

Geology, Resources and Environment of Latin America: Incorporating Earth Systems Science Education in an Undergraduate Science Service Course Intended for Hispanic Students

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ABSTRACT

With NSF funding, we have developed, taught, and evaluated a new lower-division science course for non-science majors, entitled "Geology, Resources, and Environment of Latin America" (GRELA). GRELA is intended to attract Hispanic undergraduates to science and to increase awareness among non-Hispanic students about challenges facing our neighbors to the south. GRELA is an interdisciplinary exploration of how the physical and biological environments of Mexico, Central America, and South America have influenced the people who live there. The course consists of 22 lectures in four modules (Background; Minerals; Energy and Natural Hazards, and Water and the Environment). Presentation of ESS topics dominates the last part of the class and includes lectures on El Niño, glaciers, the Amazon, rain forests, and coral reefs; a final set of lectures focuses on challenges facing the US and Mexico over shared water resources. Grades are based on two mid-term exams, a final exam and a report developed in partnership with correspondents in Latin American universities. Evaluations indicate this course positively impacts student interest in science, although some of the favorable comments may result from small class size. We encourage adaptation of our course materials at other community colleges and universities and will share these with other instructors on request.

INTRODUCTION

Hispanics comprise 14% of the U.S. population and are, by far, the most rapidly growing ethnic group (Bureau, 2005). This increase results in a growing pool of university-age Hispanic youths who need to become scientifically literate and who could be attracted to science. A complementary challenge is to educate non-Hispanic students about our neighbors to the south. We are particularly motivated to change the attitude that many undergraduates have; that while science may be important for public health and economic progress, it is not relevant to them in their daily lives. Realizing these objectives requires innovative curriculum development, obtaining timely feedback from participating students, and broad dissemination of strategies and materials. Beyond this, we recognize the importance of Latin American people and natural resources to the healthy functioning of US government, society, and economy, and believe that university curricula should reflect this to a greater extent than is now the case.

In this spirit, we have developed and taught a new course entitled "Geology, Resources, and Environment

of Latin America" (GRELA). GRELA provides an overview of the natural environment of Latin America, how the environment and natural resources have affected civilizations in the region and how humans are impacting this environment. This also provides an opportunity to present Earth System Science Education (ESSE) components in a context that reaches a different audience.

We adopted the general strategy of Tewksbury (1995), who developed a course on African geology to attract African American students. Such a strategy applied to Latin America and Hispanic students seems promising because we expect that many Hispanics are interested in issues affecting their cultural homelands. This strategy is further encouraged because Hispanics in the US generally have strong cultural traditions, such as keeping the homeland language, food and music even after generations of living in a predominantly Anglo culture. We are especially sensitive to these issues in our state, where we teach at U Texas at Dallas, a public university with about 15,000 students. With funding from the National Science Foundation, we developed a semester-long course entitled "Geology, Resources, and Environment of Latin America" and taught it for the past three years (Fall semester 2003, 2004, 2005); only the results from the first 2 years are presented here. GRELA is a 3-credit 'service course' approved to satisfy part of UTD's 9-hour undergraduate core curriculum science requirement, and is aimed at lower division undergraduates, especially students who are not science majors. It is also the only course taught at our university that concentrates on Latin America.

This article outlines the course and its assessment.

WHAT IS LATIN AMERICA?

The term "Latin America" was originally coined by French geographers to emphasize the similar roots of the French and Spanish languages; this was motivated to reduce tensions between Mexicans and the French during their occupation of Mexico (1862-1867). It is today used to differentiate between regions in the New World where English and Romance (Latin-based) languages are spoken (Clawson, 2004). Latin America can be further divided by language and location into Ibero-America (Spanish and Portuguese speaking) portions of Central and South America and the polyglot (Spanish, French, Dutch, and English speaking) Caribbean region (Greater and Lesser Antilles, Trinidad and Tobago, Belize, Guyana, Suriname, and French Guiana). By this definition, some parts of the US and Canada could also be considered part of Latin America, especially the SW USA, southern Florida, Louisiana, and Quebec. By

Week	Class	Theme	Module
1	1	Introduction and Geography pretest	Introduction
2	2	Cultural Geography of Latin America	
	3	Physiography, Geography and Climate of Latin America	
3	4	Plate Tectonics	Background: Module I
	5	Geologic setting and evolution of Latin America	
4	6	Humans in Latin America and Pre-Columbian Cultures	
	7	Pre-Columbian history of gold, silver, and other metals	
5	8	Collision of Civilizations	Minerals: Module II
	9	Colonial Silver- Potosí (Bolivia) and Guanajuato (Mexico)	
6	10	Postcolonial Mining and Development: The Chilean Example	
	11	Review for mid term	Evaluation 1
7	12	First Mid Term	
	13	Oil and Gas Basics	
8	14	Oil and Gas in Latin America	
	15	Organizational Meeting about projects	
9	16	Geothermal Energy	Energy & Natural Hazards: Module III
	17	Earthquakes in Latin America	
10	18	Volcanic Hazards in Latin America	
	19	El Niño	
11	20	Glaciers and Climate Change in Latin America	Water and Environment: Module IV
	21	Amazon Rive	
12	22	Review; Projects and groups must be defined	Evaluation 2
	23	Second Mid Term	
13	24	Rain Forest	
	25	Coral Reefs	Water and Environment: Module IV
14	26	U.S. Mexico Water I	
	27	U.S. Mexico Water II	
15	28	Project Day- Presentation of projects I	Evaluation 3
	29	Project Day- Presentation of projects II	
16	30	Final Exam	

Table 1. Semester schedule for Geology, Resources, and Environment of Latin America.

common usage however, Latin America is accepted to be that part of the New World that lies south of the United States of America, which is how we define the GRELA region of interest.

COURSE PHILOSOPHY AND ORGANIZATION

This course is an overview of the natural environment of Latin America, and how it is impacted by human activity. It is not possible to be comprehensive in a one-semester course, so we focus on key topics and concepts; because two of us are geologists, we emphasize the physical environment although biosphere components are included in presentations on the Amazon rainforest and coral reefs. After a short introduction the course is taught in order of events, and sequentially: geology, the human presence, use of resources, and environment (Table 1). This organization naturally puts Earth and human history at the beginning of the course and Earth System Science at the end. We choose examples from different countries, so some aspect of nearly every Latin American nation is the focus of at least one lecture.

The 22 lectures are ordered into an introduction and 4 modules (Background; Minerals; Energy and Natural

Hazards; Water and the Environment). Since we have not found a suitable textbook, the course is taught using PowerPoint® presentations. Literature sources are very important for providing content, and in the following sections of this paper we mention a few of the more important references. Most lectures are given by Dr. Pujana (Argentinean paleontologist) and Dr. Stern (US tectonicist). Dr. Ledbetter was responsible for evaluating the course but also delivered two of the biology-related lectures (rainforest and coral reefs), which are in her area of expertise.

The introductory lecture presents the course structure and the instructors' expectations of the students. After this, four lectures (Module 1; Table 1) provide overviews of Latin American cultural and physical geography (Burns and Charlip, 2002; Clawson, 2004), and acquaint students with plate tectonics (Lamb, 2004) and geologic history (Almeida et al., 2000; Cordani et al., 2000).

The second module (Table 1) focuses on metals and is the most historical of the four modules. Five lectures move progressively from the beginning of human occupation almost to the present. We first set the stage for civilization in the New World, by summarizing the appearance of humans, extinctions of large mammals (Barnosky et al., 2004), and the rise of Pre-Columbian

civilizations (Harris, 1977; Meggers, 1972; Nemecek, 2000). The second lecture discusses how these civilizations used metals (Abbott and Wolfe, 2003; Hosler, 1988; Hosler and Macfarlane, 1996). The third lecture discusses how a small but technologically advanced group of Spanish invaders were able to defeat much larger Aztec and Incan armies (Hyams and Orish, 1963; Prescott, 1843), and how important metals - the search for gold and silver and use of iron and steel - were to the conquistadores. The fourth lecture discusses where and how silver was extracted in colonial Latin America, and using the bonanzas of Potosí in Peru (Cunningham et al., 1996a; Cunningham et al., 1996b; García-Guinea, 1995) and Guanajuato in Mexico (Heylum, 1999; Querol et al., 1991) as examples. Technological improvements for extracting silver from the ores is emphasized in this lecture. The fifth lecture focuses on mining and development after independence from Spain. We use the natural resources of Chile as an example, especially nitrates and copper, and discuss how this attracted foreign investors, contributed to an increasing sense of dispossession by Chileans and led to nationalization of the copper mines, and ultimately contributed to the downfall of President Salvador Allende (Cloos, 2002; Finn, 1998; Garza et al., 2001; Ossandón et al., 2001).

The third module "Energy and Natural Hazards" consists of three lectures on energy resources and two on earthquakes and volcanic hazards. Petroleum geology basics (Hyne, 2001; Selley, 1997) and the prognosis for world oil are presented in the first lecture (British Petroleum, 2003; Campbell, 2005). The second lecture presents the distribution of oil and gas resources in Latin America and how they are exploited. This lecture also considers the tension between the need for foreign investment and the sense of the local people that once again the foreigners are exploiting Latin American resources (Bolio, 1982; Brown, 1985; Grayson, 1979). The third lecture discusses geothermal energy, including the association of geothermal energy with volcanoes, the technology used to extract hot water and steam and convert this to electricity, and where in Latin America geothermal energy is and could be exploited (I.G.A., 2005). Because El Salvador, Costa Rica, and Nicaragua produce large proportions of their electricity by this means, this lecture gives us a chance to focus on Central America. This lecture also allows us to review basic plate tectonic concepts, especially the association of Latin American volcanoes with subduction zones and also provides a smooth transition to the fourth lecture, on volcanic hazards. This lecture focuses on the very different styles of devastation associated with the two deadliest Latin American eruptions: 1902 Mt. Pelée, Martinique (29,000 killed as a result of pyroclastic flows) and 1985 Nevado del Ruiz, Colombian (>23,000 killed by mudflows; Bruce, 2001; Schmincke, 2004). The final lecture in the third module concerns Latin American earthquakes. This allows us to further review and expand on the nature of subduction zones, the significance of shallowly-dipping or 'flat' slabs (Gutscher et al., 2000), how earthquake energy is measured, and the nature of the seismogenic zone. We use as examples the magnitude 9.5 1960 Chile earthquake and associated tsunamis (Atwater et al., 1999) and the 1746 Lima, Peru earthquake (Walker, 2003).

The fourth and final module focuses on issues related to ESSE, including the atmosphere, hydrosphere, cryosphere, and biosphere. Latin America provides

special perspectives on the Earth System, specifically El Niño, glaciers, the Amazon and its rain forest, and coral reefs. This module also allows us to discuss global features of atmospheric circulation. The first lecture presents El Niño - Southern Oscillation (ENSO), in the context of the Hadley and Walker circulations and the trade winds, and its effects on ocean circulation (especially upwelling off the Pacific coast of South America) and thus on fisheries. We discuss how El Niños affect rainfall today (Curtis and Adler, 2003), and how they affected Pre-Columbian civilizations (Keefer et al., 2003; Sandweiss et al., 2001). This material is difficult to present well in a single lecture; it probably should be expanded into two lectures. The second lecture is entitled "Latin American Glaciers and Climate Change". This is also a challenging lecture, which explains what glaciers and the cryosphere are and then shows where the glaciers of Latin America are found today (White, 2002; Williams and Ferrigno, 1998). We present the Patagonian ice sheets in this lecture (Rignot et al., 2003). We also explain how oxygen isotopes are used to infer paleoclimatic conditions, using ice-cores from Quelccaya and Huascaran, Peru and Sajama, Bolivia (Thompson et al., 2000) as examples. The third lecture focuses on the Amazon and why this is by far the largest river in the world (Goulding et al., 2003). We emphasize that this superlative river exists because it drains the world's second tallest mountain range and drains a basin beneath the Intertropical Convergence Zone, the seasonally migrating zone of atmospheric upwelling and intense rainfall that marks rising limbs of the Hadley circulation. The fourth lecture concerns the Amazon rain forest, particularly how fragile this ecosystem is (Amazon-Alliance, 2003; Chiras, 1989; Smith, 1990). The fifth lecture focuses on coral reefs of Latin America, which are overwhelmingly concentrated in the Caribbean (Spalding et al., 2001; Wells, 1988). The reasons that Latin American reefs are concentrated well to the north of the equator, on one side of the continent, are discussed (corals need warm, clear water to thrive. Seawater is too cold on the Pacific coast and too muddy on the Atlantic coast of South America; water is warm and clear in the Caribbean).

The final two lectures in the course focus on resource and environmental issues of direct concern to residents of Texas, New Mexico, Arizona, and California: water resources along the US-Mexico border. The Colorado River and Rio Grande systems are the natural foci of these lectures; at UTD we naturally concentrate on the Rio Grande. We build on earlier discussions of Hadley cell circulation to discuss why water is scarce in the region around 30°N (this is where the Hadley cells descend). We then present the geography of the Rio Grande drainage basin and talk about the challenges of allocating scarce water among nations sharing a 'transboundary river'. This discussion also allows us to summarize the historical basis for tension between US and Mexico on this and other issues, including the Mexican-American War. We discuss how this war, which started over a minor dispute about which river the US-Mexico border lay along the south side of Texas (Rio Grande or Nueces River), grew into a conflict which allowed the US to annex half of Mexico. We discuss the treaties between the US and Mexico about how to share Colorado and Rio Grande waters and how explosive population growth along especially the Texas-Mexico border is challenging these agreements.

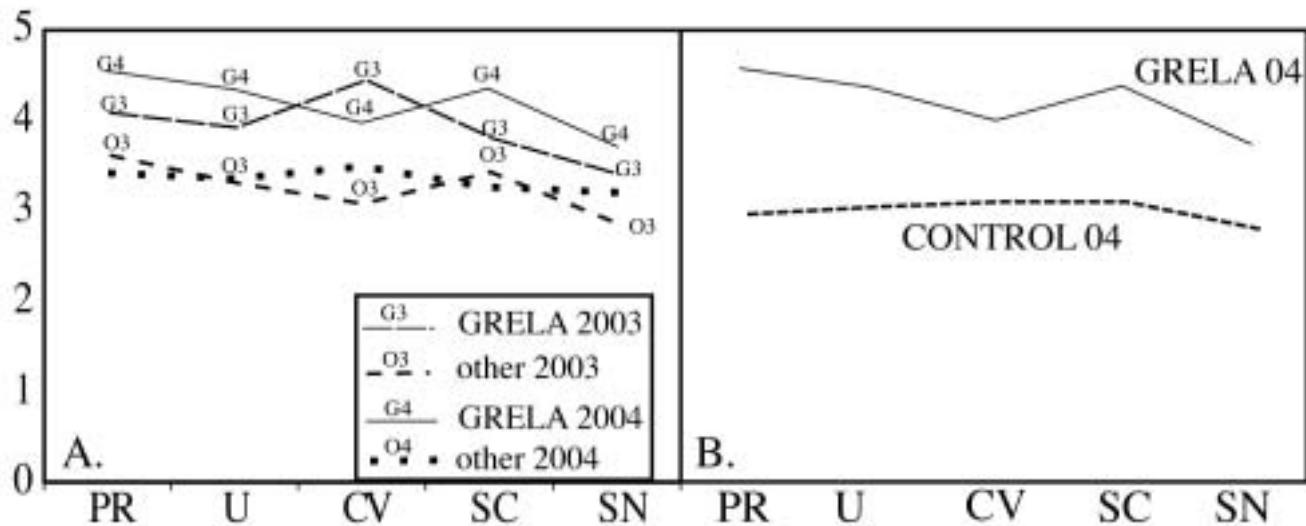


Figure 1. Results of CLES-CS test for GRELA class. Abbreviations along the horizontal axis: PR = Personal relevance, U = Uncertainty of science, SC = Shared control, CV = Critical voice, and SN = Student negotiation. A) Comparisons of CLES-CS average scores for THIS (GRELA course) and OTHER (other science courses taken by the student), GRELA classes 2003 and 2004. B) Comparison of THIS (CLES-CS) for 2004 GRELA and control group.

In summary, the sequence of lectures begins with a discussion of basic concepts (Module I) before progressing to a largely historical presentation focused on past resource utilization and technological innovation (Module II). Module III is a discussion of modern resources and natural hazards that also serves as transition from the largely historical issues of Module II to the material presented in module IV that is clearly ESSE-related; Module III also facilitates transition from issues related to the solid Earth to hydro-, bio-, and atmospheric issues that dominate ESSE and Module IV. The final two lectures focus is intended to be particularly relevant to the student by focusing on an issue close to the US, using historical perspectives, limitations placed on our options as a result of the way that the Earth System operates, and politico-social realities. Some of these lectures spark discussions on controversial issues, such as US involvement in the politics and economy of Latin America and the mixed emotions that many Latin Americans feel towards the U.S. We encourage these discussions because they show how important good science is for making good policy and emphasize that science and the healthy functioning of society are intimately related. We encourage students' questions and comments, although we strive to ensure that both sides of any controversy are considered.

TERM PROJECTS

We require that the students find and correspond with researchers in a Latin America institution on some topic of their choosing (subject to our approval and guidance) related to geological sciences or environmental studies pertaining to Latin America. The students alone or in a team (no more than four) research the problem and collaborate about their findings and questions with the Latin American correspondent using e-mail. A list of researchers in geology departments (with information about their expertise and interests) and societies in Latin America is provided to the students as a starting point. Examples of this work for Fall 2003 and 2004 are:

- Volcanoes and earthquakes in Costa Rica

- US-Mexico border area pollution (the maquiladora effect)
- Water pollution in Mexico City
- Mercury pollution in Taxco, Mexico
- Volcanism in Colima, Mexico
- Brazilian building stones

The term project gives students the opportunity to proactively identify and pursue their interests, at the same time they learn about the importance of initiative and networking in research. We are flexible about how the project results are reported, but students seem to prefer oral presentations, which are done during one or two class periods at the end of the semester.

MENTORING AND EVALUATING STUDENTS

A geography 'pretest' is given at the first class meeting. This pretest is corrected but not graded because it is only intended to inform the instructor about how familiar students are with the region and to alert the students to the first-order geographic features of the region. Class grades are based on two midterm exams, a final exam, the term project and class participation. All students receive CD-ROMs containing all lecture materials. In addition, several class periods are spent helping the students prepare for exams and the class projects. The class period before each of the midterms is spent reviewing the lecture material that is likely to be covered on the exam. Study guides are distributed at this time. Such review is considered to be especially important because there is no textbook for the course. After the first midterm a class period is devoted to organizing the class into small groups (one to four students) for the purpose of identifying and working on the term project. We emphasize to the students that these projects cannot be done at the last minute and push them early to find a team, a topic and a correspondent and get to work. This is followed up at the time of the second midterm review, by which time the projects, groups, and correspondents in Latin America must have been defined.

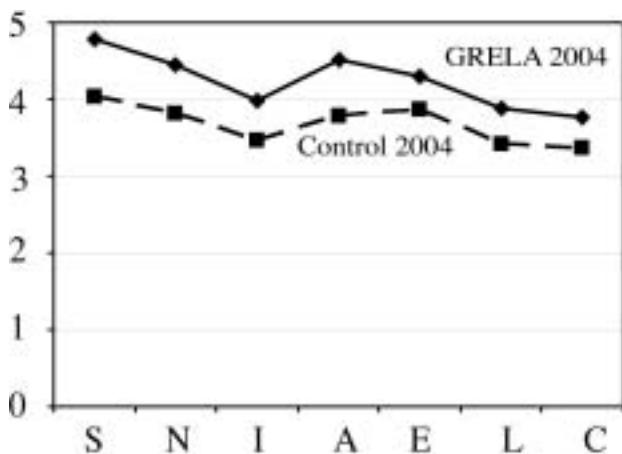


Figure 2. Comparison of TOSRA2 post-tests for 2004 GRELA and control group. Abbreviations along the horizontal axis: S= Social implications of science, N=Normality of scientists, I = Attitude to scientific inquiry, A = Adoption of scientific attitudes, E=Enjoyment of science lessons, L=Leisure interest in science, and C = Career interest in science

COURSE EVALUATION

Three instruments were used to assess student learning and attitude: TOSRA-2, CLES-CA, and a class interview. The Test of Science Related Attitudes (TOSRA, developed by Fraser (1981) and modified by Ledbetter and Nix (2002)) as TOSRA-2 was chosen to assess change in students' attitudes, specifically seven types of information: Social Implication of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. The Constructivist Learning Environment Survey--Comparative Student (CLES-CS; Nix et al., 2003; 2004) evaluated student perceptions of the learning environment of this science class relative to others they had taken at UTD. CLES-CS uses 20 questions to measure students' perceptions on a five-point scale of the extent to which important psychosocial factors (personal relevance = relevance of learning to student's lives; uncertainty of science = the provisional status of scientific knowledge; shared control = student participation in planning, conducting, and assessing learning; critical voice = legitimacy of expressing a critical opinion; and student negotiation = involvement with other students in assessing viability of new ideas) are evident in the class. This version of the CLES asks the student to provide perceptions not only of 'THIS' classroom environment, but also of 'OTHER' (other classes at the same school). Results of the CLES-CS evaluations are shown in Figure 1A. A control group of 38 students was added to the evaluation in 2004. This was also a science service course, entitled "Earthquakes and Volcanoes". The class was similarly drawn from across the university and was comparable in age and diversity to the GRELA class. The mode of instruction was similar, consisting of lectures that relied heavily on PowerPoint presentations. These results are compared with results from 2004 GRELA class in Figure 1B.

GRELA students were also interviewed as a group by the evaluator to tease out information about the class structure, presentation and content. Classes were also

observed to note student/instructor interactions, student/student interactions and pedagogy.

This evaluation is modest, based on a sample of only 19 students, of which 7 were Hispanic and 14 of which were non-science majors and 7 were Hispanic. Because of the small size of the GRELA samples, student responses were analyzed using the non-parametric Wilcoxon matched pair test to compare the students' perceptions of the classroom learning environment which they experienced in THIS and OTHER science classes (Kirk, 1984). This approach was also used to analyze the TOSRA2 responses. Analysis of the CLES-CS student responses (Figure 1A) show that students were consistently more positive about the GRELA class than other science classes they had taken. In spite of this, student attitudes do not appear to have changed much by their experience in the class, with the possible exception of the extent to which scientists are regarded as "normal" (TOSRA results not shown). The instructors found this result to be particularly encouraging. TOSRA2 responses by the GRELA class were significantly more positive than responses by the control group on all scales, particularly with regard to Social Implications of Science and Adoption of Scientific Attitudes (Figure 2).

Interviews of GRELA students confirmed that they were positive about the class, finding it interesting and timely. Some had already recommended the class to their peers. One criticism is that a laboratory or hands-on activities should be included. Other student suggestions were:

- Too many PowerPoint presentations
- Don't read from the sides-add to the information
- More student/professor interaction and discussion
- Better organization needed to tie topics together
- Emphasize what is on the maps
- Too much information
- Give more quizzes
- Make the study guides shorter and give them out sooner
- Do not turn it into an on-line class, but there could be supplemental information online
- Keep it as a co-taught class; professors had different strengths

Students' recommendations along with the results of the CLES-CS and the TOSRA2 were used to make changes in the presentation of the class in 2004. Student interviews in 2004 revealed that these changes were received well. They were most positive about the interactions the professors had with the students and with each other. This included class discussions, personal experiences of the professors, and the extra effort each made to find answers to students' questions. Students said that they felt free to ask questions and could continue to ask for clarification. Students also commented on the frequent use of maps and that this helped them identify and locate countries and regions. Going from country to specific locations, then making specific applications helped student understanding. Students also encouraged adding more current events to the lectures. For example, earthquakes in the region during 2004 stimulated interesting discussions.

FUTURE DIRECTIONS

Our experience with developing and teaching GRELA has been very encouraging. Assessment of the class

indicates that it is more favorably received than other science classes, although this may partly reflect small class size. Further evaluation of the course is needed, especially for larger classes. We are quite willing to share all of our instructional and assessment materials and to work with potential instructors in any way we can. Two additional issues concern the lack of a textbook and the need to develop a laboratory. Students clearly relish the opportunity to learn more about some of the themes in the class through a lab experience. Students generally did not complain about the lack of a textbook, but some of their comments indicate that this would be useful, such as "Too much information" and "Hand out study guides earlier". We think that developing lab components and a textbook would be very useful for the further development of this course.

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