4.2 INCORPORATING ACTIVE LEARNING INTO SMALL GROUP MEETINGS IN AN UNDERGRADUATE INTRODUCTORY METEOROLOGY COURSE

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1. INTRODUCTION

Introductory courses in atmospheric science are taken by tens of thousands of undergraduate students each year at junior colleges, colleges and universities in the United States. Most of these students are non-science majors, for whom the introductory course is likely to be their only exposure to atmospheric science and one of their few exposures to any type of science courses. Atmospheric science naturally lends itself to hands-on activities relating to real-world conditions and current events that can be used to put conceptual material into a practical context. Consequently, introductory courses in atmospheric science have the potential to excite students about science, to involve them in science, and to motivate them to pursue science further.

Unfortunately, most introductory courses in atmospheric science are offered in the large-lecture format, often with more than a hundred students per lecture. Classroom note-taking, textbook reading and textbook homework problems constitute much of a student's involvement in this type of course. Such activities are inherently passive, resulting in missed opportunities for active involvement of students in the learning process. This situation is even more unfortunate because the obvious ties to "weather" has put atmospheric science at the forefront of the technological revolution in information availability and learning opportunities provided by the World-Wide-Web. A key to tapping the potential of atmospheric science in the development of scientific skills is the engagement of students in "active learning". Active learning, which requires student participation in classroom discussion, problem-solving, or other activities, has gained widespread support in the educational community.

2. ACTIVE LEARNING IN THE CLASSROOM

During the spring 1999 semester, approximately 250 undergraduate students at the University of Illinois were enrolled in ATMOS 100, "Introduction to Meteorology". For the previous fifteen years, this course had been offered in a lecture-only format (three one-hour lectures per week). For most of this time, the course has used the textbook Essentials of Meteorology (C. D. Ahrens, 1998, Wadsworth Publ. Co.) and its predecessors. In the spring 1999 offering, one of the lectures was replaced by one-hour discussion sections in which students worked on exercises designed to foster active learning. These "discussion sections" did not follow the traditional format of a discussion section and will therefore be referred to herein as "small group meetings". A total of nine small group meetings were offered; the mean size of these groups was 28 students, with a range from 15 to 40.

In order to address the instructor-dependence of the success of the discussion sections, the sections were divided among four instructors: two instructors who had taught ATMOS 100 several times previously and who also taught the lecture sections during the spring 1999 semester; one senior faculty member who had not taught the course previously; and one graduate teaching assistant (TA), who was responsible for only one discussion section. This graduate student was a TA for the same course the previous semester and was therefore familiar with the course content and structure. During each week of the 14-week semester, all discussion sections covered the same material and used the same student activities. At the end of the semester, the students completed a survey/evaluation form in order to provide an initial assessment of the effectiveness of the discussion sections.

2.1 *Developing Active Learning Exercises*

At each small group meeting students were presented with an exercise designed by the course instructors (with input from the other meeting leaders). Instructors chose to design activities due to the lack of current active learning exercises available in the atmospheric sciences. Most activities they researched just *reviewed* concepts presented during lectures rather than *applied* concepts to real-time situations. The 14

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weekly exercise modules, were designed to correspond with the textbook material being covered in the twice-weekly lectures and to incorporate current weather data when possible as well as foster active learning by the students. The time constraint of weekly meetings coupled with the necessity of developing original activities each week impacted the quality of some of the activities, especially the earlier activities where material is heavily based on conceptual theory. Additionally, as the semester progressed, instructors had a better idea of what types of activities worked well in the classroom and which ones were less effective, and applied this experience to activities developed later in the semester.

In most discussion meetings, students were introduced to material not previously presented in the lecture meetings, but related to or building on the topics most recently discussed. The instructor spent 15-20 minutes introducing the topic before the activity was started, and addressing the rationale, context, and any underlying concepts or "missing links" relative to the lecture-session material. Students were given a handout describing the task/objective and containing space for their completion of the task. Depending on the nature of the activity, the worksheet also contained background material, data, base maps or tables to be completed by the student. The handout was supplemented by material presented by the instructor using an overhead projector (e.g., for color maps) and a blackboard. The format of the discussion section was interactive, as students asked questions of the instructor, were asked questions by the instructor, and were encouraged to work in small groups in completing the activity. In some weeks, the students handed in their worksheets for evaluation and credit; in other weeks, they did not. The subject matter of the worksheets and "lessons learned" by students from the worksheets were included on the regular tests given in the lecture portion of the course.

The student activity phase of each meeting was typically the final 15-30 minutes, during which questions from and discussions among students were encouraged. Instructors walked among the students to oversee the activities, assist students who were having trouble, or to answer questions of individuals or small groups that they encountered while completing the task and also to offer encouragement to those making progress in task completion.

With a few exceptions, the exercises utilized actual weather data. In all cases, the exercises were designed to (1) give the students hands-on experience, i.e., to learn "actively" rather than "passively", and (2) enable students to appreciate better the fundamental concepts and textbook material by seeing concepts put into practice. Table 1 provides a brief summary of the activity designed each week.

3. EVALUATION OF EXERCISES

At the end of the semester, the students were asked to complete an evaluation form addressing the effectiveness of the exercises as learning tools and, more broadly, the effectiveness of the "active learning" approach used in the discussion sections. Students also rated the exercises according to how much they learned and according to the level of interest generated by the exercises. The students were asked to provide the reasons for their rankings (at both ends of the scale). The most highly rated activities were those requiring an analysis or forecast based on actual weather data. The lowest-rated activities were those that had a stronger conceptual emphasis and did not include some component of weather data utilization.

The students were also asked whether the course should include such discussion sections in the future. The results were tabulated by instructor and are shown in Table 2. The vast majority of students prefer the discussion sections to a third lecture (88% of 200 students). It was also found that the responses are instructor-dependent. Prior experience in teaching the course and a concurrent lecture role were associated with more favorable evaluations of the discussion sections. However, given the experimental nature of this initial attempt to bring the active-learning approach into a large introductory course, we believe that the results represent a student endorsement of the approach. The student responses indicate that an active-learning component of an introductory science course does stimulate student interest and involvement in science, even at the college level.

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Table 1: Weekly Active Learning Exercises

Activity	Objective
1. Decoding surface weather maps	Learn how surface observations are recorded, transmitted and processed into a weather map.
2. Heat transfer mechanisms	Understand how different heat transfer mechanisms are responsible for commonly experienced phenomena in atmosphere, land surface and ocean.
3. Air temperature, degree days, astronomical data	Lean how to interpret all information in a daily climatological summary, especially the information in internet and newspaper summaries.
4. Upper-air data	Understand how upper-air data are measured, and data-plotting conventions.
5. Environmental lapse rates & stability	Interpret static stability in terms of atmospheric lapse rates and parcel displacements (dry and saturated); interpret soundings in terms of associated physical processes.
6. Use of soundings to determine surface weather	Infer surface weather from actual soundings by reasoning in terms of stability, temperature-dewpoint spread (clouds), winter precipitation (snow, sleet, freezing rain, rain) via thermal structure.
7. Upper air maps : balance of forces	Relate upper-air winds to geopotential height contours by using force balances (gradient wind); use ageostrophic reasoning to infer convergence and divergence relative to ridges and troughs.
8. Local wind circulations	Use reasoning about forces to relate local (nongeostrophic) wind systems to synoptic-scale setting, particularly the interplay between synoptic pressure pattern (force balance) and effects of heating.
9. Analysis of surface weather maps	Learn the processes of contouring sea level pressure maps, locating fronts, etc. develop appreciation for difficulties inherent in automation of weather map-drawing.
10. Weather forecasting	Understand NWP and other guidance sufficiently well to be able to anticipate future weather.
11. Thunderstorm prediction	Understand how thunderstorms can be anticipated from atmospheric soundings, measures of instability (Lifted Index)wleund on

D. REFERENCES

Aguado, E., and J. E. Burt, 1999: Understanding Weather and Climate, Prentice-Hall, 474 pp.

Ahrens, C. D., 1998: Essentials of Meteorology: An Invitation to the Atmosphere, Wadsworth Publ. Co., 444 pp.

Ahrens, C. D., 1994: Meteorology Today (Fifth Ed.), West Publ. Co., 591 pp.

American Meteorological Society, 1999: Online weather studies new for fall of 1999, Bull. Amer. Meteor. Soc., 80, 950.

Danielson, E. W., J. Levin and E. Abrams, 1998: Meteorology, WCB/McGraw-Hill, 462 pp.

Frederick, P. J., 1987: Student involvement: Active learning for large classes. In "Teaching large classes well", New Directions for Teaching and Learning (M. Gleason-Weiner, Ed.), 32, 45-56.

Geske, J., 1992: Overcoming the drawbacks of the large lecture class, College Teaching, 40 (4), 151-154.

Lutgens, F. K., and E. J. Tarbuck, 1998: The Atmosphere (Seventh Ed.), Prentice-Hall, 434 pp.

McKeachie, W. J., 1999: Teaching Tips: Strategies, Research and Theory for College and University Teachers (Tenth Ed.), Heath, Lexington, MA, 199 pp.

Meyer, C., and T. B. Jones, 1993: Promoting active learning: Strategies for the college classroom, San Francisco, Jossey-Bass.

Moran, J. M., 1999: Online Weather Studies: The Textbook, Amer. Meteor. Soc., Boston, MA. (Adaptation of Moran and Morgan, 1997 – see following citation).

Moran, J. M., and M. M. Morgan, 1997: Meteorology, The Atmosphere and the Science of Weather (Fifth Ed.), Prentice Hall, 530 pp.

Sutherland, T. E., and C. C. Bonwell, 1996: Using active learning in college classes: A range of options for faculty, New Directions for Teaching and Learning, 67.

References from Bob W:

National Science Foundation, 1996: *Shaping the Future of Undergraduate Earth Science Education: Innovation and Change Using an Earth system Approach*.

National Science Foundation, 1997: *Geoscience Education: A Recommended Strategy,* Report based on August 29-30 Workshop from the Geoscience Education Working Group to the Advisory Committee for Geosciences and the Directorate for Geosciences of the National Science Foundation, NSF 97-171.

American Geophysical Union, 1994: *Scrutiny of undergraduate Geoscience Education: Is the Viability of the Geosciences in Jeopardy?* Chapman Conference proceedings September 7-11.

Table 1. Summary of activities used during Spring 1999

1. Decoding of surface weather maps

Objective: Learn how surface observations are recorded, transmitted and processed into a weather map.

Activity: Decode 4-5 station data clusters, illustrating widely different types of weather, from weather maps; units emphasized.

Materials: Surface weather map.
Optional: aviation weather reports in line-coded form.

2. Heat transfer mechanisms

Objective: Understand how different heat transfer mechanisms are responsible for commonly experienced phenomena in atmosphere, land surface and ocean.

Activity: Given a list of common phenomena (e.g., wind-induced warming, nighttime heating, heating of pavement), identify primary heat transfer mechanisms; students then provide additional examples.

Materials: List of heat transfer mechanisms and their distinguishing characteristics; list of phenomena to be addressed.

3. Air temperature, degree days, astronomical data

Objective: Learn how to interpret all information in a daily climatological summary (e.g., newspaper, television).

Activity: Explain all entries in a daily climatological summary, including computations of degree-days, reasons for different changes in daylength at stations at different latitudes, different ranges of temperature at various stations, etc.).

Materials: Recent daily climatological summaries from several stations (examples with heating- and cooling-degree days, large range of latitude – e.g., Florida to Alaska, coastal and interior locations)

4. Upper-air data: decoding, plot of sounding

Objective: Understand (a) how upper-air data are measured, and (b) data-plotting conventions.

Activity: Decode several upper-air reports; plot a sounding.

Materials: Upper-air maps for different levels; tabulation of data from a radiosonde launch (all significant and mandatory levels).
Optional: classroom demo of radiosonde instrument package.

5. Environmental lapse rates and stability

Objective: Interpret static stability in terms of atmospheric lapse rates and parcel displacements (dry and saturated); interpret soundings in terms of associated physical processes.

Activity: Compute temperatures of parcels relative to environment after prescribed displacements from points on idealized soundings.

Materials: Hypothetical soundings (stable, unstable, neutral, conditionally unstable); numerical values of lapse rates (e.g., moist adiabatic).

6. Use of soundings to determine surface weather

Objective: Infer surface weather from actual soundings by reasoning in terms of stability, temperature-dewpoint spread (clouds), winter precipitation (snow, sleet, freezing rain, rain) via thermal structure.

Activity: From actual soundings, reconstruct the observed surface weather at several stations; include cloud elevation, cloud type, precipitation/type.

Materials: Plotted soundings on Stuve diagrams; examples include soundings with low-level temperature inversions enabling distinction of sleet, freezing rain, snow, rain; accompanying surface reports for validation.

7. Upper air maps: balance of forces

Objective: Relate upper-air winds to geopotential height contours by using force valances (gradient wind); use ageostrophic reasoning to infer convergence and divergence relative to ridges and troughs.

Activity: For several prescribed locations on upper-air maps, sketch the force vectors and the relative wind speeds; use confluence/diffluence (including jet streaks) to infer convergence and divergence aloft.

Materials: Upper-air contour maps for 500 mb, 300 mb; also 850 mb to illustrate vertical variation; radiosonde wind data to check students' conclusions.

8. Local wind circulations

Objective: Use reasoning about forces to relate local (nongeostrophic) wind systems to synoptic-scale setting, particularly the interplay between synoptic pressure pattern (force balance) and effects of heating vis-à-vis sea breeze, Chinook, Santa Ana, etc.
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Activity: Use geographical maps with sea level pressure analyses to infer types of local circulation and associated force balances/imbalances.

Materials: Sea level pressure analyses (idealized/actual) for cases with sea/lake breezes, Chinook, Santa Ana, monsoon, etc.

9. Analysis of surface weather maps (isobars, fronts, pressure centers)

Objective: Learn the processes of contouring sea level pressure maps, locating fronts, and relation of surface winds to pressure pattern; develop appreciation for difficulties inherent in automation of weather map-drawing.

Activity: Analyze a surface weather map (isobars, fronts) from plotted surface reports covering a large area, e.g., the contiguous U. S.

Materials: Surface map of U. S. containing plots of hourly observations; a near-real-time or "significant" case is desirable.

10. Weather forecasting

Objective: Understand NWP and other guidance sufficiently well to be able to anticipate future weather.

Activity: Prepare a 24-to-48-hour weather forecast (temperature, wind, cloud cover, precipitation) for several cities in the U. S.

Materials: Initial (current) weather information for synoptic background; upper-air progs from NWP models (ETA, MRF), supplemented by some surface guidance; subsequent to forecast preparation, MOS and "official" forecasts can be provided for comparison; table for completion by students.

11. *Thunderstorm prediction – Lifted Index, destabilization*

Objective: Understand how thunderstorms can be anticipated from atmospheric soundings, measures of instability (Lifted Index), knowledge of destabilization mechanisms.

Activity: Use actual soundings for 5-10 locations to compute Lifted Index; use anticipated changes (surface heating, advection, etc.) to predict areas most likely to experience thunderstorms.

Materials: Soundings from 5-10 stations in a region of the U. S. where thunderstorms developed (or are likely to develop) that day; NWP or MOS progs of temperature changes over 12-24 hour range; base map of U. S. for student use.

12. Tornadic thunderstorms – tornado watch box

Objective: Use concepts helicity (vertical rotation of wind vector) and vertical structure of temperature/humidity to anticipate likelihood of tornadic thunderstorms.

Activity: Work with actual soundings (wind, temperature, dewpoint) to emulate process used by severe storm forecasters; determine location for issuance of hypothetical "tornado watch" box.

Materials: Soundings for 5-10 stations that experienced subsequent (6-18 hours) tornadic activity; validation data in form or radar and satellite imagery; base map of U.S. for student use.

13. Hurricanes: tracks, landfall, storm surge, maximum winds

Objective: Use information about hurricane's track and intensity to deduce locations of greatest storm surge and strongest wind speeds.

Activity: From 12-hourly reports of hurricane location and intensity, plot track and location/timing of strongest winds and storm surge; use historical digital archive of hurricane tracks and intensity to contrast severity of past hurricanes at specific locations (e.g., Hatteras, Key West).

Materials: Time series of location and maximum wind speeds of a major hurricane; base map for student plots of track; access to digital archive of tracks and intensities of past hurricanes (e.g., http://www.atmos.uiuc.edu/)

14. Air pollution in urban areas

Objective: Learn how meteorological and geographical factors combine to determine air quality in urban areas.

Activity: For 5-6 cities in U. S., use geographical background information and weather map/sounding for a particular day to determine where best/worst air quality is likely.

Materials: Geographical summary (topography, coastal influences) for 5-6 urban areas; soundings and SLP maps for a day in which air quality varied widely among the cities.