The relation between learning process and content coverage is becoming increasingly important for the understanding of the effects of problem-based learning (PBL) on students’ learning. In our medical school, PBL is used as a major educational strategy in the discipline of pathophysiology. A computer program was developed allowing students to register learning issues identified as needed during tutorial sessions and learning issues stated as covered during the individual study periods. In our study, we compared “planned” (learning issues identified during PBL sessions) and “accomplished” learning issues (covered after the independent study periods) identified by pathophysiology students from three consecutive years. We found that the planned learning issues raised during tutorial sessions related to the issues effectively accomplished during the independent study and that their number grew stepwise from basic to preclinical to clinical sciences. Pathophysiology was, globally, the most mentioned discipline. Moreover, the most mentioned disciplines from the basic, preclinical, and clinical areas were physiology, histopathology, and internal medicine, respectively. The single-discipline approach did not limit the student’s capacity to identify and cover learning issues beyond the objectives of pathophysiology.

Key words: content knowledge; independent learning; medical education; tutorial system
dent’s learning. Nevertheless, there are scarce reports on this topic in the literature.

In the Faculty of Medical Sciences of the New University of Lisbon, we have been using PBL in recent years as a major educational strategy in our undergraduate pathophysiology course. This discipline is placed in the third year of a six-year traditional, lecture-based, medical curriculum. The early stages of the project have already been described in detail (17), including a report of a computer simulation especially designed by our group (18) on the basis of the principles of the aforementioned student-centered tutorial system. In small-group tutorial sessions, the students analyzed complete clinical cases, adapted from the PBL-modules produced by the Southern Illinois School of Medicine (8). The use of the computer simulation enabled a detailed record of the student’s procedures, including the lists of the learning issues produced during the various steps of the tutorial sessions.

Learning issues generated by students have recently been considered important triggers for the beginning of individual study and for the selection of information from the literature (23, 24). However, these studies were more concerned with the learning process than with content coverage and emphasized the role of teachers in determining the use of literature search in the initial years of a totally PBL curriculum. Another study from a mixed PBL curriculum (21) demonstrated that content coverage in systemic pathology and microbiology was similar for both PBL and lectures, provided that both approaches were based on clinical problems.

RESEARCH QUESTIONS

This study compared two different but interrelated learning issues: those identified as “planned” (considered more dependent on the tutorial process, since they derived from the tutorial sessions) with those stated as “accomplished” (considered more related to content coverage, since they derived from the independent study periods). We formulated the following research questions aimed at understanding the relation between planned and accomplished learning issues during the students’ learning process:

- Do learning issues raised by students during their PBL sessions relate to those issues covered during independent study periods?
- Do students during their independent study periods expand their content learning beyond the issues they have identified during the PBL sessions?
- Are these issues related to disciplines other than the one for which the cases were designed?
- Do students change the scope of their learning during the various steps of the clinical problem analysis, i.e., from history taking to physical examination and to diagnostic procedures?

MATERIALS AND METHODS

The discipline of pathophysiology is part of the third year of the curriculum together with other preclinical disciplines such as histopathology, immunology, genetics, and pharmacology. The objectives of the discipline are to promote an understanding of the altered regulatory functions of the various body systems, thus allowing the students to explain the scientific rationale behind representative signs and symptoms. The course lasts one academic year (two semesters), and the main topics are addressed in lectures that occur twice a week and where the students receive specific handouts. Most of the practical period given to the discipline is taken on by twice-weekly tutorial sessions at which attendance is obligatory, contrary to the free attendance of the lectures. The average yearly intake of students is 120.

The present study lasted three consecutive years, starting in 1997–1998, during which the performance of three tutorial groups, one each year, was assessed. Each group, comprising around 10 students, was confronted with the same sequence of six computer cases covering different body systems (Fig. 1). Each case was divided into six phases: 1) patient encounter, 2) present illness, 3) review of body systems, 4) personal, familial, and social background, 5) physical examination, and 6) laboratory findings and other diagnostic procedures. The tutorial sessions lasted two hours and occurred twice a week; the study of each case lasted five sessions and was supervised by
the same tutors (one senior teacher and one junior physician). The tutorial sessions (Fig. 2) consisted of the following steps: a) information gathering obtained from the computer simulation, b) generation of an explanatory hypothesis for the abnormal findings based on the underlying pathophysiological mechanisms, c) identification of relevant learning issues, identified as learning gaps to be filled to further understand the case (“planned” learning issues), d) independent study period, e) after the independent study period, review of learning issues effectively covered by consulting reference textbooks or other sources. The “planned” learning issues became “accomplished” learning issues when they were actually covered during the study time between sessions. Steps b, c, and e occurred as group discussions with the tutors.

Appropriate areas in the computer program were reserved for the students to type both the planned and the accomplished issues corresponding to each phase.

The students were advised to start their independent study period by using standard textbooks of pathophysiology, but they received no reading assignments or handouts; they had free access to the medical school library, whose staff were aware of the PBL project but were not directly involved in it. Although there was a wide range of library resources used by the students during the learning process, it was decided, in view of the exploratory nature of the present study, to consider textbooks only.

At the beginning of each session, after the independent study period, tutors and students discussed together the relevance of the information obtained and how the acquired knowledge was relevant for the continuous analysis of the case.

As the students were asked to introduce into the computer program all the learning steps (questions asked, hypothesis raised, learning needs planned and accomplished, learning resources) a full printout was obtained at the end of each case. We used those
printouts for the present analysis of the differences in amount and diversity between planned and accomplished learning issues. For each printout, six clusters of both the planned and accomplished issues were obtained, one per phase, and labeled by the tutors in one of four areas: 1) basic sciences (anatomy, physiology, biochemistry, etc.), 2) pathophysiology, 3) other preclinical sciences (histopathology, immunology, microbiology, etc.), and 4) clinical medicine (internal medicine, pediatrics, cardiology, etc.). Aimed at obtaining uniform criteria to compare the contribution of the various disciplines, each respective entry was included only once in every phase despite the existence of obvious quantitative differences in each case and between cases. All the entries regarding the planned and accomplished issues from the six cases in each year were grouped phase by phase, and finally the three consecutive years were grouped together.

In an attempt to evaluate the influence on learning at different stages of the problem analysis, from history taking to physical examination and to diagnostic tests, the planned and accomplished learning issues of phases 1–4 were compared with those of phases 5 and 6 by use of the aforementioned methodology.

This project was undertaken within the range of the activities supervised by the Pedagogical Council of our medical school, where students and faculty are represented.

**RESULTS**

This study showed a relation between planned and accomplished learning issues in all cases and at two levels: planned issues were converted into accomplished, and new accomplished learning issues were identified as having been covered during the independent study periods (Figs. 3 and 4).

Furthermore, we found a similar pattern in the three years concerning the entries of planned and accomplished learning issues (Table 1); that is, the number of learning gaps and effectively covered issues grew stepwise from basic to preclinical to clinical sciences (Fig. 3).

Starting with pathophysiology and considering that the maximal number of single entries was 12 per year (one per case in the sum of phases 1–4 and another one in the sum of phases 5 and 6, multiplied by the number of cases), a maximal score of 36 could be achieved in the three years. We found a total of 30 single planned issue entries in pathophysiology and a similar number, 33, of accomplished issues (Fig. 4).
Regarding the basic sciences and with a focus on physiology, the most mentioned discipline of this area, the values were 14 for the planned and 19 for the accomplished. In the preclinical sciences, the highest mentioned discipline was histopathology, with 17 planned issue entries and 25 accomplished. In the area of clinical medicine, the higher scores were obtained in internal medicine, with a doubling in the number of entries between the planned and accomplished issues, respectively 14 and 28 (Fig. 4).

DISCUSSION

The present study showed that the learning issues identified by the students as needed to further pursue their self-learning analysis of each case (planned issues) related to those covered during the period of independent study (accomplished issues) occurring between the tutorial sessions. There was also evidence that the students were stimulated to learn about additional issues other than those planned during PBL sessions. The study also showed that, despite the single-discipline PBL approach, the number and diversity of learning issues, both planned and accomplished, largely exceeded the discipline-based objectives of the pathophysiology course and included not only basic and preclinical sciences but also clinical medicine. Finally, we could also verify that, during the analysis of the clinical problem (history taking, physical examination, and diagnostic procedures), students progressively changed the scope of their learning from basic concepts to clinical issues.

Contrary to other studies concerned either with the information-seeking strategies of the students (6) or with the different aspects of self-directed learning (15), or even with the effects of PBL on library use (16), our study focused on the learning issues stated as planned and actually accomplished by our students using PBL in the discipline of pathophysiology. The arbitrary grouping of the learning issues in basic, preclinical, and clinical, with the isolation of pathophysiology, displayed a balanced distribution between basic and preclinical sciences, whereas it showed a doubling between planned and accomplished issues on clinical medicine.

The balanced distribution of learning issues between basic and preclinical disciplines may be interpreted as showing that, by use of this PBL approach, a proper balance was achieved between knowledge gaps identified during the tutorial process and content coverage during the independent study periods despite its
application in a single discipline. Various factors may have contributed to such a result: 1) appropriate case design, 2) tutorial methodology, 3) “free” access to the library without specific reading assignments, 4) the specific nature of pathophysiology, which may function as a “hinge discipline” between basic and preclinical disciplines on the one hand and clinical medicine on the other.

This study also seems to indicate that identified learning issues provide an insight into student’s learning activities during the independent study periods. Despite previous reports stating that learning issues collected during PBL sessions provide only minor information about a student’s actual learning activities (9), they were, in the present study, a useful way of gaining insight into their strategy, a notion confirmed by other reports (14, 22, 24). In our case, this was particularly relevant since our students tended to regard the planned learning issues as “homework,” the proper presentation of which was to be evaluated at the beginning of the next tutorial session. This behavior, far from compromising the essence of PBL, is actually desirable, for it is well known that students tend to neglect those aspects of their educational process that are not assessed (3, 5, 7). This is in accordance with Schmidt’s commentary (20) that PBL students are no less assessment driven than their colleagues from conventional curricula. Furthermore, as stated by Dolmans and Schmidt (10), different elements of the PBL process (such as course objectives, lectures, and reference literature) can influence learning as they provide “clues and directions” to the students, who have been shown to rely heavily on external guidance as to the orientation they should take in their study, particularly at the beginning of a new experience (13). In our case, the identification of learning issues in the tutorial sessions was strongly tutor centered and so is likely to reflect, at least in part, the faculty’s objectives and the tutor’s own individual priorities. This, however, as stated by Blumberg and Michael (4), does not entirely rule out the student’s independent selection of learning materials during individual study periods. On the other hand,
the present study was concerned with what our students learned in terms of content coverage, and not directly with the effects of tutorial guidance.

In view of the discipline-oriented organization of the curriculum, needed learning issues on pathophysiology were almost always reported and as often as all of the other preclinical sciences taken together (Fig. 4). Nevertheless, many other issues from basic and preclinical disciplines were simultaneously raised, adopting here the view of Blumberg et al. (3) that "the most useful learning issues are those that are applicable to both the case at hand and to larger basic-science or clinical concerns."

The stepwise growth of the number of planned and accomplished issues from basic to preclinical to clinical sciences probably indicates that, in general terms, our students were trying to integrate newly acquired knowledge, driven by the clinical structure of the cases. Furthermore, this observation probably reflects the students’ perception that understanding the “case” should be their first priority and not specifically the discipline in question (4). This notion is underscored by the fact that internal medicine, although comprising only one-third of all the planned clinical issues, accounted for more than one-half of all accomplished clinical issues. This is in accordance with the third principle of effective case design of Dolmans et al. (11): cases should preferably be presented in a context that is relevant to the future profession.

When we compared what happened in phases 1–4 (patient encounter and clinical history) with what occurred later in phases 5 and 6 (physical examination and diagnostic tests), we found that pathophysiology and basic science issues were symmetrically distributed. On the contrary, preclinical issues diminished by one-fourth, whereas clinical issues increased by one-third (Fig. 3). Apparently, our students’ strategy evolved throughout the cases from basic through preclinical to clinical: they started by reviewing basic concepts and progressively concentrated on clinical issues, mainly internal medicine, in the final phases.

Despite the preliminary nature of the study, conceived as descriptive and semiquantitative because of the extremely heterogeneous learning issues referred by the different tutorial groups, we can conclude that the single-discipline nature of the course did not limit the students’ capacity to identify and cover learning issues beyond the objectives of the pathophysiology course. This broader pattern of learning was due not only to the nature of the discipline but also to the use of PBL as an educational strategy with a proper bal-

### TABLE 1
Planned and accomplished learning issues in pathophysiology

<table>
<thead>
<tr>
<th>Areas</th>
<th>Phases 1, 2, 3, and 4</th>
<th>Phases 5 and 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planned</td>
<td>Accomplished</td>
</tr>
<tr>
<td>1997–1998</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic*</td>
<td>6 (4)</td>
<td>7 (5)</td>
</tr>
<tr>
<td>Preclinical†</td>
<td>9 (5)</td>
<td>7 (4)</td>
</tr>
<tr>
<td>Pathophysiology</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Clinical medicine‡</td>
<td>7 (1)</td>
<td>8 (6)</td>
</tr>
<tr>
<td>1998–1999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic*</td>
<td>7 (3)</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Preclinical†</td>
<td>7 (3)</td>
<td>9 (4)</td>
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<tr>
<td>Pathophysiology</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Clinical medicine‡</td>
<td>3 (0)</td>
<td>12 (4)</td>
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<tr>
<td>1999–2000</td>
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<td></td>
</tr>
<tr>
<td>Basic*</td>
<td>3 (2)</td>
<td>4 (2)</td>
</tr>
<tr>
<td>Preclinical†</td>
<td>4 (1)</td>
<td>5 (4)</td>
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<tr>
<td>Pathophysiology</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Clinical medicine‡</td>
<td>9 (4)</td>
<td>4 (3)</td>
</tr>
</tbody>
</table>

*The most mentioned discipline from each area is in parentheses: *physiology; †histopathology; ‡internal medicine.
ance between process and content. Further studies are needed, including a quantitative analysis of the stated information supplied by the students and a more general use of the data, expanding the analysis to other tutorial groups and to the consultation of other learning materials.

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