RESEARCH ARTICLES

The Relevance of Prior Knowledge in Learning and Instructional Design

Telle Hailikari, MSc, Nina Katajavuori, PhD, and Sari Lindblom-Ylanne, PhD

University of Helsinki

Objectives. To determine how different types of prior knowledge (declarative and procedural) impact student achievement and how prior-knowledge assessment can be used as an instructional design tool.

Methods. A questionnaire was developed based on the prior-knowledge model, which distinguishes between declarative and procedural knowledge. One hundred fifteen pharmacy students were tested prior to beginning 4 successive basic science courses and then prior to beginning a pharmaceutical chemistry course. Regression analysis was used to determine which type of knowledge was the best predictor of student achievement. The 4 course instructors were interviewed and their comments analyzed.

Results. Prior knowledge from previous courses significantly influenced student achievement. Procedural knowledge was especially related to student achievement. Instructors and students had mainly positive reactions towards the prior-knowledge tests.

Conclusions. Students' prior knowledge should be taken into consideration in instructional design and curriculum planning. Furthermore, the results of prior-knowledge assessments may be used as a tool for student support in addressing areas of deficiency.

Keywords: prior knowledge, assessment, instructional design, pharmacy education

INTRODUCTION

A common problem faced by instructors in higher education is that students lack important prior knowledge and skills needed when they enter the more advanced courses in their curriculum.[1-2] This is not only a challenge for students and instructors, but also an important issue in curriculum design. The Faculty of Pharmacy of Helsinki University in Finland conducted a massive curriculum reform as part of the Bologna process, which started from the Bologna Declaration in 1998 intended to bring harmonization within the European Higher Education System.[3] The most essential targets in the Bologna process were the enchangement and facilitation of student and teacher mobility and adaption of a system with 2 main cycles, more precisely the bachelor and master degrees. Furthermore, the aims were to establish a system of credits and to improve recognition of degrees and quality assurance at the level of higher education institutions. As a result, the curriculum was restructured in 2005 to improve continuity among courses so that there was a continuum of learning from basic knowledge through advanced knowledge. However, even after these reforms, some students still had inadequate knowledge in certain areas when they reached the more advanced courses.

Therefore, there was a need to empirically explore how different types of prior knowledge impact student achievement in a more advanced course, such as pharmaceutical chemistry, and to explore whether the knowledge students gain is retained as their studies proceed. Throughout this study, we juxtaposed the results obtained with the following question: could prior-knowledge assessment be used as an instructional support tool in pharmacy education?

Prior knowledge is defined as a multidimensional and hierarchical entity that is dynamic in nature and consists of different types of knowledge and skills.[4-6] Prior knowledge has long been considered the most important factor influencing learning and student achievement.[4-10] The amount and quality of prior knowledge positively influence both knowledge acquisition and the capacity to apply higher-order cognitive problem-solving skills.[11-15] An essential factor in developing an integrated knowledge framework is to create a learning environment in which learning means actively constructing knowledge and skills on the basis of prior knowledge.[6,10] Inadequate or fragmented prior knowledge is an important issue to consider because if there is a mismatch between the instructors' expectations of student knowledge and the students' actual knowledge base, learning may be hampered from the start of the studies. Trying to learn something without having adequate prior knowledge or, worse,

Corresponding Author: Sari Lindblom-Ylanne, University of Helsinki, Helsinki, Finland. Tel: +358-9-191-20628. E-mail: sari.lindblom-ylanne@helsinki.fi

having misconceptions, may result in rote memorization. This type of surface learning may occur if students cannot relate the new knowledge to their existing knowledge frameworks.[13,16-17]

In applied science education, such as pharmacy, where knowledge is learned in order to be able to apply it, it is important for students to develop an integrated knowledge framework from the start of their studies.[16] Therefore, deep-level understanding in basic courses is extremely important in promoting good quality learning because these courses usually form an important base for future learning.[14] Inadequate learning in basic courses may have long-term effects that get in the way of learning later in the students' studies.[2] One way to enhance students' high quality learning may be the use of prior-knowledge assessment as a tool for evaluating the level of support a student will need.[18-21]

In prior-knowledge assessment as in assessment in general, the instructor should be aware of what type of knowledge is being assessed. Distinguishing between different types of prior knowledge is important because not all types of prior knowledge have similar relevance to student achievement. More detailed prior-knowledge assessment provides detailed information about the students' prior-knowledge base[7,20,22] and, further, may be more beneficial as a diagnostic tool for student support. In the prior knowledge model[6] applied in the present study, a distinction was made between declarative and procedural knowledge. At the lowest level, prior knowledge may consist of declarative knowledge, which is the knowledge of facts and meanings that a student is able to remember or reproduce. This type of declarative knowledge is often referred to as "knowing about" or surface learning.[23] Declarative knowledge can also be described as rote learning or "knowledge-telling" which may include many facts and details that do not form an integrated whole.[23] Students who have declarative knowledge are able to answer fairly simple reproduction tasks that do not require an ability to integrate or apply knowledge.[4] Procedural knowledge, on the other hand, is characterised by an ability to integrate knowledge and understand relations between concepts and, at the highest level, apply this knowledge to problem-solving. It is often referred to as "knowing how" and is closely related to higher-order cognitive skills (Figure 1).[4]

A previous study found that prior knowledge that mainly consisted of declarative knowledge did not contribute to student achievement.[6] On the other hand, students who had a more integrated prior-knowledge base and were able to operate on higher levels of procedural prior knowledge at the beginning of the course were more likely to be successful. These results emphasize the importance of recognizing students' prior-knowledge base at the beginning of the learning process. Therefore, the focus should not only be on *what* students know but also on *how well* they know it.[23]

The study was conducted at the Faculty of Pharmacy of Helsinki University in Finland. The Faculty confers bachelor, master, and doctoral degrees. The aim of the 3-year bachelor's degree program is to provide qualifications for working in the field of health care in positions that require pharmaceutical expertise. Part of the students enter the master's degree program after competing the bachelor's program. The aim of the 2-year master's program is to enhance the students' research and leadership skills in addition to the qualifications provided by the bachelor program.

The first semester of the bachelor's program includes mainly science courses (eg, mathematics and chemistry), which form a basis for more advanced pharmacy courses. The bachelor's curriculum is constructed as a continuum from basic courses towards more advanced courses. Nevertheless, it was found that pharmacy students lacked prior knowledge from their basic science courses when they entered the more advanced laboratory course in pharmaceutical chemistry. Students had problems with basic science concepts, and furthermore, difficulty applying this knowledge to practice during their laboratory work.

Thus, there was a need to explore how the first science courses at the beginning of the bachelor's program prepare students for the laboratory course in pharmaceutical chemistry and how learning from these courses is retained and whether students are able to apply this knowledge as their studies proceed. Furthermore, we wanted to explore faculty members' experiences using the prior-knowledge assessment as a tool for instructional support and students' experiences in taking the prior-knowledge test.

METHOD

Data were gathered in 2006 during 5 different courses over a half-year period (Figure 2). Mathematics and chemistry courses were taught simultaneously followed by organic chemistry courses, and finally the laboratory course in pharmaceutical chemistry. Before starting each course, students' prior knowledge was assessed. The tests were based on the model of prior knowledge, which offers a theoretical framework for prior-knowledge assessment but allows course instructors to develop the specific tasks for the tests. (Figure 1).[6] Thus, each of these tests was designed to measure the hierarchical levels of knowledge content of the courses: knowledge of facts, knowledge of meanings, skills to integrate knowledge and understand relations between concepts, and, finally, skills to apply knowledge to problem-solving. The tasks measuring
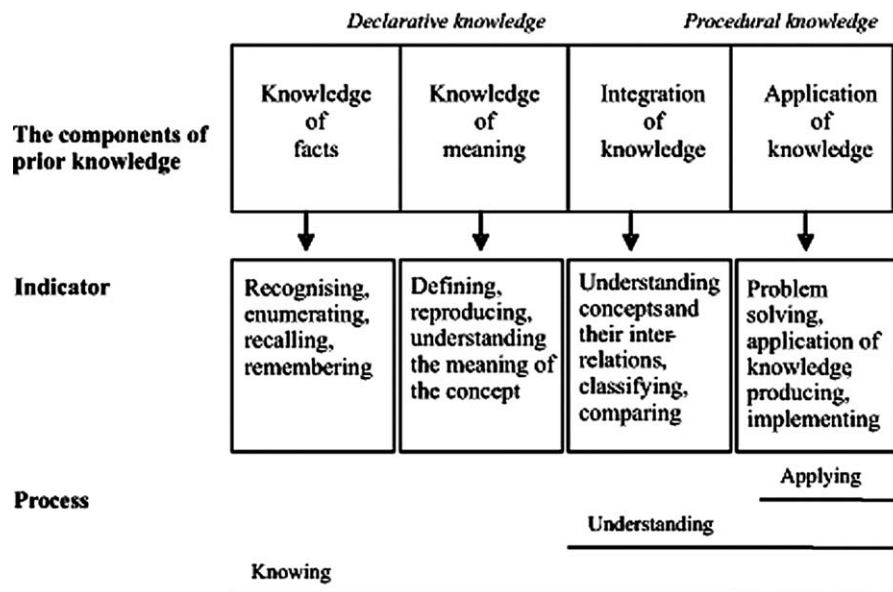
Figure 1. The model of prior knowledge. (Copyright 2007. Hailikari, Nevgi & Lindblom-Ylänne.)

"knowledge of facts" were fairly simple reproduction tasks, such as enlisting or recognition of a correct answer. "Knowledge of meaning" tasks required deeper understanding, such as providing a definition or understanding the meaning of a concept or formula. The tasks measuring the integration of knowledge required deep understanding and an ability to relate different concepts to one another. The task measuring application of knowledge required an ability to apply knowledge in problem-solving. The instructors of the courses created the tasks of the tests in cooperation with the authors. The authors provided the framework (the model of prior knowledge) and the nature of the tasks was discussed thoroughly.

The students were given 1 hour to complete the prior-knowledge tests at the beginning of each of the 5 courses.

In addition, in the prior-knowledge test for the pharmaceutical chemistry course, 1 task from each of the prior-knowledge tests for the preceding courses was included. We chose tasks from the preceding prior-knowledge tests that measured the 2 highest levels of prior knowledge, that is, the integration of knowledge and the application of knowledge components. The reason for this was that these types of tasks require high-quality learning and understanding and are assumed to subsume lower levels of knowledge.[6] Mastering these types of tasks is hypothesized to form a foundation for future learning. The purpose of these repeated tasks was to explore whether the knowledge was retained and whether there were changes in performance between the first and second measurement.
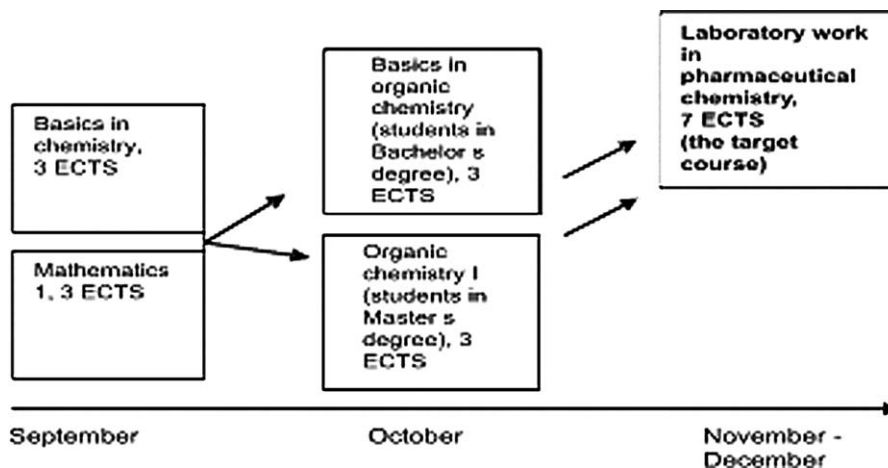

Figure 2. The structure of the first term curriculum.

The course instructors also scored the prior-knowledge tests for their respective courses. In each course, the tasks were scored from 1 to 6, with 1 being the minimumand 6 being the maximum number of points. One point was given if there were some elements right in the answer but the final answer was incorrect. Three points were given if about half of the answer was correct. Six points were awarded for a correct answer. After the instructors' scoring, the authors double-checked the scores.

The 4 prior-knowledge tests are referred to as the first measurement. In the present study, we focus on the prior-knowledge test of the pharmaceutical chemistry course (the fifth test) where the chosen tasks from previous courses were repeated along with the prior-knowledge tasks from the pharmaceutical chemistry course. The prior-knowledge test of the pharmaceutical chemistry course is referred to as the second measurement (Table 1). It comprised 8 tasks, which included 4 tasks of the pharmaceutical chemistry course content and 1 task repeated from each of the previous courses.

In addition, we interviewed the 4 instructors of the courses in order to explore their experiences regarding the usefulness of the prior-knowledge test as an instructional design tool. Recorded interviews were conducted after the courses. In the interviews, we asked instructors how they had used the prior-knowledge assessment tool, how it had impacted their teaching, what were their opinions of the tool, and how useful was it. Furthermore, students were given space in the tests to comment on their experiences with the prior-knowledge assessment test. This was voluntary and the comments were gathered during the fall term (Table 1).

Correlation analysis was used to explore the interrelations between different types of prior knowledge. Regression analysis (enter) was carried out to explore which types of prior knowledge predicted student achievement in the pharmaceutical chemistry course. Paired samples *t* test was used to explore the changes in performance between the first and second measurement. The instructors' interviews and students' written comments were analysed by qualitative content analysis.[24,25]

RESULTS

The majority of the 115 students (95%) enrolled in the pharmaceutical chemistry course were first-year students. The rest were second- or third-year students who for some reason did not complete these courses during their first year.

The majority of the students were female (79%). Ninety-seven percent of the participants were pharmacy students. The remaining 3% consisted of biochemistry and chemistry students. Most of the students (60%) had completed less than 10 European Credit Transfer System (ECTS) credits before participating in the courses under study. (One credit is equivalent to 27 hours of work in the European Credit Transfer System). One fifth of the students (22%) had completed from 10 to 30 ECTS credits and the rest (18%), over 30 ECTS credits. Four instructors of the courses included in the study were also interviewed about their experiences with the prior-knowledge test.

Overall, the students performed fairly well in the prior-knowledge test in the pharmaceutical chemistry course (Table 2). Students performed especially well in tasks that measured optimal-requisite prior knowledge for the pharmaceutical chemistry course. The performance was weakest in the tasks that measured knowledge from previous courses, that is, the mathematics task and organic chemistry tasks. (Table 2)

Analysis of prior-knowledge scores revealed that performance on almost all prior-knowledge tasks was correlated with the final grade in the target course (laboratory course in pharmaceutical chemistry) with the exception of tasks that measured knowledge of (pharmaceutical chemistry) facts and the application of basic chemistry knowledge. Students who possessed relevant and deeper-level prior knowledge from previous courses were also likely to get better final grades in the pharmaceutical chemistry course. The strongest correlations were found between performance on organic chemistry tasks and the final

Table 1. An Overview of the Prior Knowledge Tests and the Number and Type of Different Prior Knowledge Tasks in the Target Course

Type of Prior Knowledge Task	First Measurement			Second Measurement (Target Course)			
	Math	Chemistry	Organic Chemistry	Math	Chemistry	Organic Chemistry	Pharmaceutical Chemistry
Knowledge of Facts	1	1	2				1
Knowledge of Meaning	1	1	2				1
Integration of Knowledge	1	1	2			1 (r)	1
Application of Knowledge	1	1	2	1 (r)	1(r)	1 (r)	1

Abbreviations: (r) = repeated tasks from previous courses as a part of the second measurement

Table 2. Performance in Different Prior Knowledge Tasks[a] in Laboratory Course in Pharmaceutical Chemistry (N=115)

Subject and Type of Prior Knowledge Task	Mean (SD)
Pharmaceutical chemistry (fact)	4.99 (1.62)
Pharmaceutical chemistry (meaning)	4.23 (2.66)
Pharmaceutical chemistry (integration)	4.64 (2.52)
Pharmaceutical chemistry (application)	4.70 (2.49)
Mathematics (application)	3.01 (2.60)
Basics in chemistry (application)	4.41 (2.31)
Organic chemistry (integration)	2.30 (2.24)
Organic chemistry (application)	3.83 (2.72)

[a]Performance on the tasks was rated on a scale of 0-6 on which 0 = completely wrong answer

grade in the pharmaceutical chemistry course. Furthermore, performance on the organic chemistry application task was also strongly correlated with the other tasks (Table 3).

Regression analysis was conducted to determine which type of prior knowledge had the strongest relationship with the final grade in the pharmaceutical chemistry course. Only the variables that were significantly correlated with the final grade were included in the analysis. The association between the criterion and explanatory variables was moderate (multiple R = 0.53). The only variable that was positively related to the final grade was the application task in organic chemistry, which accounted for 24% of the variation in the final grade (adjusted R^2). The regression coefficient for the organic chemistry application task was 0.22 and the standardized coefficient (β) was 0.36 (F (6,107 = 6.9; $p < 0.01$). The other variables were not related to the final grade, although the application task in mathematics and the knowledge of meaning in pharmaceutical chemistry were close to the significance level ($p = 0.06$ for both).

Analysis of prior-knowledge scores indicated that knowledge was retained over the 5 courses examined. There was a clear and significant increase between the first and second measurement in all tasks included in the follow-up, with the exception of *Basics of Chemistry*. In the mathematics application task, the mean in performance increased from 1.95 to 3.12 ($p < 0.01$). In the organic chemistry task measuring the integration of knowledge, the mean increased from 1.46 to 2.15 ($p=0.003$). In the organic chemistry task measuring the application of knowledge, the mean increased from 3.08 to 3.78 ($p=0.008$). However, in the chemistry application task, the mean of the performance decreased from 4.90 to 4.35 ($p=0.030$). This deviant result may be explained by the nature of the task. When the instructors were scoring the results they noticed that the task was slightly imprecise and there were multiple ways to interpret the task. Therefore, the results may also be interpreted with the fact that students' understanding increased and therefore performance in this task decreased because they noticed the impreciseness of this task. The results suggest that the learned knowledge did not disappear but rather increased.

All 4 course instructors participated in the postintervention interviews and provided feedback about the prior-knowledge assessments. The instructors felt that the prior-knowledge tests helped them to recognize the different types of knowledge and to acknowledge the importance of structuring the nature of knowledge in more detail. The model of prior knowledge (Figure 1) and prior-knowledge test derived from this model were considered useful and helpful in designing the questions for prior-knowledge test but also for other examinations. The model helped instructors reflect on the content of their own examinations.

In the present study the instructors did not give any feedback to the students about their performance in the

Table 3. Intercorrelations Between Prior Knowledge Types and Final Grade in Pharmaceutical Chemistry (N = 115)

Type of Prior Knowledge Task	Type of Prior Knowledge Task								
	1	2	3	4	5	6	7	8	9
1 Final grade in pharmaceutical chemistry course		0.13	0.31[a]	0.25[a]	0.21[a]	0.19[a]	-0.07	0.24[a]	0.46[b]
2 Pharmaceutical chemistry (Knowledge of facts)			0.09	0.25[a]	0.19[a]	0.09	-0.03	0.12	0.25[b]
3 Pharmaceutical chemistry (Knowledge of meaning)				0.32[b]	0.20[a]	0.07	0.06	0.20[a]	0.26[b]
4 Pharmaceutical chemistry (Integration of knowledge)					0.17	0.05	-0.03	0.17	0.40[b]
5 Pharmaceutical chemistry (Application of knowledge)						0.13	0.02	0.17	0.31[b]
6 Mathematics (Application of knowledge)							-0.19[a]	-0.05	0.05
7 Basics in chemistry (Application of knowledge)								0.01	0.05
8 Organic chemistry (Integration of knowledge)									0.33[b]
9 Organic chemistry (Application of knowledge)									-

[a]$p < 0.05$
[b]$p < 0.01$

prior-knowledge test. However, the instructors said that it would be important to provide feedback to the students as early as possible during the course. This would enable the prior-knowledge test to enhance students' learning in a more efficient way. The instructors suggested that the test should be conducted before the course began so that they would have sufficient time to score the answers.

The instructors did not apply the results of the test to modify their teaching but they felt that the test helped them to become aware of students' knowledge levels. Two instructors called for guidance in how to use the results of the prior-knowledge test results in their instruction. All the instructors felt that prior-knowledge assessment could help instructors recognize students with problems. They also felt that the prior-knowledge assessment would be useful, especially in the basic courses.

Most of the students did not comment on the test at the end of the test. Only 48 of the 115 students who completed the prior-knowledge test provided comments about the assessment. Of these comments, 41 were positive and 6 were negative. The most common positive comment was that the prior-knowledge test made students more aware of what they knew and did not know (n = 30). Thus, it served as a means of self-assessment. It also made them think about what they needed to do in order to succeed, like rehearsing or finding support from instructors or fellow students.

Six students commented that the prior-knowledge test made them feel that their instructor cared about their learning and that it was important for the instructor to know the prior-knowledge level of the students. Five students commented that the prior-knowledge test was a good way to rehearse and activate knowledge from previous courses.

Negative student comments dealt with negative feelings that arose from taking the test. Two students commented that a prior-knowledge test which is conducted without warning is not a true measure of students' actual knowledge base. These students wished that they had been allowed time to study for the test. Three students commented that the prior-knowledge test made them feel anxious and worried that they did not know enough. One student commented that the test was a "useless waste of time."

DISCUSSION

The purpose of this study was, first, to explore how prior knowledge from previous courses influences student achievement in a more advanced pharmaceutical chemistry course, and second, to determine whether the learned knowledge is retained as the students' education proceed.

The results revealed that prior knowledge from previous courses indeed contributed to learning in a more advanced pharmaceutical chemistry course. These results imply that the curriculum reform was successful in constructing courses as a continuum. Students who possessed relevant and deeper-level prior knowledge from previous courses were also likely to get better final grades in the pharmaceutical chemistry course. Furthermore, prior knowledge that consisted of facts did not contribute to student achievement. This result provided further support for previous findings.[6] It seems that even a large body of factual knowledge is not enough if students do not understand the interrelations between those facts. Thus, teaching in higher education should actively aim at helping students reach higher levels of understanding where knowledge is active and functioning and not expect students to reach those levels on their own.[23] This may be done by providing powerful learning environments where students' prior knowledge is taken into account in instruction.[11] Interestingly, good performance in organic chemistry appeared to predict student achievement especially well. Performance in the organic chemistry task was also strongly related to performance in other tasks. This suggests that if a student was able to perform well in the organic chemistry task, it is likely that he/she would perform well in other tasks as well. It can be concluded that other courses contributed to performance in organic chemistry, which seems to subsume the knowledge from previous courses. This result further implies that the sequencing of the courses is an essential issue that should be considered. Purposeful integration of knowledge from previous courses should be attempted whenever possible in order to help students form an integrated knowledge base.[16,26]

Another important finding to emerge was that student performance was fairly heterogeneous at the beginning of the pharmaceutical chemistry course. This highlights the variation in students' knowledge bases and the inter-individual differences that influence student achievement. These results underscore the importance of prior-knowledge assessment in recognizing the variation between students. Good performance in the more advanced course goes back to the basic courses. Therefore, if students drop behind at the beginning of their studies, it is reflected in their performance in more advanced courses. A positive result to emerge was that knowledge was retained and, furthermore, it increased as the studies proceeded. This implies that the instruction achieved its objectives in teaching students the basics in mathematics and chemistry.

Both the students and the instructors were mostly positive towards prior-knowledge assessment. The

instructors had a clearer impression of the students' prior-knowledge level, which helped them to adapt their teaching to the needs of the learner.[20] This knowledge of learners and reflection on its implications provides a good basis for improving teaching.[27] Furthermore, prior-knowledge assessment helped students become more aware of their own knowledge base and helped them to understand that their investment is needed during the forthcoming courses as was also shown in previous research.[5,19] Therefore, even without feedback from their performance, the students felt that they benefited from the assessment by becoming aware of their weak points. Some student responses revealed that students experienced the assessment as a test for which they should have been prepared. This underscores the importance of clarifying the purpose of prior-knowledge assessment to the students. Students may not be used to the "new assessment culture" where assessment is used for learning and where the emphasis is on the beginning of the learning process.[28] However, since the number of students' comments was fairly limited, more research is needed on this issue.

CONCLUSION

The results of this study imply that prior-knowledge assessment that happens at the beginning of the course may be an important tool for instructional support. By assessing prior knowledge, it is possible to identify students who are struggling with their studies. However, prior-knowledge assessment alone is not enough: students should be provided with feedback on their performance and instructors should be aware of how the assessment results can be used in instructional design. Prior-knowledge assessment results can be used for various purposes: identifying students who are struggling with their studies; finding an appropriate level at which to start the course; provision of feedback to students; bridging the gap between instructors' expectations and students' actual knowledge base; and grouping students according to their abilities. Furthermore, in prior-knowledge assessment it is important to acknowledge that different types of prior knowledge have different relevance to student achievement. The instructors should help students develop an integrated knowledge framework and move beyond factual knowledge. This may be done by building on students' existing knowledge and helping students see interrelations between the courses and the ideas presented.

ACKNOWLEDGEMENTS

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