REFLECTIONS ON A LARGE-LECTURE, INTRODUCTORY METEOROLOGY COURSE

Goals, Assessment, and Opportunities for Improvement

BY JONATHAN D. W. KAHL

A systematic study on teaching and learning goals in an introductory meteorology course: are students learning what we want them to learn?

The Atmospheric Science program at the University of Wisconsin—Milwaukee regularly offers the general education course Survey of Meteorology. For many students this is one of only two natural science courses they will take in their college career. In addition to its laboratory component, this popular course includes two lecture hours each week, offered in two or three large sections with typically 250–375 students served each semester.

To assess what students learn in the lecture sections of Survey of Meteorology, the instructors administer two or three multiple-choice exams during the semester (the laboratory component of the course is assessed separately and is not addressed in this study). While this assessment methodology is expedient and prevents an onerous burden on the instructor, it is unclear whether it accurately measures the degree to which students meet the course goals. Here I describe the results of a systematic inquiry into the teaching and learning goals of the course and the adequacy of current methods used to assess student performance.

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DATA AND METHODS. As an initial step, I asked the six atmospheric science faculty who regularly teach the lecture component of Survey of Meteorology (including myself) what they wanted their students to learn. All faculty identified an understanding of meteorological content as an important learning goal. Four of the six faculty added the application of meteorological concepts to observations, such as interpreting weather charts and making forecasts, as another learning goal. Other responses included a desire for students to understand media presentations of scientific issues and to make informed voting decisions when political issues involve atmospheric science.

TABLE 1. Summary of survey questions administered to students at the beginning and the end of the Survey of Meteorology course. Each survey contained 15 questions.

Subject areas	Question types within each subject area
Solar radiation	Content
Water	Application
Wind and forces	Deeper application
Weather systems	
Climate	

Example questions

Content question (solar radiation)

Two types of energy constantly move vertically through the atmosphere in the form of radiation. One type, *solar radiation,* is generated by the Sun. The second type, called *longwave radiation* or *terrestrial radiation,* is generated by the Earth and clouds.

a. I have never heard of the italicized terms before.

b. I have heard of at least some of these terms before but I really don't understand what they mean.

c. I have some idea of what these terms mean, but I would have difficulty explaining them.

d. I have a clear idea of what these terms mean and I can explain them.

Application question (climate)

The atmosphere's general circulation is modified by the irregular placement of oceans and continents across the earth's surface. The heat capacity of water is many times larger than that of soil. This means that it takes much more energy to warm water than it does to warm the land. In a laboratory experiment lasting exactly one hour, equal amounts of energy are applied to one kilogram samples of soil and water. Both samples have the same temperature at the start of the experiment. After one hour, which sample will have a higher temperature?

a. I really have no idea which sample will have a higher temperature.

b. I'm certain that the soil will have the higher temperature, and I can explain why.

c. I suspect that the soil will have the higher temperature, but I would have difficulty explaining why.

d. I'm certain that the water will have the higher temperature, and I can explain why.

e. I suspect that the water will have the higher temperature, but I would have difficulty explaining why.

Deeper application question (water)

During winter when temperatures are very cold, frost sometimes forms on poorly insulated windows. Does frost form on the inside or the outside of the windows?

a. I really have no idea on which side of the windows frost will form

b. I'm certain that the frost forms on the outside of the windows, and I can explain why.

c. I suspect that the frost forms on the outside of the windows, but I could have difficulty explaining why.

d. I'm certain that the frost forms on the inside of the windows, and I can explain why.

e. I suspect that the frost forms on the inside of the windows, but I would have difficulty explaining why.

Guided by the faculty responses, I constructed student surveys to assess the extent to which the most commonly reported learning goals of "content" and "application" are being met. Following the Background Knowledge Learning Probe model (Angelo and Cross 1993), the survey design enabled as much specificity as possible in the subsequent data analysis. This specificity included assessments of student learning in specific content areas within the course, as well as the depth of learning that took place. As summarized in Table 1, three survey questions were designed within each of five meteorology subject areas. One question within each subject area addressed content, while the other two addressed the application of meteorological theory to observations. The latter two questions were also designed to assess

Table 2. Student survey results on content, application, and deeper application learning in the Survey of Meteorology course.							
		Application learning			Deeper application learning		
Subject	Content learning	Improvement	Correct to correct	Total	Improvement	Correct to correct	Total
Solar radiation	73.9%	43.1%	27.2%	70.3%	38.8%	29.6%	68.5%
Water	84.9%	18.8%	59.2%	78.0%	22.3%	42.0%	64.3%
Wind and forces	93.4%	34.5%	21.9%	56.4%	8.5%	0.5%	9.1%
Weather systems	85.3%	36.2%	15.6%	51.8%	41.4%	6.2%	47.6%
Climate	74.4%	35.3%	38.8%	74.1%	27.5%	6.1%	33.6%
All subjects	82.4%	33.6%	32.5%	66.1%	27.7%	16.9%	44.6%

the depth of learning as framed by Bloom (1956), addressing both the application and the deeper application or "analysis" levels of Bloom's taxonomy of cognitive learning.

During the 2005–06 academic year, four lecture sections of Survey of Meteorology were taught by three atmospheric science faculty members. These individuals will be referred to as instructors A, B, C1, and C2 (instructor C taught two lecture sections). Surveys were administered to students at the beginning and end of each semester. Participation was voluntary, but virtually all students present on the days the surveys were administered elected to participate. A total of 241 paired survey responses were obtained, comprising a response rate of 51% of all students enrolled in the course during the 2005–06 academic year. Each survey contained 30 responses (15 beginning-of-semester answers and 15 end-of-semester answers).

RESULTS. *Content learning.* The content questions were designed such that content learning within each subject area could be distinguished from prior knowledge. Referring to the sample content survey question shown in Table 1, answers a, b, c, and d were given corresponding scores of 0, 1, 2, and 3, respectively. For each specific subject area, content learning was assumed to have occurred if the difference between the end-of-semester and beginning-of-semester responses was greater than zero.

The content learning survey responses demonstrate that the goal of content learning, common to all faculty who teach Survey of Meteorology, is being met (Table 2). Content learning varied somewhat among the different subject areas: 74% of all students learned content in both radiation and climate, while 93% of students learned content in wind and forces. To a lesser extent, content learning also varied among the different instructors/course sections. While factors other than teaching practices (e.g., textbook selection, student background, lecture time slot) may contribute to this variability, the majority of students in all course sections have clearly satisfied the content learning goal.

The survey responses also permit identification of the depth of content learning, as defined by the magnitude of the difference between the end-of-semester and beginning-of-semester responses. Figure 1 demonstrates that for instructor B, the depth of content learning for the wind and forces subject area was greater than that for all other subjects. This type of assessment allows instructors to identify and exploit teaching practices that work particularly well.

Application learning. The application learning survey questions were designed to assess whether students had learned to use meteorological methods, concepts, or theories acquired in the class in new situations or to solve problems. As illustrated in Table 1, these questions give students the opportunity to respond "I don't know" (answer a), to respond with reservations (answers c and e), or to respond confidently

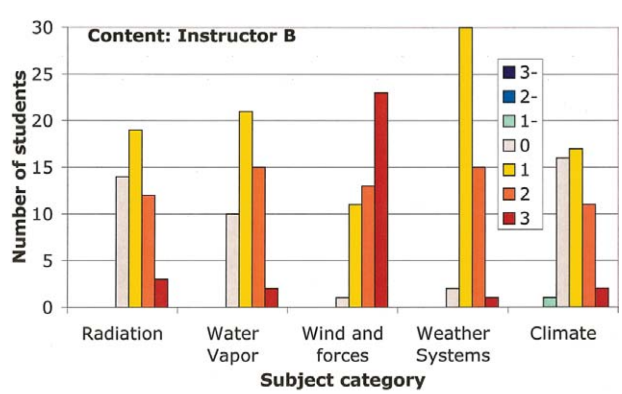

Fig. 1. Depth of content learning for instructor B. Note that survey response values of –2 and –3 did not occur.

(answers b and d). This variety of responses affords the opportunity to assess prior abilities and the depth of application learning that took place.

The application learning results are presented in Table 2. "Improvement" occurs when a beginning-of-semester survey answer of "incorrect" or "I don't know" is followed by a correct end-of-semester answer, or when a beginning-of-semester "correct with reservations" answer is followed by an end-of-semester "correct with confidence" answer. Overall, improvement in application learning took place in around 35% of the students. Some variation among different instructors and subject areas was evident, presumably due to differences in teaching practices or to the relative difficulty of the application survey questions. The "correct to correct" scores in Table 2 indicate prior abilities, which were identified when both beginning-of-semester and end-of-semester answers were correct. The sum of "improvement" and "correct to correct" scores indicates the percentage of students that correctly answered application questions at the conclusion of the Survey of Meteorology course, either due to prior ability or application learning. This sum averages 66% for the five students, which is rather low compared to the 82% of students (averaged over all subjects) whose survey results indicated content learning.

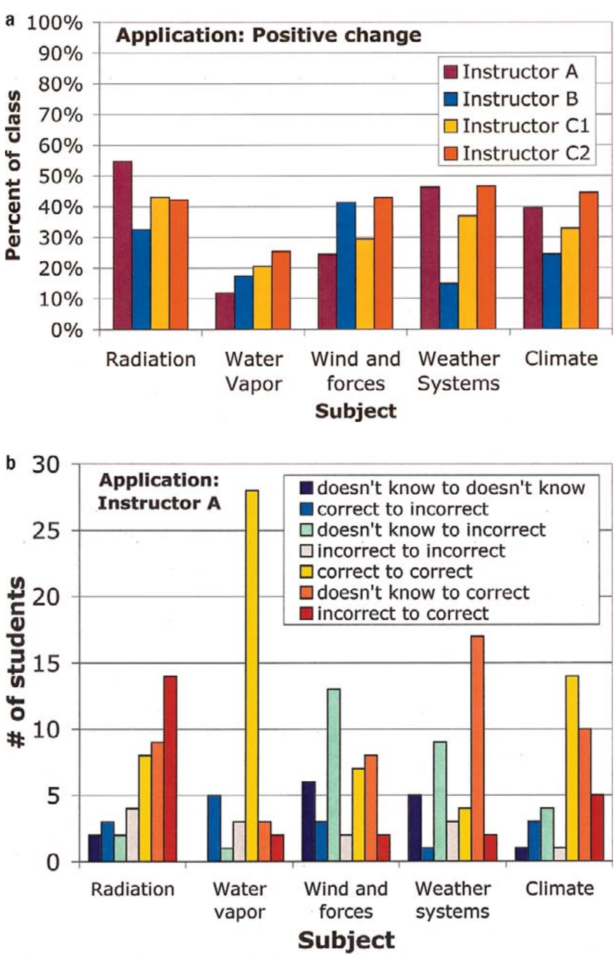

FIG. 2. Survey results on application learning. (a) Variation in application learning among different instructors. (b) Details of application learning results for instructor A.

A substantial amount of variation in application learning was evident among the three instructors (Fig. 2a), reflecting differences in teaching techniques or in the emphasis that instructors place in the different subject areas. This variation can be explored further by examining the nature of paired beginning-of-semester and end-of-semester responses for specific instructors. Such an analysis for instructor A (Fig. 2b) reveals the following useful details that can guide improvements in teaching practices:

- The most improvement in application learning took place in the radiation subject (23 students with paired scores classified as "doesn't know to correct" to "incorrect to correct"), indicating successful teaching and learning;
- Substantial "negative learning" is taking place in the wind and forces subject, indicating a need for change in teaching practices.

Deeper application learning. The deeper application survey questions were designed to assess students' ability to see patterns and to separate concepts into component parts, thus exploring a deeper level of application learning (Bloom 1956). Like the application questions, the deeper application questions were structured to assess both prior abilities and the depth of analysis learning that took place between the beginning-of-semester and end-of-semester surveys.

The deeper application results are presented in Table 2. The "improvement" results are similar to those found for application learning (Fig. 2a) for all subjects except wind and forces, where significantly less deeper application learning took place. However, if we compare the sum of "improvement" and "correct to correct" scores for deeper application questions to the corresponding sum for application questions, we find that fewer students were able to correctly answer the deeper application questions. The difference in these sums was quite pronounced for certain subjects (47% and 41% for wind and forces and climate, respectively) and small for others (2% and 4% for radiation and weather systems, respectively).

An analysis of deeper application responses for instructor C1 is presented in Fig. 3. In wind and forces, the most problematic subject area for deeper

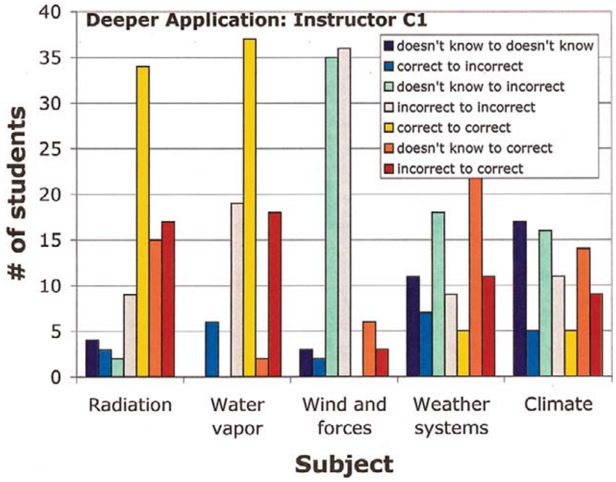

FIG. 3. Details of deeper application learning results for instructor C1.

application learning, we see that paired beginning-of-semester and end-of-semester survey responses were classified as either "doesn't know to doesn't know," "correct to incorrect," "doesn't know to incorrect," or "incorrect to incorrect" for 76 out of the 85 students surveyed (89%). In climate, the other problematic subject area, the corresponding number of students was 49 (58%). These numbers suggest that substantial improvements in deeper application learning, a goal expressed by four out of the six faculty teaching Survey of Meteorology, is needed for these subjects.

Adequacy of current assessment practices. One of the goals of this project was to investigate whether current methods of assessment are capable of evaluating whether the course goals are being met. The grade distributions for the four sections of Survey of Meteorology taught during the 2005–06 academic year are shown in Fig. 4a. These distributions differ somewhat from instructor to instructor but are similar in that the average grade for all sections was "B." Virtually all students passed the class with a grade of "C" or better, suggesting that virtually all students had met the learning goals for the course.

The adequacy of the current assessment practice can be evaluated by comparing the grade distributions with the learning results obtained from the surveys (Fig. 4b). This figure compares content learning, application and deeper application learning (the sum of "improvement" and "correct to correct" classifications from Table 2), and minimum grades of either C or B (from Fig. 4a). With respect to content learning, the comparison shows that the grade distributions reflect the learning goals: roughly 80% of students experienced content learning, which agrees well with the percentage of students receiving grades of B or better (78%). The goal of content learning, expressed by all faculty who teach the course, is thus being adequately assessed.

Application learning, a course goal expressed by two-thirds of the faculty who teach the course, is more problematic. Averaging over the five subjects, the percentage of students who successfully answered application and deeper application questions on the end-of-semester survey is 66% and 45%, respectively. These percentages are at odds with the percentages of students receiving minimum grades of either B or C and demonstrate that current assessment practices are inadequate for evaluating the course goal of application learning.

CONCLUSIONS. The results point out the need for change: while the teaching methods used in the Survey of Meteorology course are adequate for content learning, they are not adequate to accomplish the course goal of application learning. The administration of surveys such as those reported here provides detailed, instructor- and subject-specific information

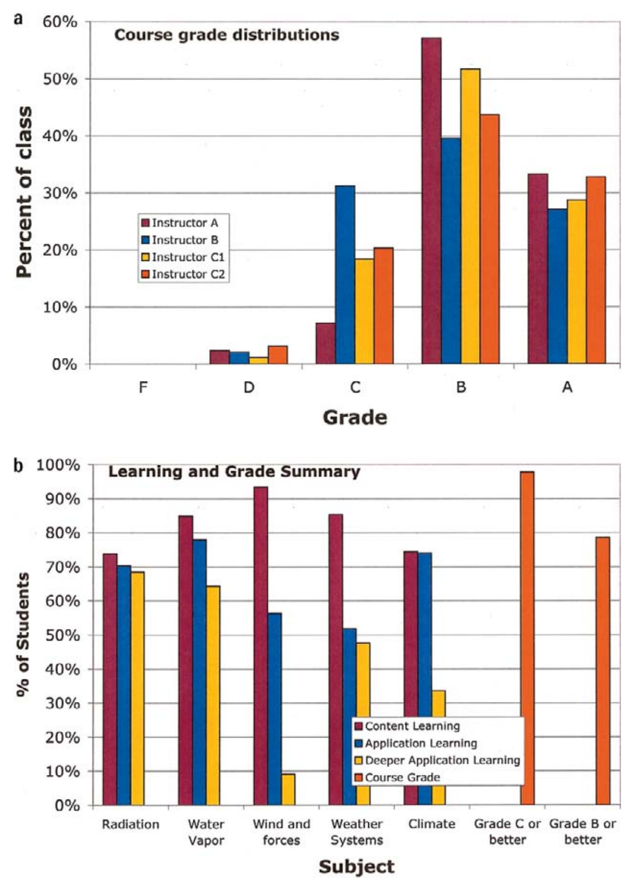

FIG. 4. (a) Course grade distributions for all instructors. (b) Comparison of course grades and survey responses.

on the effectiveness of the teaching methodologies used. Since similar teaching methods are used in other large-lecture meteorology courses at the University of Wisconsin—Milwaukee, the extent to which teaching and learning goals are accomplished in those courses may be similarly questioned. This problem may extend even further to traditional, large-lecture courses in other subjects and at other institutions.

The relationship between student performance (i.e., grades) and satisfaction of course goals identifies another "disconnect": the assessment techniques with which we are comfortable do not properly identify the degree to which students satisfy our teaching and learning goals. These problems have solutions that require ongoing study and experimentation (Bass 1999). New methods need to be utilized to assess the extent of application learning that takes place. One promising possibility is the use of student response systems, or "clickers." These devices enable active participation among students, even in large lecture halls, and are becoming increasingly popular in the science classroom (Zimmerman and Smith 2006). Adding interactive computer simulations, varying class sizes, and introducing new types of group work provide additional possibilities (Bollag 2007). As noted by Roebber (2005), active learning methods present additional possibilities.

The survey results reported here have catalyzed changes at the University of Wisconsin—Milwaukee. One Survey of Meteorology instructor now uses clickers; another is using surveys to assess learning in a different class. In addition, a similar survey approach is planned to assess specific learning outcomes in a university-wide review of general education courses.

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