In addition to preparing multiple-choice responses in advance, we have also allowed them to develop in tandem with class discussions. Students are asked to propose various answer options, and then the class "votes" on the options using the flash cards.

Flash-Card Feedback. Flash-card responses provide feedback to the instructor on two key parameters: (1) student misconceptions regarding the topic under discussion, and (2) pace of student understanding in the class as a whole. The instructor gets some feel for the degree of student comprehension by how quickly and confidently they are able to show their cards. Flash-card responses also offer students a means of testing the level of their understanding of the topic under discussion. Moreover, students see that others hold the same misconceptions. If the number of incorrect responses is high—for example, 30% or more—the instructor takes additional time to discuss that particular question before moving on.

For instance, after introducing the definition of acceleration, and discussing examples, the following question (taken from a widely used test bank[13]) was asked: *A ball is thrown vertically upward from the surface of the Earth. Consider the following quantities: (1) the speed of the ball; (2) the velocity of the ball; (3) the acceleration of the ball. Which of these is (are) zero when the ball has reached the maximum height? (A) 1 only; (B) 2 only; (C) 1 and 2; (D) 1 and 3; (E) 1, 2, and 3.* There were 60 students in the class; the numbers of students supporting each response were 0, 0, 15, 20, and 25, respectively. A spirited and intense discussion among the students followed (with guidance from the instructor), and continued for over 20 minutes. (Flash cards may also be used to gauge improvement in student understanding that results from class discussion.)

Sample Problem. It is possible to take a fairly complicated problem, involving several different concepts, and break it down into conceptual elements. We work through the problem piece by piece, with constant interaction and feedback from the students through the use of the flash cards.

Sample Problem

A 25.0-kg block has been sliding on a frictionless, horizontal ice surface at 2.00 m/s. Suddenly it encounters a large rough patch where the coefficient of kinetic friction is 0.05. How far does the block travel on this rough surface? *[Questions 1 through 10 refer to the motion on the rough surface.]*

1. How many *different* forces are now acting on the block? (Ignore air resistance.)
   A. 0 B. 1 C. 2 D. 3 ← E. 4 F. 5

2. What is the direction of the weight force? *(See Fig. 1.)*
   A. B. C. D. ← E. F.

3. What is the direction of the normal force?
   A. ← B. C. D. E. F.

4. What is the direction of the frictional force?
   A. B. C. D. E. F. ←

5. Is the block accelerating?
   A. Yes ←
   B. No
   C. Not enough information

6. What is the acceleration in the *y* direction?
   A. Greater than zero
   B. Less than zero
   C. Equal to zero ←
   D. Not enough information

7. What is the acceleration in the *x* direction?
   A. Greater than zero
   B. Less than zero ←
   C. Equal to zero
   D. Not enough information

8. How many forces are directly causing the acceleration in the *x* direction?
   A. 0 B. 1 ← C. 2 D. 3 E. 4 F. 5

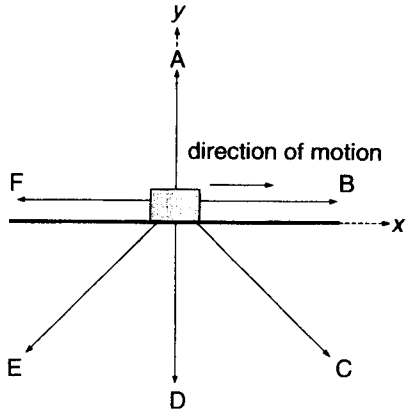

Fig. 1.

9. Put the appropriate letters in each box of the table:

	x direction	*y* direction
Weight Force	*[C]*	*[B]*
Normal Force	*[C]*	*[A]*
Friction Force	*[D]*	*[C]*
Total	*[F]*	*[C]*

[Correct answer options are indicated by letters in brackets.]

A. +245 N
B. −245 N
C. 0 N
D. −12.25 N
E. +12.25 N
F. ma_x

10. Find the *x* component of the acceleration, and use it to determine the distance traveled. *[−0.49 m/s²; 4.08 m]*

In the Sample Problem given here, the essential steps leading to the solution are dealt with in questions 1 through 8. (Each successive question is presented only after the preceding one has been answered and discussed.) After the class completes these successfully, they proceed to the quantitative phase in questions 9 and 10. In question 9, the instructor will first point to one of the cells in the table—for instance, the cell referring to "Weight force/*x* direction"—and ask the class to hold up the flash-card letter of the appropriate response. In this way, all the cells in the table will be filled in, one by one. Finally, students may be asked to complete the problem by finding the answer to question 10 and checking it with those seated next to them, or with other student groups.

IV. Assessment

We encourage students to prepare for, attend, and participate attentively in class by offering frequent in-class assessment measures that contribute to students' overall grades. In addition to the traditional exams and quizzes, we have used several methods of having students solve quiz questions by working together in groups. Reference to notes, or to both notes and textbook, may be allowed. Students work in groups of two, three, or four, and groups may be allowed to confer with each other. Individual students may be permitted to "dissent" from a