 270

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TITLE Evolution of Students' Reasoning Skills on a Two Year Basis in a PBL Curriculum in Medicine.
PUB DATE Apr 96
NOTE 31p.; Paper presented at the Annual Meeting of the American Educational Research Association (New York, NY, April 8-12, 1996). Illustrations may not reproduce well.
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Abstract Reasoning; *Cognitive Processes; College Students; Curriculum Evaluation; Foreign Countries; Higher Education; *Intellectual Development; Longitudinal Studies; Medical Case Histories; *Medical Education; *Problem Solving; Professional Education; Protocol Analysis; Skill Development; Student Development; Thinking Skills
IDENTIFIERS Canada; Cardiology; *Problem Based Learning; *University of Sherbrooke PQ; Urology

ABSTRACT

A 2-year study at the University of Sherbrooke (Quebec) investigated the changes in six medical students' clinical reasoning processes as they participated in a problem-based learning (PBL) curriculum. In each year, students performed a think-aloud protocol with two medical case problems to solve, one in cardiology and one in urology. In the second year of the study, the students were given somewhat more difficult cases to address. Student responses were compared to those of two practicing physicians, neither of them teachers at the institution. Only responses to the urology cases are analyzed here. Results showed that, as anticipated, hypotheses were generated early for both problems, illustrating the students' capacity to transfer the hypothetico-deductive model of reasoning learned in the pre-clinical PBL curriculum. Results also showed that, among the hypotheses generated early, the principal hypothesis was present, similar to the performance of the physician experts, particularly in the less advanced cases. It is concluded that the PBL approach helps students balance the importance they give to case information. The pattern of time taken to consider each case segment was very similar to that of the experts. The two urology cases and data summaries are appended. (Contains 22 references.) (MSE)

AERA 1996 Symposium: Chair D. Bédard

"The Development of Learning and Reasoning Skills in the Context of a Problem-Based Learning (PBL) Curriculum: Strengths and Limits"

Evolution of students' reasoning skills on a two year basis in a PBL curriculum in medicine

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Evolution of students' reasoning skills on a two-year basis in a PBL curriculum in medicine[1]

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1. General problem

One of the challenges facing higher education, and professions education in particular, is the capacity these programs have to develop higher order cognitive skills (e.g. critical thinking, problem-solving skills, etc.). The programs should aim to stimulate an enquiring, analytical and creative approach, encouraging independent judgement and critical self-awareness. In this context, many professors in universities and colleges intend that their instruction enables students to achieve not only lower cognitive skills such as recall of information, but also higher skills such as critical reflection. However, in regards to student learning, comparing goals to outcomes in terms of teaching does not present an encouraging perspective, especially in the context of training for the professions (Bédard and Turgeon, 1995; Margetson, 1994).

These cognitive skills are required to face the demands and challenges that most professions will require. In order to support such changes, different curriculum and pedagogical innovations are actually being considered. Among these, one approach that has received a lot of attention over the last two decades is problem based-learning commonly known as PBL (Barrows & Tamblyn, 1980; Birch, 1986; Moust, De Volder & Nuy, 1989; Scheiman & Whittaker, 1990; Tedesco, 1990; Winslade, 1994). Medical education has the best established examples of problem-based learning (e.g., Des Marchais, 1996). Since it was introduced at McMaster University in the late sixties, this pedagogical approach centered on students learning has been implemented in numerous Faculties of Medicine across North America and Europe.

2. Academic context of the present research

The Faculty of Medicine at the University of Sherbrooke (Quebec, Canada), revised its undergraduate curriculum and in 1987 implemented a full class changeover from a traditional to a small-group, tutorial, problem-based curriculum (Barrows & Tamblyn, 1980, Schmidt, 1983, Des Marchais and Dumais, 1990). This problem-based learning (PBL) curriculum is student-centered. It uses PBL almost as the sole instructional method for the preclinical years. The program lasts four years (see Figure 1). A two and a half year pre-clerkship period includes a first semester of introduction and 13 organ system units, each lasting four to five weeks. The pre-clerkship phase ends with unit 14, a four month unit which is in the first semester of the third year. This phase is devoted to the integration of previously studied content while students deal with multidisciplinary and more complex clinical problems. Throughout the 14 units, there is a half day a week longitudinal unit used for the acquisition of clinical skills and humanistic dimensions in the doctor-patient relationship. The following semester the students begin their clerkship which lasts until the end of the following year.

(Insert Figure 1 here)

In the Sherbrooke curriculum, the PBL preclinical two and a half year program is aimed at

[1] This research was supported by a grant from the Social Sciences and Humanities Research Council of Canada

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facilitating the study of basic medicine which is the integration of basic and clinical sciences through the analysis of problems, the identification of what needs to be learned and the application of such learning to the problem. At the levels of analysis, synthesis and evaluation, understanding the underlying principles and mechanisms becomes the main focus of the instructional method. Clinical diagnosis is not essential at this stage and is not explicitly solicited by PBL tutors. In the multidisciplinary unit (unit 14) held in the first semester of the third year, the focus progressively shifts toward problem solving, investigation, and therapeutics. At this point in the curriculum, the pedagogical approach is called "learning by problem solving" (LPS). During the clerkship, students receive by-weekly sessions on learning clinical reasoning (LCR - Chamberland, Des Marchais, & Charlin, 1992).

A typical PBL session on a given problem lasts one week. During that week, the group of 8 students and a tutor (generally a specialist in the discipline) meet twice. The first meeting is aimed at introducing the problem, formulating explanatory hypotheses about the underlying mechanisms of different symptoms, and identifying learning objectives to guide the reading process from the material made available. The following two to three days, students are asked to review the documentation. During the second meeting, the group summarizes the explanations of problems and produces a synthesis of the information gathered and discussed.

3. Specific Problem

The prime function of a physician is clinical reasoning (Kassirer et Kopelman, 1991). Therefore, one of the main learning objective of a medical curriculum should be to further the development of such skills. The Faculty of Medicine at the University of Sherbrooke considered that a curriculum centered on teachers and on disciplines was no longer a viable model for undergraduate education. A better integration of basic sciences with clinical sciences was identified as being a key objective of the reform.

The study of basic sciences through a PBL preclinical curriculum is a considerable change from a traditional approach. In this context, students are bound to have experienced a quite different preparation for the clerkship if they come from a PBL curriculum. PBL is based on the early generation of hypotheses (Schmidt, 1983) according to the hypothetico-deductive model (Elstein et al., 1978), and the enquiring process follows the generation of hypotheses. The PBL model differs from that used in a traditional clerkship where the student is asked for a formal and comprehensive assessment of the patient's problems; traditionally, all clinical cues must first be assembled before any generation of hypotheses is permitted. Yet in clinical reality, the clinician generates early on a series of hypotheses (Barrows & Tamblyn, 1980) which guide his search for relevant cues.

In a PBL curriculum, students would be expected to be more active in discussing clinical assumptions and to suggest early exploratory hypotheses. But is it the case? How well does the PBL approach prepare the students for the clerkship? What knowledge is being processed during problem solving? How is knowledge structured during problem solving? The issue under consideration in the present paper is how the PBL curriculum acts on the development of reasoning skills during the preclinical program in medicine.

4. Theoretical approach

Research studies have been conducted in medicine on the development phases of clinical reasoning. Schmidt and Boshuizen (1992) and Schmidt and al. (1990) describe four phases: (1) development of elaborated networks of causal relationships based on pathophysiological processes; (2) compiling of these causal networks into more inclusive structures; (3) emergence of pathological "scripts" in which the links are more temporal than causal; (4) development of more inclusive scripts as a result of various clinical experiences. When trying to investigate the state of knowledge in medical students, the nature of the problem used should be considered. Boshuizen & Schmidt

(1992) reported that in domains with a tight relation between biomedical and clinical knowledge (e.g., cardiology) less of a gap should be found between the two types of knowledge. They also suggest that the curriculum format of medical schools might affect the developmental course taken by medical students.

Research done by Patel and her team, parallel to the works of Schmidt and his colleagues, has also been very influential. Patel and Groen (1991) conclude that expert doctors in their field of expertise solve problems through forward reasoning, while in other fields they reason much like novices do using backward reasoning. However, these conclusions are questioned by Lemieux and Bordage (1992, 1993).

The following question is at the basis of this research : what is the evolution of the clinical reasoning of students registered in medicine, in the predoctoral phase of a PBL curriculum? The structure of the approach used to answer this question allows some conclusions about the nature of the knowledge used by subjects toward specific problems and on the reasoning processes they use in solving these problems. The main objective of this longitudinal research is to describe the evolution of students' clinical reasoning skills.

5. Methodology

This longitudinal research, which is on a two year basis, uses the same six subjects for both years. The second-year students were evaluated after having completed the endocrinology unit (the 11th of a series of 13 units that compose the first two years of the program). The third-year students were evaluated after having completed the multidisciplinary unit (unit 14). This unit is aimed at integrating knowledge acquired in the previous two years along with some training in clinical diagnosis. Subjects' participation was on a voluntary basis for which they were financially compensated.

The second and third-year students were presented with two written problems to be solved and they were asked to "think aloud" while solving them (Fonteyn, Kuipers & Grobe, 1993). All subjects were put through a training session (Ericsson and Simon, 1984) which consisted of two tasks: a "talk aloud" task (naming as many countries as possible and naming the ten provinces of Canada, from west to east) and a "think aloud" task (thinking aloud while solving two arithmetic problems). During the second task, if the student stopped thinking aloud for more than 4 or 5 seconds the experimenter would then ask the subject what he or she was thinking about. Then the subjects engaged in the problem-solving task which consisted of reading a medical case (history and physical exam) while thinking aloud. At the end, the subjects were asked to give a differential diagnosis ordering, when applicable, each hypothesis according to its likelihood or prevalence.

It was decided that two problems (originating from two different disciplines of medicine) were going to be used instead of one, in order to show how consistent subjects were across both problems. By doing so, we could better assess if their performance was due directly to more knowledge of the discipline or to problem-solving skills. The order in which the problems were presented to the subjects was counterbalanced. Each unit of information (usually a sentence) regarding the patient was presented on a different page. They were asked to think aloud for each page in order to evoke the hypotheses they were considering at the moment. This procedure was used (1) to follow more accurately the evolution of the diagnostic process and (2) to better assess the impact of each unit of information in the case on the diagnostic process.

In each case, the information typically gathered during the initial encounter between the physicians and the patient is presented: (1) patient's history (symptoms, medical history, social and physical habits, medication) and (2) data from the physical examination. These problems were taken from two different disciplines: cardiology and urology. Only the two urology problems (one for the 2nd-year students, the other for the 3rd-year students) will be discussed here. The problems presented

to the third year students were more complex, i.e. more pathophysiological hypotheses had to be explored. This change in complexity fits the evolution of the PBL curriculum at the University of Sherbrooke Faculty of Medicine (see the next section for a description of the two urology problems). Both problems were designed to have similar levels of complexity, taking into account the background knowledge students received.

Two expert models of the reasoning process were constructed and used to assess the students' performance. Two experienced physicians were asked to participate as experts. They both are Internists and have an average of 7 years of practice in their field. Neither of them teaches at the Faculty of Medicine. One was presented with the two problems used for the second-year students (Expert A) and the other one was presented with the two problems presented to the third-year students (Expert B). The expert models were used as a template against which subjects' protocols were contrasted. The resulting analysis gives information on differences in the nature of the diagnostic processes and knowledge used between the groups according to what year in the program they are in.

6. Urology Cases[3] (see Appendix A)

The two urology cases have common links : a previous history of three or four episodes of low urinary infections which have always been therapeutically neglected (see Appendix A for the presentation of the second year case). Followed by an appearance of acute lower urinary symptoms and lower abdominal pain. There is a high digestive clinical picture in the second year case and a low one for the third year case. The third year case also indicates a fever and the hemodynamic state of a preshock. In both cases there is lumbar pain. In the second year case, this pain is directly related to the pathology presented. In the third year case, the lumbar pain is associated with either a genital, digestive or urinary pathology.

The context in which the second year case occurs seems insignificant, but the context of the third year case is rich with previous pathologies. Actually, the patient in the third year case is suffering from Crohn's disease and has stopped taking her steroids, which conjures up a suprarenal insufficiency. She has just returned from a trip to Mexico where there is a high prevalence of bacteria and entero-pathogenic parasites. Moreover, this patient's sexual history greatly increases the risks of gynecological pathologies.

The diagnosis of the second year case is considered a prototypical case of high urinary infection, pyelonephritis. Since the patient is young, a digestive pathology such as appendicitis or a genital pathology such as an inflammatory pelvic disease, salpingitis, a tubo-ovarian abscess or other is eliminated. If a proper investigation eliminates a urinary or digestive infection, then it is possible to suggest the hypothesis of an infection of the locomotive system such as vertebral osteomyelitis or spondylodiscitis.

In the third year case, many diagnostic hypotheses may surface taking into consideration the fever, the abdominal, lumbar and urinary pain associated with Crohn's disease, the administration of steroids and a recent trip to Mexico. It could very well be an exacerbation of Crohn's disease with or without complications, digestive perforation and an intra-abdominal abscess. Since this patient had previously taken steroids, a suprarenal insufficiency, which is caused by other forms of stress could have been the cause. Appendicitis, pyelonephritis, salpingitis or gastro-enteritis with ileitis or an E. Coli-invasive gastro-enteritis or finally, an amoebic dysentery, are other possibilities.

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[3] The problems/cases used in this research were prepared by Dr André Plante, Professor in Internal Medicine, Faculty of Medicine, University of Sherbrooke. His assistance was greatly appreciated.

7. Protocol analysis

The method proposed by Fonteyn, Kuipers & Grobe (1993) has been used to analyse the protocols, taking into account both the nature of the knowledge used and the reasoning process evoked. The objectives of this process were (1) to identify which information was considered by the subjects, (2) to describe which relation the subjects made from this information and, (3) to describe the reasoning process used to diagnose the patient. Each of the protocols was divided into syntactic units in order to facilitate both the identification of information and the analysis of the different parts of each protocol.

Referring Phrase Analysis: This analysis was made to determine the conceptual field of concepts (objects) in an explanation or in a segment. First, a concrete conceptual vocabulary showing the subjects' representations was collected. Partly defined from the information in the protocols, the conceptual objects represent the information on which the subjects focus on at a specific point in problem solving (e.g., patient, sign, time, etc.). This first analysis allowed for subsequent steps of the analysis to occur (see Table 1 for a definition of each of the operators used).

(Insert Table 1 here)

Assertional Analysis: This analysis tried to identify the assertions made by the subject regarding each of the concepts identified in the previous analysis. These assertions are present in the segments and are aimed at establishing links between the different objects (e.g., causal, condition, elaboration, etc.). For example, the segment: " Her pain is due to a recurrence of Crohn's disease" is a causal link (see Table 2 for a definition of each of the operators used).

(Insert Table 2 here)

Script analysis: This analysis consists a global description (representation) of the thinking process which emerged from the protocol and is based on the two previous analyses. The script analysis enables an analysis of each segment in the protocol. Furthermore, the structure of the problem and the reasoning process may also be analysed using this method. Thus, the problem-solving process may be analysed more thoroughly. This process, which involves actions such as study, explain, conclude, etc., is described using a series of coding operators based on reasoning. For instance, the segment: "Her pain is due to a recurrence of Crohn's disease" is coded "Conclude" (see Table 3 for a definition of each operator used).

(Insert Table 3 here)

8. Data analysis

Data:	• think-aloud protocols
Variables analysed:	• hypothesis generation — distribution as a function of segments (compared with expert) • differential diagnosis (compared with expert) • total time for each problem (compared with expert) • time for each segment — distribution (compared with expert) • nature of the knowledge used • reasoning process

9. Results

A) Hypotheses generation

Figure 2 (second year case) and Figure 3 (third year case) show a distribution table of the

diagnostic hypotheses according to segments of each of the problems. The numbers in the boxes correspond to the number of subjects who have made this hypothesis. The value of each of the hypotheses can also be described according to its weight relative to the group. The darkened boxes represent the hypotheses mentioned by the medical specialist. Finally, the hypotheses in bold characters are the ones evoked by the experts for each of the cases at the time of the differential diagnosis (later called main hypotheses).

Twenty-one hypotheses were generated by the subjects in the second year case. The hypotheses are unevenly distributed depending on the segment[4]. However, it is possible to note that many hypotheses were generated very early in the reasoning process. In the first two segments of the problem, there is a total of 11 hypotheses including the main hypothesis for this problem which is mentioned five times out of six in the second segment.

(Insert Figure 2 here)

Seventeen hypotheses were generated by the overall subjects in the third year case. They are also unevenly distributed depending on the segments. Contrary to the second year problems, not many of the hypotheses were generated at the beginning of the problem-solving process. They are distributed more evenly than in the previous problem, although four of the five main diagnostic hypotheses were frequently mentioned as early as in the fourth segment.

(Insert Figure 3 here)

Of the 21 hypotheses of the second year case, 11 were generated by expert A and, of the 17 hypotheses of the third year case, 10 were generated by expert B. In the second year case as well as in the third year case, more than two-thirds of the hypotheses mentioned by the experts were also mentioned by at least one subject. This proportion decreases to less than half the hypotheses of the experts when only those mentionned by at least two subjects is considered.

(Insert Figure 4 here)

Figure 4 (second year case) and Figures 5a and 5b (third year case) show the graphic distribution of the main diagnostic hypotheses according to the segments of each of the problems. The three Figures clearly identify the sequences where the main hypotheses have been considered.

(Insert Figure 5 here)

In Figure 4, the generation of the main hypothesis presents many similarities between the second year group and the specialist. The performance of the third year group and the medical specialist in the more complex problem does not show this tendency (see Figure 5). In the context of this last problem, the generation of the main hypothesis by the expert is more fragmented.

B) Differential diagnosis

Of the 21 hypotheses considered when reading the second year case, 11 have been retained for the differential diagnosis (see Figure 2). They were chosen by only one subject, except for two hypotheses which included the main one. All of the subjects have mentioned the main hypothesis in their differential diagnosis and five out of six considered it the most likely hypothesis.

Of the 17 hypotheses considered when reading the third year case, 13 were retained for the differential diagnosis (see Figure 3). This represents a proportion of more than two-thirds. More than half of these 13 hypotheses were mentioned by at least two subjects. The expert has retained 5

[4] Please refer to Appendix A for information on each segment.

21	Dehydration												5									
20	Hypothyroidia									1												
19	STD																	1				
18	Peritonitis	1																				
17	Cervicitis																		1			1
16	Enteritis	1									1							1				1
15	Urethritis		1																			1
14	Septicemia									2	4	1		1	1	1	2					1
13	Aortic Stenosis																1					
12	Bacterial Endocarditis																2					
11	Nephretic Colic			1	1	1	1															
10	Urinary Lithiasis		1	2	2						1											1
9	Kidney Cancer				1																	1
8	Cystisis		4	3	2		2			1							1	2				1
7	Endometriosis		1				2											1	2			1
6	Ectopic Pregnancy	1		1															1			
5	Tubo-Ovarian Abscess	1																				
4	Salpingitis	1	1	1			2												1			3
3	Pelvic Inflammatory Disease (PID)																	2				1
2	Appendicitis	2																				
1	**Pyelonephritis**	2	5		3	5	2	1		3	1	1	1				1	2				6
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19		DDx

Expert's hypotheses

Figure 2 : Hypothesis generation for each segment, second-year case - Urology

17	Dehydration								1	1		4	3	2								
16	Peritonitis				1											5	2	1				
15	Septicemia													3	1							1
14	Cystisis				6	3	2						1									
13	Endometriosis			1				1						1			1	3	1			1
12	Pregnancy							2														
11	Vaginitis												3	1								1
10	Salpingitis							3					1			1	2	2	2			2
9	TSD						2	5					6	1			1	1				1
8	Dysentery						1		1	3	1		1				1					2
7	Appendicitis			3	1						1					3	1					2
6	Gastroenteritis E.Coli									1	1											1
5	**Suprarenal Insufficiency**													2								2
4	**Pyelonephritis**				1	4	2				1			1								2
3	**Gastroenteritis**			2			3	1	1	2	2			1			1					3
2	**Crohn's Disease**	3	2	3		2	1		2	4	1		2		4	3	1		1			5
1	**Pelvic Inflammatory D. (PID)**			1				2	1				1					1	1			3
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18			DDx

Expert's hypotheses

Figure 3 : Hypothesis generation for each segment, third-year case - Urology

main hypotheses which were mentioned by at least 2 subjects.

C) Total time

Figure 6 shows the average total time devoted to each of the two problems for the experts and the subjects. The subjects spent more time on the third-year case than on the other case. The expert who evaluated the third year case took half the time of the expert evaluating the second-year case. Moreover, in the second year case, the expert took more time than the students solving the case; whereas, with the third year case, the group of students took twice the time the expert in solving the case. These results reveal the experts' major individual differences, pointing out the limits of considering global quantitative data in studies looking at information processing while problem solving.

(Insert Figure 6 here)

D) Time for each segment

Figure 7 (second-year case) and Figure 8 (third-year case) show the graphic distribution of the average time (expert and group) taken for each segment in both problems. It is interesting to note that for both cases, the experts and the groups of subjects follow quite similar patterns, even though they do not devote equal amounts of time. There are a few exceptions : segments 4, 7 and 18 of the second-year case indicate that the subjects took more timre than the expert and, segment 12 for the third year case indicates that the expert took more time.

(Insert Figure 7 here)

In the second problem : segment 4 indicates the presence of blood in the patient's urine. Similar hypotheses were generated by the expert and the subjects. Segment 7 indicates a loss of appetite, vomiting with mucoid secretions. Only one hypothesis emerged from the expert and the group. Segment 18 indicates sensitivity in the mobilization of the cervix and pain preventing palpation of the uterus. As a result, the subjects formulated hypotheses related to gynecology; hypotheses having very little compatibility with the preceding information. In the third problem : segment 12 indicates that in the past ten days the vaginal secretions have increased. are greenish and foul-smelling. The expert derived four hypotheses, the subjects derived eight.

(Insert Figure 8 here)

E) Nature of the knowledge used

The next two variables will be presented using a single case instead of taking an average. This choice was made in order to clearly indicate the changes that occur in knowledge and clinical reasoning from the second to the third year of the preclinical curriculum. The student called Marie (one of the subjects) was selected to represent the performance of the group. We also decided not to compare her with the experts' performance since two distinct individuals have solved each of the cases.

(Insert Figure 9a here)

Figure 9a (second-year case) and Figure 9b (third-year case) indicate the percentage of "referring phrases" (in phrase analysis) of each category according to Marie's total amount. For the second-year case, Marie has mostly referred to signs of the patient (32%), general hypotheses (22%) and specific hypotheses (19%). For the third-year case, Marie has mostly referred to signs of the patient (42%), specific hypotheses (30%) and the patient herself (12%). Noticeable fact : although the proportion of general and specific hypotheses were similar for the second-year case, it varies

greatly (1/10) for the third-year student!

(Insert Figure 9b here)

Figure 10a (second-year case) and Figure 10b (third-year case) indicate the percentage of assertions of each of the categories according to Marie's total. For the second-year case, Marie has mostly established elaboration (30%), meaning (27%) and causality (22%) relationships. For the third-year case, Marie has mostly established causality (38%), meaning (33%) and conditionality (19%) relationships. Noticeable fact : the proportion devoted to establishing elaboration relationships has fallen from 30% to only 3 %!

(Insert Figure 10a & 10b here)

F) Reasoning process

Figure 11a (second-year case) and Figure 11b (third-year case) indicate the percentage of each type of operators used according to the total used by Marie. For the second year case, Marie has mostly used the conclude (48%), explain (24%) and study (19%) operators. For the third-year case, she has mostly used the conclude (42%), study (295) and metacognition (20%) operators. Noticeable fact : the proportion given to the use of metacognitive operators has quadrupled and the use of the explain operator has decreased by three times!

(Insert Figures 11a & 11b here)

The results of Figures 10 and 11 reflect the evolution of the clinical reasoning skills of the students in the Faculty of medicine at the University of Sherbrooke.

10. Conclusion

As was expected with the PBL preclinical curriculum, hypotheses were generated early on for the two problems. This result demonstrates the capacity of students to transfer the hypothetico-deductive model of reasoning learned during the pre-clinical years in a problem-solving context which explicitly asks them to produce a clinical diagnosis from reading a written case. Results also show that among the hypotheses generated early, the principal hypotheses (or hypothesis) are present. This is similar to the performance of the two experts. When considering the distribution of hypotheses for each segment for the second-year problem, it is possible to notice that the students' performance is similar to that of the expert. This is not as much the case for the third-year problem. Hypoheses generation by the expert is more fragmented.

From the results obtained for the differential diagnosis, the students' performance is excellent for the second-year case and good for the third-year case. For the first problem, students demonstrate their ability to sort out the hypotheses and identify the main hypothesis as the most probable one, five times out of six. The second problem being more complex, this task was more difficult and, considering their limited exposure to cases where the context is rich in terms of previous pathologies, their clinical diagnosis was less specific as a group, but still included all the main hypotheses.

According to results of the time spent on each segment and the experts' performance, the PBL approach seems to have contributed in helping students maintain a balance of the importance they give to the information in the case. The pattern of the time taken to consider each segment is very similar to the one taken by the experts.

The case-study analysis of the knowledge and the reasoning process does validate the current models of developing clinical-reasoning skills in medicine, which suggests a process of gradual

knowledge compilation. The results show that, as the second-year student reasons about the case at hand, she refers less to clinical knowledge, contrary to the third-year student. Also, the second-year student demonstrates less integration of both biomedical and clinical knowledge. As Marie moves on to her third year, she will begin more explicitly to link elements of her biomedical knowledge and to use her clinical knowledge.

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Appendix A

SECOND YEAR UROLOGY CASE

1. A 32 year old single woman is in the emergency room consulting for a high fever, asthenia, pain in the lower right lumbar area and diffuse abdominal pain progressing for the last 12 hours.
2. In the past few days, she has noticed that she urinates more often, a little bit at a time, and she has experienced burning pain at micturition.
3. These symptoms occurred three or four times in the past two years but always disapeared.
4. Once however, she noticed red blood in her urine. Since the problem went away by itself she did not see a doctor.
5. This time, she is experiencing right back pain and after a bout of shivering that lasted 15 minutes, she has an oral temperature of 39°C.
6. She also has lower abdominal pain with heaviness.
7. She hasn't eaten all day, is not hungry, feels nauseous and has vomited mucoid secretions twice with no traces of food.
8. No bowel movement in the past 24 hours.
9. During the examination, the patient is lethargic, drowsy and in diaphoresis.
10. Oral temperature at 39.7°C, arterial pressure at 90/75, rapid pulse at 120/min., regular. Respiratory rate 28/min.
11. Eyes : isocoria, photomotor reflexes present and symmetrical.
12. Mouth : dry mucous.
13. Neck : no adenopathy, normal thyroid.
14. Lungs : vesicular murmur heard in both lungs, no rale.
15. Heart : the cardiac rhythm is at 120, normal B1-B2, B4.
16. Systolic murmur II/VI ejection in the second intercostal space right parasternal.
17. Abdomen : increased sensitivity in the lower hemi-abdomen, no defence, no palpable mass, no rebound tenderness, reduced intestinal noises. Normal rectal examination.
18. Gynecological examination : sensitivity in the mobilization of the cervix, pain preventing palpation of the uterus, annexes not palpated.
19. Normal limbs.

THIRD YEAR UROLOGY CASE

1. A 32 year old patient arrives at the emergency room. She has had Crohn's disease for the past 10 years. She has been treated intermittently with steroids and Salazopyrine (Sulfa).
2. Four months ago, she stopped taking all medication.
3. She has a high temperature, lower colicky abdominal pain mostly on the right side and right lumbar pain.
4. She has also experienced burning mictional symptoms in the past 2 days.
5. She has had these burning pains 3-4 times in the past 2 years.
6. She came back last week from a two-week stay in Mexico.
7. While traveling, she had unprotected sex a few times with a traveling companion.
8. Since she's been back, she has had frequent bowel movements (6-8/24 hours), sometimes during the night.
9. Her stools are liquidy and sometimes have blood and mucous in them.
10. Although she has no appetite, she is not showing important digestive symptoms like nausea, vomitting, epigastric burning sensations or other.
11. She has lost 5 pounds since she came back.
12. After a review of the systems, the presence in the past 10 days of increased vaginal secretions, greenish and foul-smelling is noted.
13. During the examination : arterial pressure 90/75, pulse 120/min., T° is at 39°C. The patient is worried, in pain and tanned.
14. Eyes are normal. Mouth : 2 aphthas. Neck is normal. Breasts : no mass. Lungs are normal. Heart is normal.
15. Abdomen : sensitive right iliac fossea with bogginess, no defence, positive right rebound, increased intestinal noises, liver and spleen not palpated.
16. Rectal examination : no stool, slightly bleeding mucous, pain when palpating the Douglas.
17. Vaginal examination : the mobilization of the cervix is very painful.
18. Bogginess of the right annexal area. Normal limbs.

Table 1

Referring phrase analysis: definition of concepts

General Hypotheses:	A physiological process (e.g., inflammatory process)
Location:	Any reference to a location in the human system
Patient:	An individual with health problem
Sign:	Objective clinical information indicative of status
Specific Hypotheses:	A disease or an etiology (e.g., Crohn's disease or salmonella diarrhea)
Time:	A chronological reference
Value:	A rating or scaling of usefulness, importance, or worth

Table 2

Assertional analysis: definition of assertions

Causal:	Assertions that form relationships of causality
Condition:	Assertions that form relationships of "conditionality"
Connotative:	Assertions that form relationships of meaning
Elaboration:	Assertions that form relationships of elaboration
Temporal:	Assertions that form relationships of temporality

Table 3

Script analysis: definition of operators*

Conclude:	To decide on the significance, value, or meaning of information
Explain:	To provide an explanation about a system, organ or action
Investigate:	To require further information about the patient (questions, tests, observations)
Metacognition:	To refer to one's own reasoning or thought process
Study:	To consider information carefully

* Operator is defined as a reasoning process.

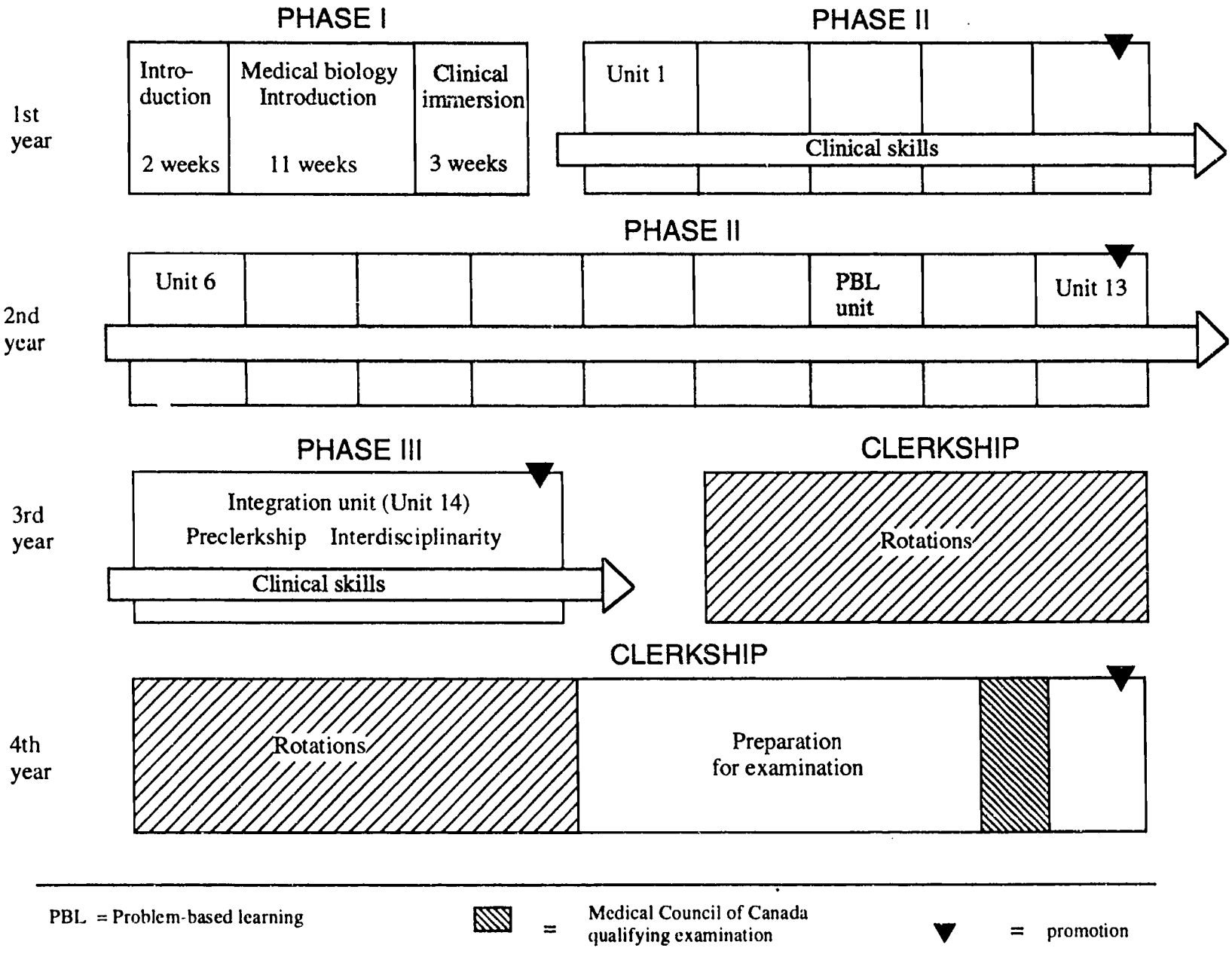

Figure 1: The M.D. program at the University of Sherbrooke

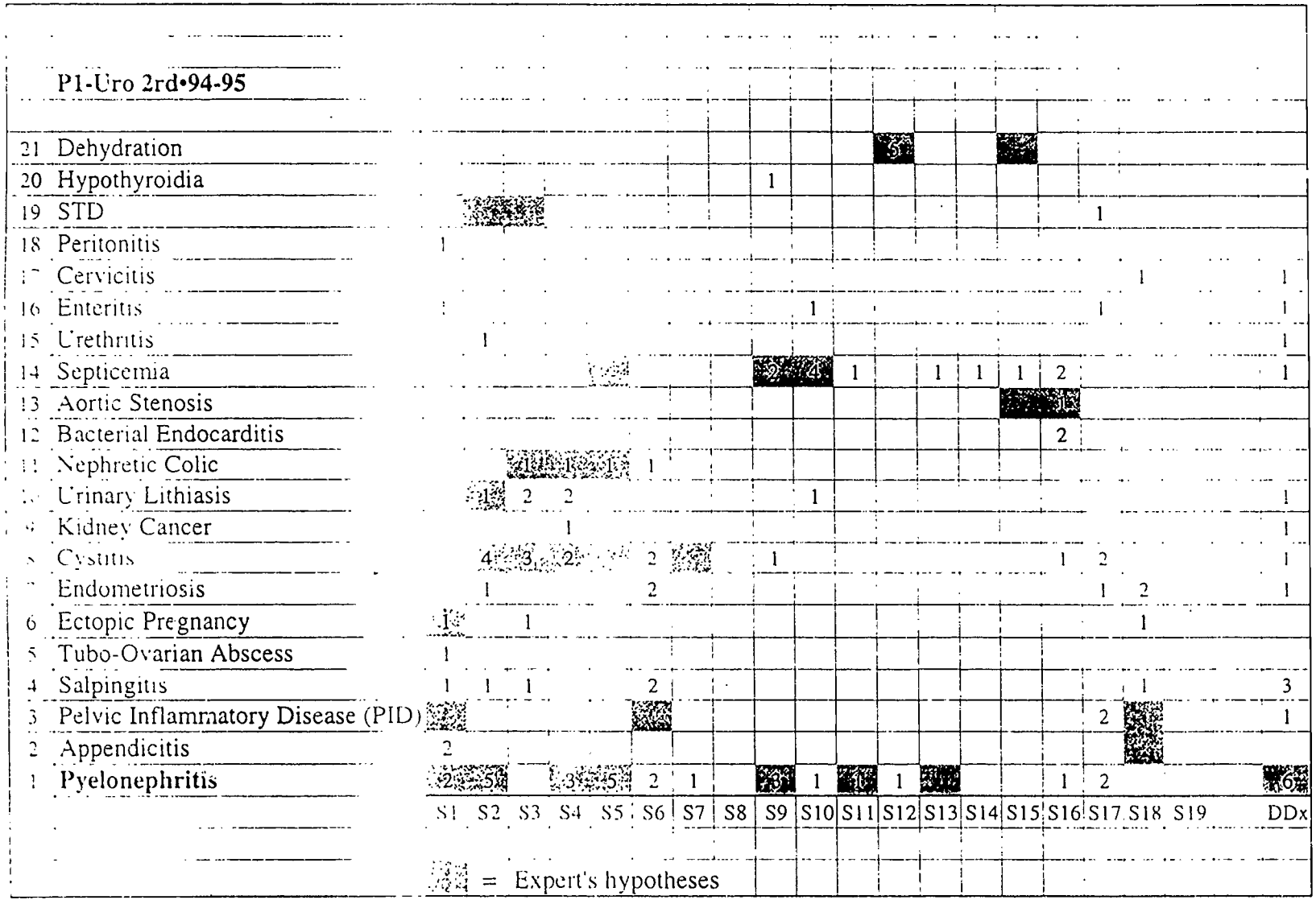

Figure 2: Hypothesis generation for each segment, second-year case.

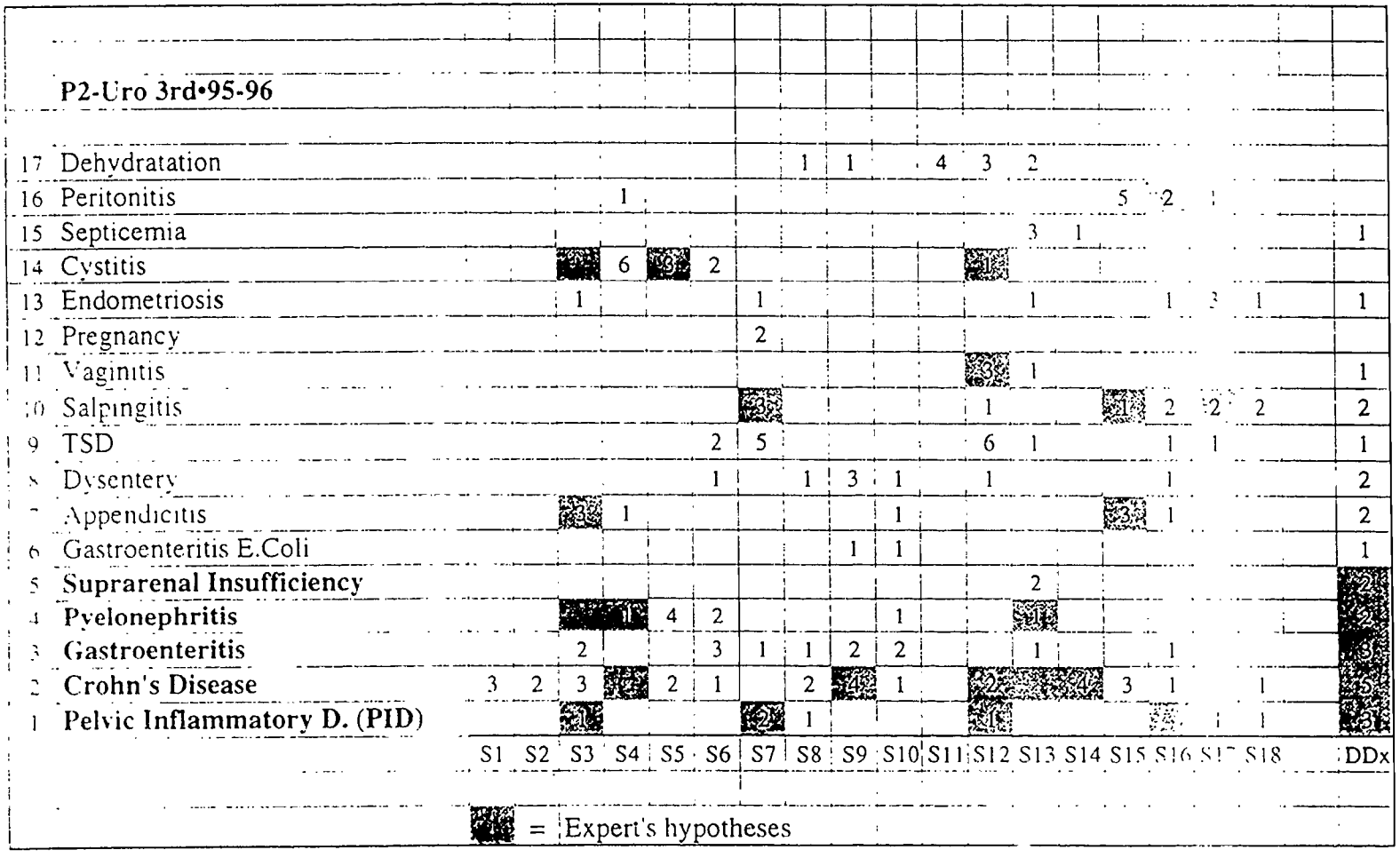

Figure 3: Hypothesis generation for each segment, third-year case.

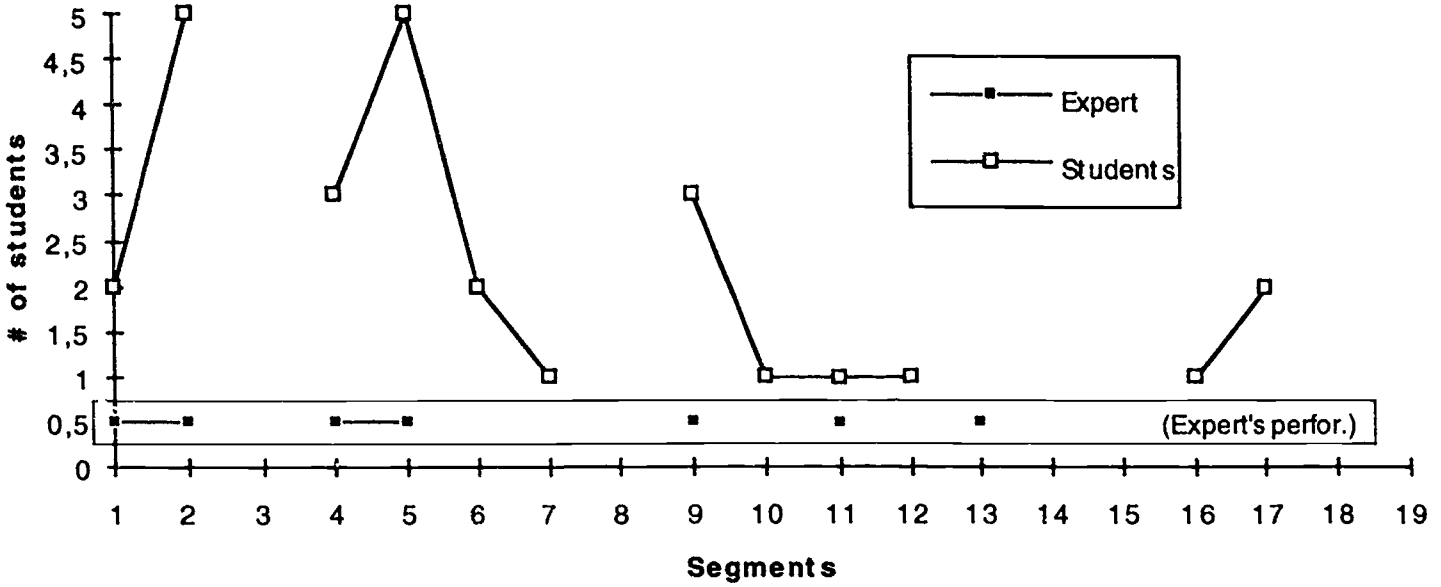

Figure 4: Distribution of the main hypothesis • Urology.Second-year

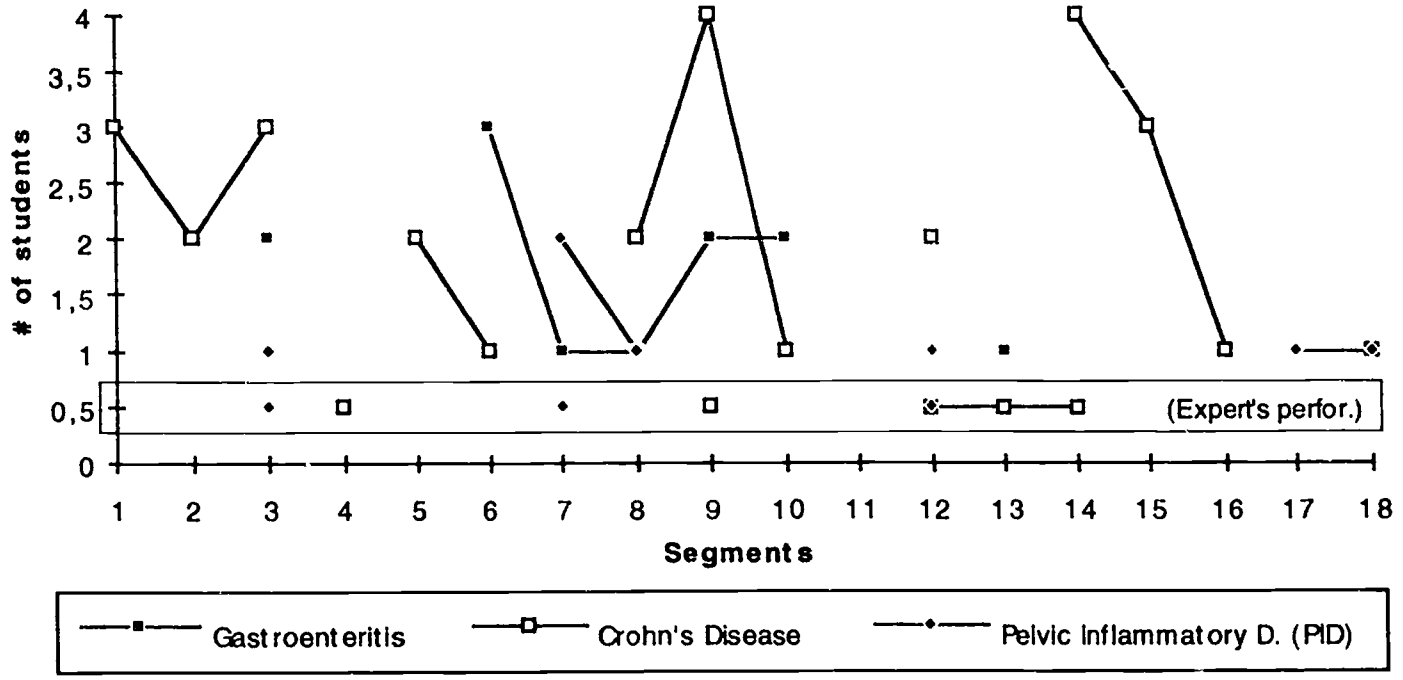

Figure 5: Distribution of the three main hypotheses • Urology.Third-year
(expert's performance represented at the bottom)

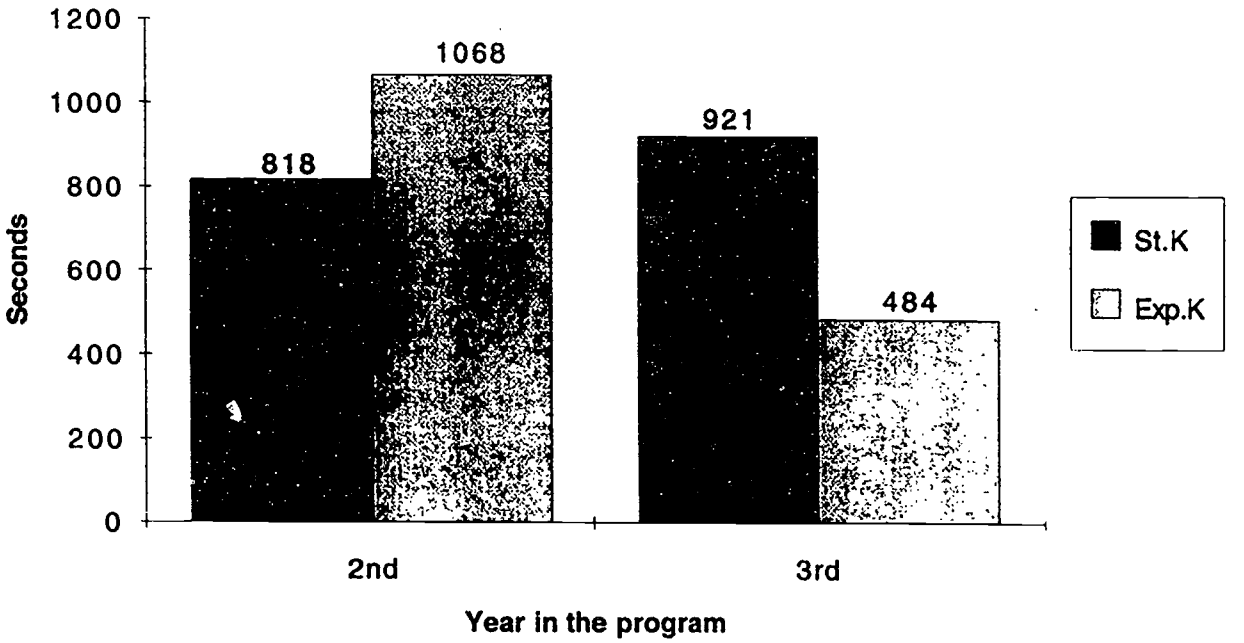

Figure 6: Total amount of time spent on each problem.

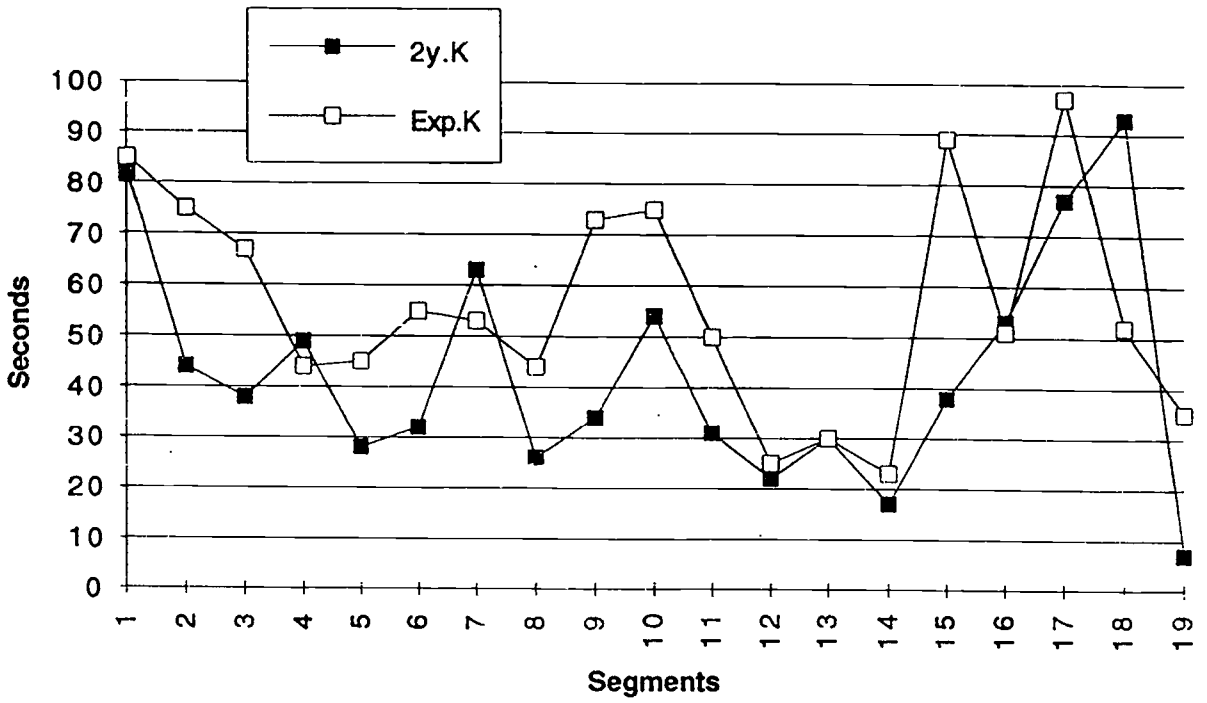

Figure 7: Time spent for each segment of the second-year case - Urology.

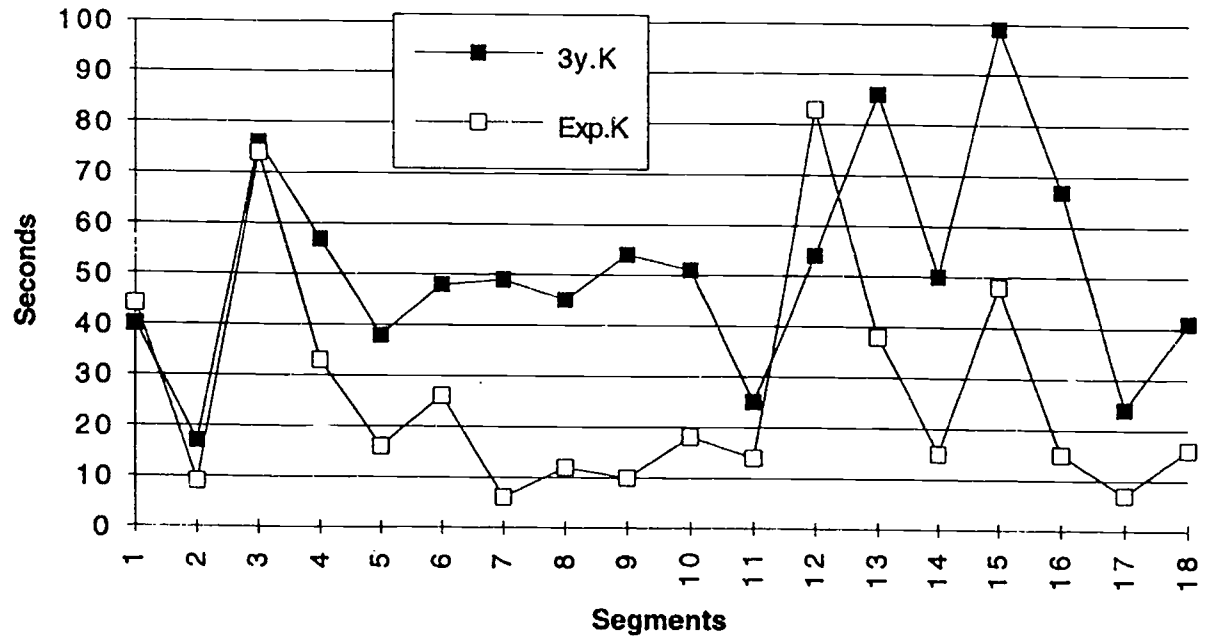

Figure 8: Time spent for each segment of the third-year case - Urology.

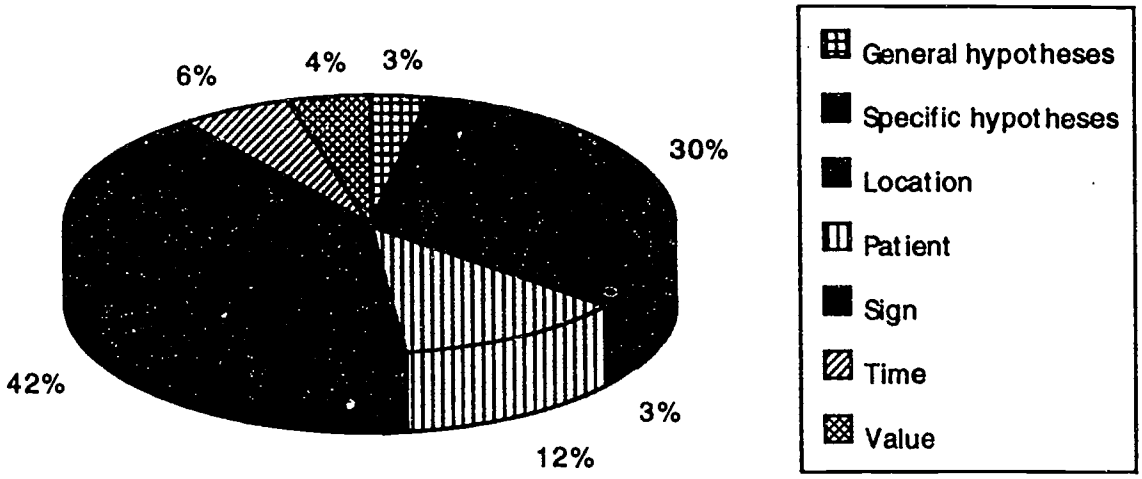

Figure 9a: Referring Phrase Analysis • Second-year case - Urology.

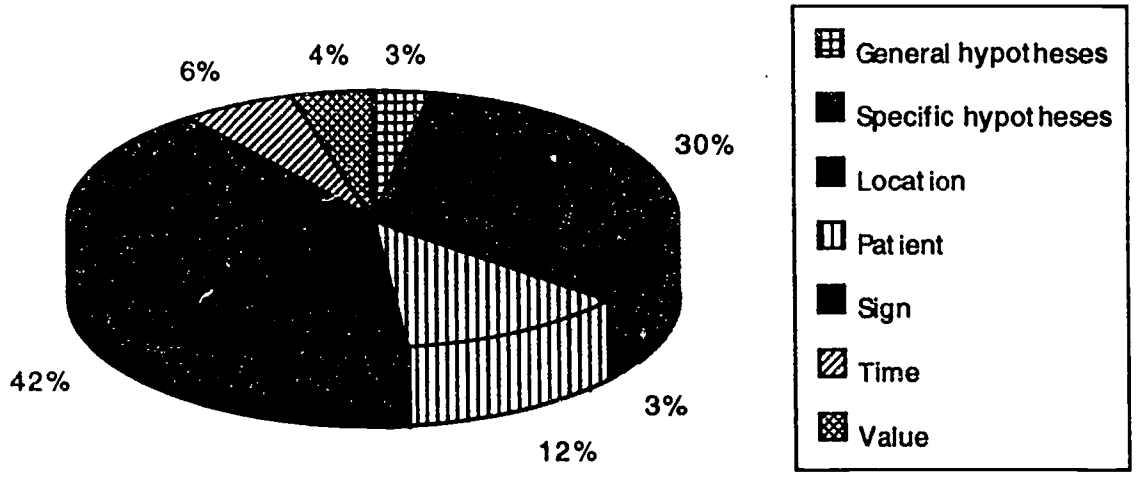

Figure 9b: Referring Phrase Analysis • Third-year case - Urology.

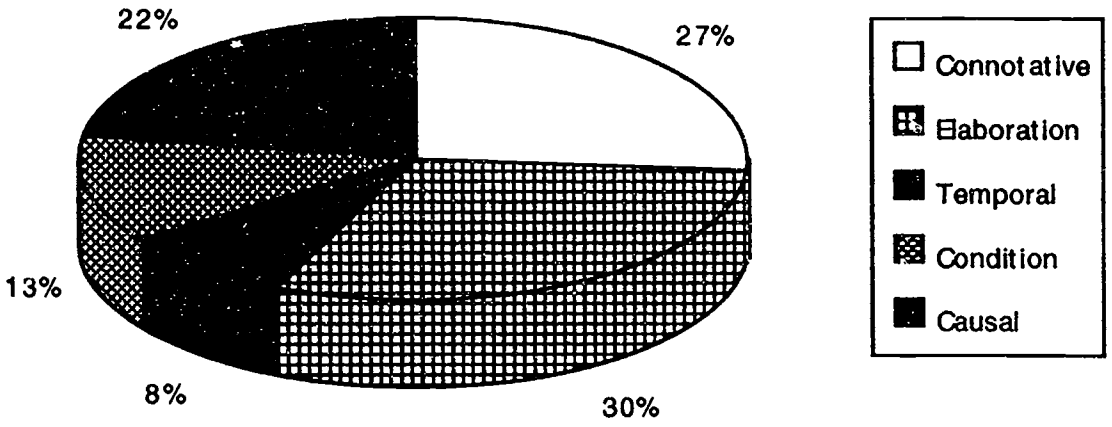

Figure 10a: Assertional Analysis • Second-year case - Urology.

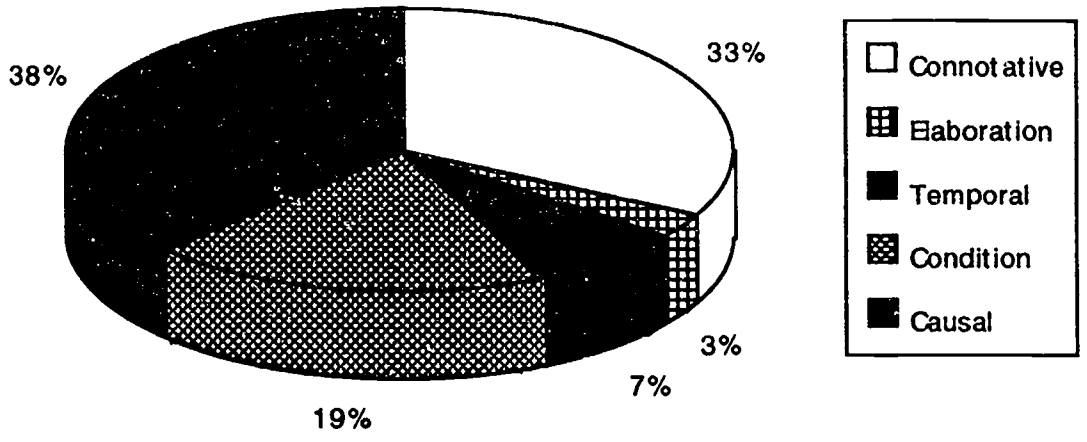

Figure 10b: Assertional Analysis • Third-year case - Urology.

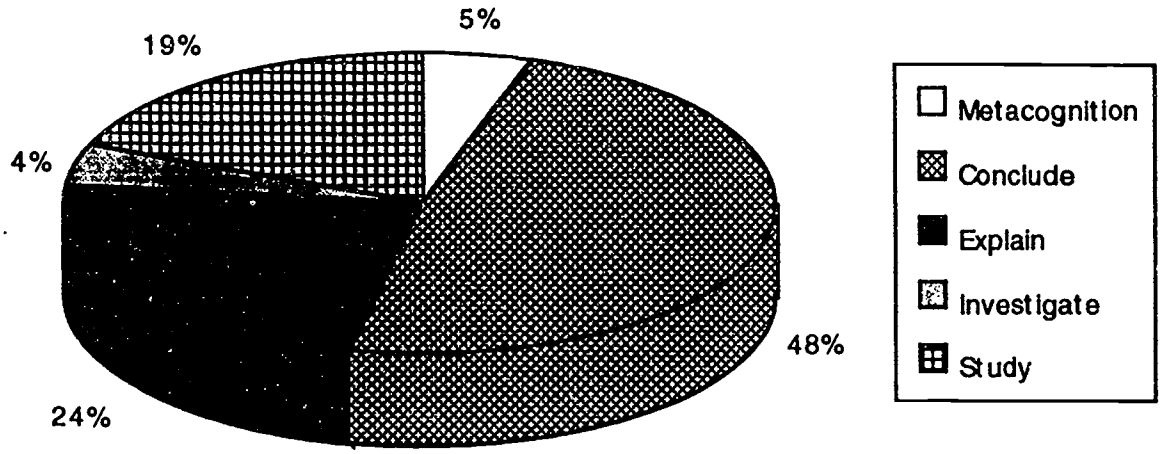

Figure 11a: Script Analysis • Second-year case - Urology.

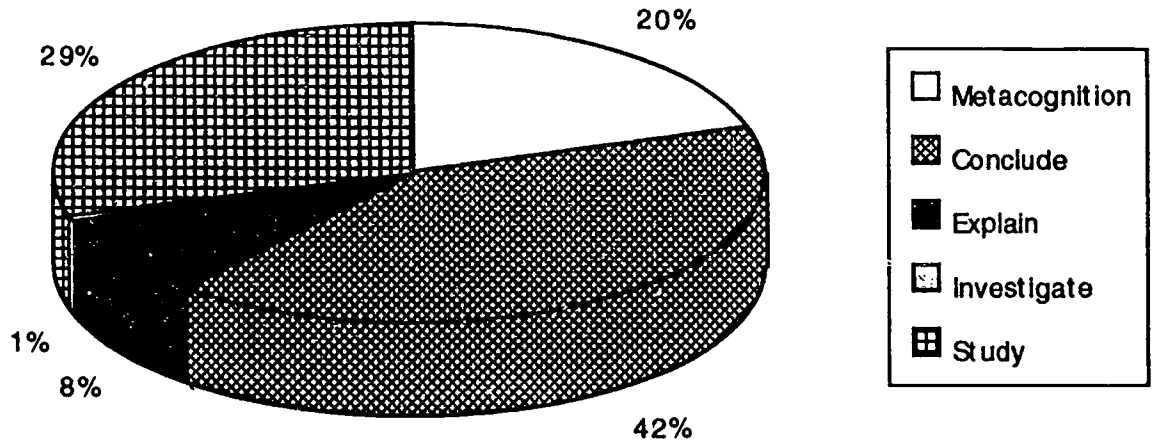

Figure 11b: Script Analysis • Third-year case - Urology.