

DEVELOPMENT OF IN-CLASS EXERCISES TO ACCOMPANY INTERACTIVE, HANDS-ON METEOROLOGY FOR UNDERGRADUATE NON-MAJORS

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1. INTRODUCTION

Active learning in the classroom is known to benefit students in a variety of ways and can come in the form of group projects, quizzes, in-class exercises, utilization of technology in the classroom, case studies, and many others. During the past five years active learning was incorporated into several courses taught by the Department of Atmospheric Sciences (DAS) at the University of Illinois at Urbana-Champaign (UIUC). In the past year DAS has worked to incorporate active learning formally into the curriculum of the Introduction to Meteorology course by using in-class exercises of both the pen/paper and computer variety.

Curriculum redevelopment focused on (1) increasing the quantitative level, (2) providing many opportunities for meaningful active learning activities, and (3) utilizing current technology and computing. Over a period of nine months, several faculty, staff and students worked to develop in-class exercises that would achieve all three goals listed above. The end result is an active learning package "Hands-On Meteorology" that consists of pedagogically sound curriculum, a wide variety of in-class exercises and complementing Java applications. Combined together, these elements provide students with a comprehensive introduction to meteorology and incorporates both quantitative and qualitative understanding of atmospheric processes and phenomena.

2. PROJECT BACKGROUND

The Introduction to Meteorology (ATMOS 100) course at UIUC has been offered every semester for over twenty years. Prior to the past year, it met three times per week for lecture sessions; it was not designed to facilitate discussion sections or labs. Traditionally, there was little active learning formally incorporated into the curriculum. It is intended to be a survey of meteorology and has traditionally covered many topics. The primary textbook in recent years has been C. D. Ahrens Meteorology Today or Essentials of Meteorology.

The course is designed for non-majors and fulfills the general education requirement for physical sciences; it typically did not have a strong quantitative component to it.

The College of Liberal Arts and Sciences (LAS), of which DAS is a part of, requested that the ATMOS 100 course be redesigned to be the first course to meet the college's new "Quantitative Reasoning II" requirement. (As defined by LAS, 'quantitative' includes problem formulation, mathematics emphasizing logical thought processes, the algebra of symbolic and scientific reasoning, the use of scientific information in decision making, and methods for the valuation of scientific evidence.)

As a part of the curriculum redesign, the course would be offered as a lecture/discussion with lecture consisting of two hours per week and one hour of discussion, where graduate students would be employed to teach discussion sections. Additionally, the use of a computer laboratory would be available for use during the discussion sections. Funding for a programmer was provided for the development of computer applications related to the course content.

The three faculty assigned to the curriculum redevelopment formed a team consisting of themselves, a graduate assistant, and a programmer. The goal was to develop a fluid curriculum that incorporated the three key points listed above.

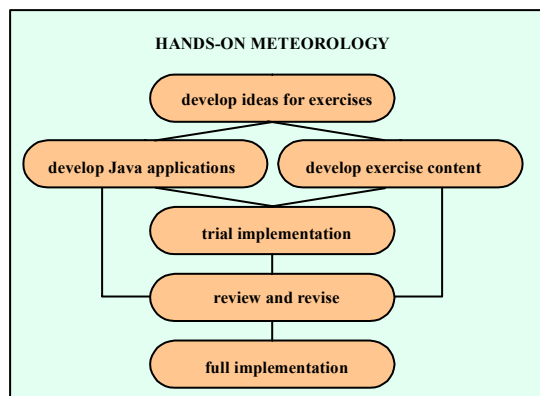
3. HANDS-ON METEOROLOGY

The project was named "Hands-On Meteorology" to convey the interactivity of the project. We did not want to include "laboratory" in the title because while some activities are similar to lab exercises, many are not. Additionally, we avoided including "discussion section" in the title because the activities would also be conducted in the lecture hall, and the discussion meetings would not follow a traditional discussion format.

The project had several stages including exercise designation, development of Java applications (Bramer *et al.*, 2003) and student exercises (concurrent development), initial implementation, revision and full implementation (Charlevoix *et al.*, 2003) (Figure 1).

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Figure 1: Development of Hands-On Meteorology



The three faculty on the team determined what topics would be most conducive to hands-on activities. It was decided which of these would have an accompanying computer application and which would be better as stand-alone paper exercises. Java applications were developed for appropriate topics and a suite of exercises was developed for all topics initially identified.

During summer 2002, the AMTOS 100 course was offered during the eight week summer session at UIUC in the new proposed format. As many exercises as possible were incorporated into the curriculum and tested. Revisions and adjustments were made where necessary. The entire Hands-On Meteorology project was fully implemented in fall 2002.

4. IN-CLASS EXERCISES

In-class exercises were developed for each topic identified in the first stage of the project. A graduate student, with teaching and educational research experience, was brought on to the team to take on the task of designing the exercises. The exercises were designed to be as flexible as possible. They were independent from one another so that subsequent exercises did not necessarily rely on information gained from previous exercises. If an instructor decided not to cover a particular topic in a given semester, they would still be able to incorporate many of the exercises. However, the exercises had to have some continuity to them so that students could see that they all fit together to form a “big picture.” We did not want students to get the feeling that these were unrelated topics that had no connection to one another.

There were two types of exercises designed: traditional in-class exercises (pen and paper) and computer-based in-class exercises that utilized a Java application.


In-class exercises were designed primarily to be incorporated into lecture meetings. They were

designed to be short enough so as not to take up more than ten or fifteen minutes of a class. They also did not require students to complete any tasks prior to the exercise (e.g., print out diagrams or figures, access web sites for supplemental information.)

Typically, the instructor would provide a brief introduction to the topic and then hand out the exercise to students. On occasion, students were required to collaborate with at least one other person, but most frequently could choose to work in a small group or independently. During the time students worked on the exercise, the instructor and teaching assistant walked through the lecture hall, assisting students, answering questions, and providing guidance. When it appeared that most students had finished or were near finishing the exercise, the instructor went over the exercise and provided the correct answers. Students turned in the completed exercise for credit. The exercises were not graded. This allowed the student to focus on the concept being presented in the exercise rather than on the correct answer.

An example of a in-class exercise is shown in Figure 2. This particular exercise is carried out after the discussion of the various ways to describe humidity. The students have already learned how to decode a station model and for those who may have forgotten, the instructor reminds everyone how to read the data prior to handing out the worksheet. By the end of the exercise the students have practiced decoding models and learned the relationships between

ATMOS 100: Introduction to Meteorology
Hands-On Meteorology



Name: _____ #7


Circle your Hands-On Section:

A1 Julie	A3 Redina	A5 Larry	B2 Donna	B4 Lourdes
A2 Julie	A4 Chris	B1 Chris	B3 Lourdes	B5 Redina


Moisture in the Atmosphere

Below are surface station models from four cities.
Use this data to answer the questions.


City A




City B



City C



City D



Which city has the:

1. highest temperature? _____
2. lowest temperature? _____
3. highest dew point temperature? _____
4. lowest dew point temperature? _____
5. highest saturation vapor pressure? _____
6. lowest saturation vapor pressure? _____
7. highest vapor pressure? _____
8. lowest vapor pressure? _____
9. highest relative humidity? _____
10. lowest relative humidity? _____
11. In order to get fog to form at City D, how much does the temperature have to fall? _____
12. For City B, at what temperature would the air become saturated? _____
13. Which city is furthest from being saturated? _____

saturation vapor pressure, temperature, vapor pressure, dewpoint temperature, and relative humidity.

Figure 2: Example of in-class exercise used in lecture. Computer-based exercises were used during the small group meetings during the discussion sections. The discussion sections were renamed “Hands-On sessions,” to convey to students that the meetings would not follow the traditional science class discussion.

Each week, prior to the Hands-On session, students were informed as to which exercise would be conducted during the Hands-On session. They were asked to access the Hands-On Meteorology web page (http://www.atmos.uiuc.edu/courses/atmos_100) to print a copy of the exercise and bring it to class with them. The motivation for having the students print the exercise prior to class was two-fold: it provided the students the opportunity to look over the exercise before class and it prevented class time from being wasted while students printed out the exercises in the computer lab.

Each of the computer-based exercises utilized one of the Java applications developed for the course. Each Java application illustrated a particular concept in meteorology. The exercises were designed to let the students explore the Java application while applying either what they learned in lecture that week or were asked to read prior to the Hands-On session. Computer-based exercises were used both as a review of previous material and an introduction to new material.

For example, Figure 3 shows the first two pages of an exercise that introduced the concept of lapse rates (Air Temperature with Flow over a Mountain). Prior to this exercise, students have learned about humidity, condensation and cloud formation. The students had no formal instruction on the topic prior to this exercise. During this Hands-On session, students are provided with an overview of the Java application they will use and a definition of lapse rate. They are then asked to run the program. The program illustrates an air parcel flowing over two mountains of differing heights (Figure 4). The initial temperature and dewpoint are specified and if the rising parcel reaches saturation, a cloud forms. During the parcel descent of the mountain, the relative humidity lowers and any cloud dissipates. Students examine how the temperature and dewpoint of the air parcel change over the mountains by recording the temperature, dewpoint temperature and relative humidity at various locations across the two mountains in a table. After completing the table, they are asked to compute the lapse rates for different height intervals. Upon completion, they find that the lapse rates are either 10 °C/km (dry adiabatic lapse rate) or ~6 °C/km (moist adiabatic lapse rate). In the following lecture class, the adiabatic lapse rates are formally presented. Students can draw on the

Figure 3: Example of computer based in-class exercise

ATMOS 100: Introduction to Meteorology
Hands-On Meteorology
 Air Temperature With Flow Over a Mountain



WHAT YOU SHOULD LEARN IN THIS EXERCISE:

- Identify how air temperature changes when wind flow encounters topography.

BACKGROUND INFORMATION

Program

In the program for today, you will see a graphic representing two mountains. The first is 2000 m high (2 km) and the second is 3000 m high (3 km). The small circle windward of the mountains represents an air parcel.

Clicking the “Start” button will cause the air parcel to move toward the mountain, and to flow over it. There is a information about the air parcel temperature, dewpoint temperature, relative humidity and altitude to the right of the mountain diagram.

After you start the experiment and the parcel moves to the lee of both mountains, you can drag the air parcel with the mouse back over the mountains.

Necessary Knowledge

A lapse rate is a variable that describes how much temperature changes with altitude:

$$\text{Lapse Rate} = \frac{\text{change in temperature}}{\text{change in altitude}}$$

The units of lapse rate are: $\frac{^{\circ}\text{C}}{\text{km}}$

Example:

If your data shows: T = 10°C at 1 km
 T = 5°C at 2 km

The lapse rate is:

$$\text{LR} = \frac{-(10^{\circ}\text{C} - 5^{\circ}\text{C})}{1 \text{ km} - 2 \text{ km}} = \frac{-5^{\circ}\text{C}}{-1 \text{ km}} = \frac{5^{\circ}\text{C}}{1 \text{ km}}$$

WHAT YOU NEED TO DO IN THE COMPUTER LAB:

Part A: Getting Started

- A1. Launch the application:
 → Go to the Hands-On Meteorology web page
 → Open the program “Mountains”

Part B: Investigating Air Temperature over a Mountain

- B1. Click the Start button. [Run the program using the initial settings (Temperature = 25°C; Dewpoint temperature = 17°C).]
 B2. Move the air parcel circle back over the mountain to the locations listed in Table B, and fill in the table.

Table for Part B

What were the temperature, dewpoint temperature, and relative humidity at each of the following altitudes and locations?

	Table B		
	Temperature (°C)	Dewpoint Temperature (°C)	Relative Humidity (%)
surface windward of 2 km high mountain			
1 km altitude windward of 2 km high mountain			
top of 2 km mountain			
1 km between mountains			
2 km altitude windward of 3 km mountain			
top of 3 km mountain			
2 km altitude lee of 3 km mountain			
1 km altitude lee 3 km mountain			
surface lee of both mountains			

knowledge gained from the computer exercise to better understand the difference between adiabatic lapse rates and environmental lapse rates (traditionally a difficult concept for students to grasp).

The computer-based exercises have a final part called "Questions for Thought" that is optional depending on the instructors wishes. During the semester, these "Questions for Thought" are assigned as extensions to the exercise. Students utilize the information gained from the computer exercise (data, graphs, or charts) and material presented in lecture to answer a series of questions that are related to the exercise and that go beyond the initial concept presented in the Hands-On session. These extended exercises are completed by the student over a one-week period, handed in during the next Hands-On session, and assigned a grade that counts toward their final course grade.

5. ACCESSIBILITY

The Hands-On Meteorology exercises were designed both for use in the ATMOS 100 course at UIUC, but also for the entire meteorology community. At the time of this pre-print, the project is still underway. To date we have twenty-one (21) computer based programs and thirty-five (35) in-class exercises. To facilitate the availability of the programs and exercises to both the ATMOS 100 students and the community, a Hands-On Meteorology web site was developed (<http://www.atmos.uiuc.edu/courses/atmos100/>).

The site has several pages, one is directed to the ATMOS 100 students and the others are available for public use. All the Java applications used in the exercises are provided under a "programs" link. Every exercise that was developed, both traditional and computer-based exercises, are provided under an "exercises" link.

The web page listing the exercises includes:

- the topic each exercise addresses,
- a description of the exercise,
- a PDF version of the exercise used in class, and
- a link to any required Java application programs to complete the exercise.

The web site will remain dynamic in that as new exercises are developed they will be added and as current exercises are revised the revisions will be incorporated into the on-line versions. In the near future, the project will be submitted to the Digital Library: DLESE Collections Review System and formally be made available to the earth science education community (<http://www.dlese.org/>).

6. ACKNOWLEDGEMENTS

Funding for the exercise and the Java application development for the Hands-On Meteorology project was provided by the College of Liberal Arts and Sciences at the University of Illinois.

7. REFERENCES

Bramer, D., D. Charlevoix, G. McFarquhar, R. Herman, L. Avilés, L. Di Girolamo, M. Ramamurthy, and R. Wilhelmson, 2003: Developing Interactive Models to Support a Digital Collection of Earth System Science Resources. Proceedings of the Twelfth Symposium on Education, Long Beach, CA, American Meteorological Society.

Charlevoix, D., L. Avilés, and L. Di Girolamo, 2003: Assessment of Interactive, Hands-On Meteorology Exercises in a course for Undergraduate Non-Majors. Proceedings of the Twelfth Symposium on Education, Long Beach, CA, American Meteorological Society.

Figure 4. Graphical interface to mountain exercise

