DOCUMENT RESUME

ED 373 987 SE 054 718

AUTHOR Rosenthal, Judith W.
TITLE Theory and Practice: Science for Undergraduates of Limited English Proficiency.
PUB DATE Oct 92
NOTE 28p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *English (Second Language); *Higher Education; *Limited English Speaking; *Science Instruction; *Teaching Models; Undergraduate Study

ABSTRACT

Between 1980 and 1990, the total number of Asian, Hispanic, American Indian, and foreign undergraduates increased by more than 50% at public, private, 4-year and 2-year colleges. Many of these students may be of limited English proficiency, suggesting that the traditional science lecture/lab format may need modification to incorporate the theory of second language acquisition as it pertains to the practice of content instruction. Various methods exist to improve science instruction for limited English proficient undergraduates. These include the Adjunct and Tutorial Models, Sheltered or Bridge science instruction, faculty development, and science instruction in the students' native language. Any plan for science education reform at the collegiate level or for increasing minority participation in science must address the needs of the growing population of undergraduates who speak English as a second language. (Author)

THEORY AND PRACTICE: SCIENCE FOR UNDERGRADUATES OF LIMITED ENGLISH PROFICIENCY

by Judith W. Rosenthal
Professor, Biological Sciences
Kean College of New Jersey
Union, N.J. 07083

phone (908) 527-2469

(Oct. 1992)

Abstract: Between 1980 and 1990, the total number of Asian, Hispanic, American Indian, and foreign undergraduates increased by more than 50 % at public, private, 4-year and 2-year colleges. Many of these students may be of limited English proficiency, suggesting that the traditional science lecture/lab format may need modification to incorporate the theory of second language acquisition as it pertains to the practice of content instruction. Various methods exist to improve science instruction for limited English proficient undergraduates. These include the Adjunct and Tutorial Models, Sheltered or Bridge science instruction, faculty development, and science instruction in the students' native language. Any plan for science education reform at the collegiate level or for increasing minority participation in science must address the needs of the growing population of undergraduates who speak English as a second language.

KEY WORDS: Bilingual higher education; limited English proficient undergraduates; science education; second language acquisition; college science; minorities in science; adjunct model; tutorial model; sheltered science

INTRODUCTION

In the last decade, all levels of the U.S. educational system have experienced marked increases in the number of limited English proficient (LEP) students. While concerns about these students were, in the past, confined to the K-12 system, that no longer is true. Today, enrollment of LEP students in our U.S. colleges is rising dramatically and changing the composition of the undergraduate population. For example, between 1980 and 1990, the total number of undergraduates identified as American Indian, Hispanic, Asian, or foreign increased 54.2 % (from 978,000 to 1,508,000). This trend was seen in public (+56.7%), private (+62.1%), 4-year (+60.9%), and 2-year (+54.1%) institutions of higher learning (*The Chronicle of Higher Education*, March 18, 1992, p. A35). In 1990, 12.7% of the undergraduate population was identified as belonging to these four undergraduate subpopulations, but most were Asian- and Hispanic-Americans. These figures suggest a potentially large number of students of limited English proficiency; unfortunately, data are not available[1] as to the actual percentage of these students who are LEP's nor the number enrolled in English as a second language programs.

The swelling ranks of LEP students in our schools and colleges reflect not only the difference in fertility rates among the various ethnic and racial groups (U.S. Bureau of the Census,

[1] The following organizations and governmental agencies could not provide such data: The Office of Bilingual Education and Minority Language Affairs, the National Center for Education Statistics, the National Association for Bilingual Education, and Teachers of English to Speakers of Other Languages.

1990) but also the effects of massive immigration. Between 1981 and 1990, more than seven million immigrants entered the United States. This wave of immigration ranks second to the peak years between 1901 and 1910 when almost 8.8 million immigrants, predominantly Europeans, were admitted to the U.S. (U.S. Immigration and Naturalization Service). Today's immigrants, however, are mostly from Asia, the Caribbean, and Central and South America (U.S. Immigration and Naturalization Service), so it is not surprising that the 1990 Census reported that during the last decade, the Hispanic population increased by 53 % and Asians by 108 %. Accompanying the changing demographics is enormous language diversity. According to the recent Census, 13.8 % of persons ages 5 years and older "sometimes or always" speak a language other than English at home, and twelve states exceed that national average: New Mexico (35.5 %), California (31.5%), Texas (25.4%), Hawaii (24.8%), New York (23.3%), Arizona (20.8%), New Jersey (19.5%), Florida (17.3%), Rhode Island (17.0%), Connecticut (15.2%), Massachusetts (15.2%), and Illinois (14.2%) (*The Chronicle of Higher Education*, Aug. 26, 1992, pp. 39-112). Such pronounced ethnic and linguistic pluralism cannot help but affect educational practices at all levels in the U.S..

Why should LEP students be of special interest to the scientific community? First, they represent a potential pool of talent. They could be among tomorrow's university and industry researchers, high school and college science teachers, technicians, and/or technologically and scientifically

literate members of the public. Secondly, they bring to the classroom a wide range of previous educational experiences as well as ethnic, cultural, and linguistic diversity that many teachers and professors of science have never before encountered. Finally, science as taught traditionally may no longer be effective in multicultural classes with mixed populations of native English speaking and LEP students.

SCIENCE REFORM AND THE UNDERGRADUATE LEP STUDENT

Since 1989, numerous commissions and task forces have issued reports on science education reform at both the pre-college and college level (The Final Report of the Task Force on Women, Minorities, and the Handicapped in Science and Technology, 1989; AAAS, 1989; A Report of the Carnegie Commission on Science, Technology, and Government, 1991; AAAS, 1990; Project Kaleidoscope, 1991). They duly note the changing demographics of U.S. society as well as the importance of making science, math, engineering, and technology education accessible to all students regardless of their "race, language, sex, or economic circumstances". Unfortunately, some scientists and science educators still view speaking English as a second language or being bilingual as a handicapping condition (A Report of the Carnegie Commission on Science, Technology, and Government, 1991; Miller, 1988). For example, In the National Interest: The Federal Government in the Reform of K-12 Math and Science Education (1991, p. 7) states that in the year 2000, "one child in three will be a minority group member; and one child in twelve *will lack the English language proficiency required for learning*" (italics for

emphasis here). Clearly, students all over the world learn in many languages, and being a native speaker of English has never been shown to be a key factor for achievement in science. Many Nobel Prize winners as well as numerous foreigners studying science at the graduate level in the U.S. speak English as a second language. The truth is that there is no reason why the millions of LEP students moving up through our K-12 system (U.S. Dept. of Education, 1991; Carrasquillo, 1991) and who will enter into our colleges and universities - and who will be joined there by other newly arrived immigrant students - cannot do science. At the college level, what needs examination is how we teach science to undergraduates who are increasing multilingual and multicultural. What we should be asking ourselves is what we can do to attract and retain more LEP students in science majors. Yet, in spite of the new demographics, plans for science education reform do not address the "language barrier".

Instead, what is notable about recommendations for reform is that attention is almost invariably paid to factors which are totally unrelated to how professors teach science to undergraduates. Rather, suggestions are more along the following lines: Math and science instruction in high schools must be strengthened. The teaching techniques and English language proficiency of foreign graduate assistants must be improved. Introductory science courses must include more hands-on research experience. College science professors should work with elementary, middle, and secondary school teachers to improve K-12 science instruction. Unquestionably, these may be some of the

variables contributing to the shrinking number of undergraduate science majors. Nevertheless, focusing on such issues may also be diverting attention from two additional key points.

First, since the 1960's, the demographics of our undergraduate population has changed dramatically so that classroom practices that were successful in the past may no longer be appropriate (Bennett, 1990; Banks, 1988; Scarcella, 1990). Is it just a coincidence that during the last thirty years, the number of undergraduates majoring in science significantly decreased (Green, 1989), the number of non-traditional students (minority, women, and of limited English proficiency) enrolled in college increased, but the nature of science instruction remained unchanged?

Secondly, until very recently, how science is taught to undergraduates has remained almost sacred territory and subject to little scrutiny. It is only within the last few years that several "outsiders" have begun to examine what goes on in the classroom and to question students to find out why they are losing interest in science (Tobias, 1990; Tobias, 1992; Seymour, 1992a; Seymour, 1992b). These studies have shown that students who are both academically capable of and interested in studying science are switching to other majors because (1) they have discovered that another discipline is more interesting and because (2) they get "turned off" to science due to "poor teaching and the unapproachability of SME (science, math, and engineering) faculty" (Seymour, 1992a, p. 233). The first observation comes as no surprise. Students have always discovered new areas of interest and changed majors as a result of the new experiences and wide

range of courses to which they are exposed in college. The second observation , however, may attest to the changing nature of the undergraduate population and advises us that attrition from science at the undergraduate level may have less to do with "external" factors (like large classes, poor laboratory equipment, and foreign teaching assistants) and more to do with science professors and how they teach and interact with students. Why should the old methods of teaching science necessarily be effective with this new population of students?

TRADITIONAL SEPARATION OF LANGUAGE AND SCIENCE INSTRUCTION

At the college level, professors across the curriculum depend on the English department or the ESL program at their institution for the teaching of English to speakers of other languages. They also assume that their students are capable of communicating in and comprehending English since English is almost always the language of classroom instruction. Instructors - whether in math, science, the arts, business, or history - also expect that an ESL program will produce students who are sufficiently proficient in English so that they can function adequately in the mainstream classroom. This means that ESL students should be able to simultaneously listen to lectures and take notes; read and comprehend college textbooks; learn new academic subject matter; take timed exams (which may require written essays or include multiple choice items where wording is intentionally misleading); participate in discussions; understand and follow oral directions;

carry out lab. experiments; write papers and lab. reports, and demonstrate critical thinking and problem solving skills. These are activities with which many U.S. educated, native English speaking students struggle. Imagine the persistence and motivation needed by a student to do this in his or her second language.

What takes place in a college ESL program? Typically, there are regularly scheduled, intensive courses in reading, writing, listening, speaking, and pronunciation skills in English. Students are tested to determine where they should be placed initially in the program, but most need two years to complete the required course sequence. Such two-year ESL Programs are, however, not universal, and institutions of higher education vary considerably in the support services they provide to ESL students. In fact, some colleges have no ESL classes while others only offer a few ESL courses.

Needless to say, most professors outside of English and ESL have no idea how foreign or immigrant students learn English. The end result of this traditional separation of language and content instruction is that in the academic disciplines - including the sciences - instruction is provided by professors who are extremely knowledgable about their subject matter. However, they (1) often know little or nothing about the acquisition of a second language nor (2) how to teach students who are simultaneously acquiring English as well as new content area material taught in the new language. In the past, with a homogeneous population of native English speaking undergraduates, language was not an issue. However, with today's new undergraduate demographics, how the English language is used in the classroom

can assist or hinder the learning of content material.

Several studies (Smoke in Benesch (Ed), 1988; Ostler, 1980) have shown that the majority of college students who have successfully completed a program in ESL do not feel ready to compete in the mainstream classroom. They are concerned with their oral and written English skills, their ability to listen to lectures and simultaneously take notes, to read and understand textbooks, and to take tests. Such observations are consistent with research findings on second language acquisition which consistently show that *academic* language proficiency (not basic conversational skills) in a second language requires five to seven to develop (Cummins, 1980; Cummins, 1981; Cummins and Swain, 1986; Collier and Thomas, 1989). That is considerably longer than a two year college ESL program.

PRINCIPLES OF SECOND LANGUAGE ACQUISITION

Clearly, learning English as a second language is a complex process. What follows is a description of some of the central concepts of second language acquisition (SLA) theory. They are presented here to provide science professors with background information which will increase their understanding of the special needs and unique problems faced by the LEP undergraduates in their courses. In no way do the following nine points explain all there is to know about SLA theory nor do all researchers in the field agree on these issues. Nevertheless, the information that follows may reduce some common misunderstandings between science professors and their LEP students.

1. <u>There exist two levels of second language skills - basic conversation and academic - which develop at different rates</u> (Cummins, 1980; Cummins, 1981; Cummins and Swain, 1986). Basic conversational ability in a second language emerges in about two years and is "context embedded". In communication of this type, there are many clues to meaning beyond the content of the words which are spoken. Speakers typically observe each other, watch facial expressions and hand gestures, note the tone of voice of the other person, and sometimes actual objects may be pointed to or shown. In contrast, academic language proficiency develops in five to seven years and is "context-reduced" or "decontextualized". This is exemplified by the kind of language ability needed to learn cognitively demanding academic subject matter where clues to meaning are often lacking, and the subject matter is abstract (such as a college lecture). Academic language ability reflects language proficiency as well as cognitive and memory skills, and it ultimately determines academic success.

These two levels of language proficiency, basic conversational vs. academic language, can confuse instructors. For example, some ESL students speak English well, but do poorly in their classes. This is because their academic English proficiency is weak while their conversational skills are well developed. On the other hand, some LEP students can hardly speak a word of English, yet on tests and written reports their grades are high. For whatever reasons, their academic language proficiency far exceeds their conversational ability in English. Content professors must be very careful not to misjudge their LEP students

by equating basic conversational proficiency in English with academic English skills. The two are distinct, and it is the latter that most significantly contributes to success in the sciences.

2. A student's knowledge, skills, and conceptual abilities in his or her native language strongly influence the development of academic language proficiency in the new or second language (Cummins 1980; Cummins, 1981; Cummins and Swain, 1986). In other words, the student who is literate and educated in his or her native language - be it Korean, Spanish, or Farsi - will more easily acquire academic English. This is possible because study skills, content knowledge, and problem solving abilities readily transfer from the first to the second language, and don't have to be learned or relearned. Thus, LEP students who are well educated in their native language not only master academic English more rapidly but also succeed academically in spite of deficiencies in their oral English production.

3. Language can be "learned" or "acquired" (Krashen, 1981; Krashen, 1987). For example, babies and little children in a seemingly effortless and unconscious manner "absorb" their native tongue. This is language acquisition. The minds of these young learners "appropriate" the language, and without any formal study or training, they begin to speak and communicate.

Taking a course in a foreign language in high school or college is an example of "learning" a language. This involves attending class several times a week and actively, consciously, memorizing rules, verbs and vocabulary. Unfortunately, language learning is not particularly successful; most students can never

speak the foreign language, and they abandon their studies because it's "too hard" and/or they don't have a "gift" for languages.

Language learning for most individuals is limited in its usefulness (Krashen, 1981; Krashen, 1987). If the person has enough time and if he or she can remember the rules, then learned language can help to correct mistakes when speaking or writing. However, conversation generally proceeds rapidly and the rules are usually forgotten so that "learned" language is not particularly helpful; the second language speaker is left tongue-tied.

4. Adults only feel comfortable using a second language and become fluent in it if "acquisition" occurs (Krashen, 1981; Krashen, 1987). When this happens, the individual develops an intuitive sense that the language sounds right or looks right even if he or she can't remember any of the "learned" rules. Acquisition is subconscious and requires sufficient exposure to "comprehensible input" in the new language. This means that in order to acquire a new language, the language learner must be taking in meaningful messages, ones that are just "a little beyond" his or her current level of language competence.

5. LEP college students are adults who are simultaneously learning English in their ESL courses and acquiring English in a variety of ways. The latter takes place, for example, in their mainstream, academic classes, while using English to communicate with friends and others, by watching TV and listening to the radio, and by reading U.S. newspapers.

In the case of the mainstream college classroom, LEP students are learning new ideas, concepts, and terminology through the medium of their second language. They must successfully employ a

wide range of skills in English - reading, listening, comprehension, writing, problem solving, test taking, etc. - in order to to pass. In other words, they must fulfill the same course requirements as their native English speaking peers, but they do so while still learning and acquiring the language of instruction.

During the traditional science lecture or laboratory, there are a variety of techniques that professors can use to make "input" more comprehensible and to enhance the acquisition process. Not surprisingly, many students, not just LEP's will benefit: Teachers should pay closer attention to how they speak and to their word choices. This doesn't mean watering down the content or talking ridiculously slowly. However, an effort should be made to speak clearly and at a reasonable pace, to use relatively simple sentence structure and many synonyms, to repeat key words, to summarize periodically the material being covered, and to use several examples to illustrate major concepts. The overuse of jokes, slang, and idioms (which LEP students won't understand) should also be avoided. Other helpful instructional techniques are legibly writing major concepts and new vocabulary on the chalkboard (or presenting them on overheads), providing written directions for assignments, paraphrasing students' questions before responding to them, and being selective about the reading assignments (choosing materials that will be not only comprehensible but also of a length that LEP students can read in a reasonable amount of time).

6. Attitudes and emotions significantly influence learning and language acquisition (Krashen, 1981; Krashen, 1987). In

other words, classroom atmosphere affects how much of the information transmitted by professors is taken in and processed by LEP students. Learning in a second language requires more than comprehensible input; the learning environment must reduce anxiety, enhance motivation, and increase the student's self-esteem. Under these conditions the LEP student not only processes content but also increases his or her proficiency in English.

Needless to say, classroom atmosphere is not a central topic in plans for science education, nor do science professors spend much time discussing it. Nevertheless, the learning environment may be a critical issue in the multicultural, multilingual classroom.

7. Correcting language errors does not promote second language acquisition (Krashen, 1981; Krashen, 1987). Making errors, whether written or spoken, is an integral part of developing second language proficiency. Mistakes do not mean that the individual is not trying hard enough or not studying enough; rather, they are clear evidence that the ESL student is making an effort to use and master the new language. Communicating effectively in a second language is very different from memorizing the rules of grammar, vocabulary words, and verb conjugations, and it just is not possible to become proficient in a second language without making mistakes.

No matter how well intentioned, the urge to correct the language mistakes made by LEP students should be resisted. If LEP students are constantly interrupted when they speak (to correct, for example, verb tenses or pronunciation) and if their

written assignments are covered with red-inked corrections (to fix things like grammar and spelling), they can rapidly become discouraged. As a result, they will try to avoid communication in their new language and will talk less and write less. This, in turn, will slow down both the acquisition of English as well as subject matter learning. Instructors, rather than correcting the language errors of their LEP students, should model both the proper use of English and/or the correct response. They should try to focus their attention on content rather than on the form or correctness of the language.

How error correction is handled may increase or decrease a student's anxiety, thereby strongly affecting the intake of "comprehensible input", the learning process, and the acquisition of English. This is particularly relevant in the sciences since the language of science is both precise and concise, possibly making science instructors more prone to error correction. In fact, when faculty members in various disciplines were asked to react to the writing of ESL students, professors in the physical sciences were more irritated by language errors than their colleagues in the humanities and social sciences (Santos, 1988).

8. Students studying ESL in college will not lose their accents. In general, only young children have the ability to make all the sounds appropriate to a specific language; around puberty, that vocal flexibility disappears (Harley, 1986). College-age LEP students, like most adult second language learners, almost never sound like native English speakers no matter how long their length of residence in the U.S.. In fact, many feel especially self-conscious when speaking English. They are

embarrassed by having an accent and afraid that others will make fun of them. This is particularly unfortunate because an accent does not reflect intellectual and problem solving abilities, study skills, nor memory, those proficiences which are essential for success in most academic areas including science.

9. Becoming proficient in a second language shows "considerable variation from one language learner to another. The process is nonlinear, gradual, complex, and dynamic; learners learn when they are ready to do so, and learning a language is a social phenomenon" (Larsen-Freeman, 1991). In other words, professors should not expect the same level of English proficiency, either conversational or academic, from all LEP students. Each progresses at his or her own pace which in turn is influenced by prior educational experiences and the learning environment. There is no single formula which holds the key to mastery of English, nor is there one time table that all students follow. As a result, teachers must appreciate the differences among LEP students and be flexible in how they present content material. This is true in all subject areas and at all levels in the educational system. Undergraduate science is no exception.

MODELS FOR IMPROVING UNDERGRADUATE SCIENCE INSTRUCTION FOR LEP STUDENTS

To date, there has been almost nothing published on science instruction for LEP college students in the mainstream science classroom (Sutman *et. al.*, 1986; Rendon and Triana, 1989; Rosenthal, in press), nor has there been investigation of how various campuses across the Nation are dealing with increasing

numbers of LEP students in basic science courses. This very much contrasts with the situation for grades K-12 in which science instruction has been affected by bilingual and ESL considerations. Therefore, it is not surprising that at the precollege level, there exists a growing body of literature on appropriate science instruction for LEP students (Sutman *et al.*, 1986; Cantoni-Harvey, 1987; CA Dept. of Educ., 1990; Crandall (Ed.), 1987; Gonzales, 1981; Reilly, 1988; Secada, 1991; *NCBE Forum*, 1987; Rendon and Triana, 1989; Mason and Barba, 1992).

The author of this paper has begun compiling information on the strategies used by different colleges to improve science instruction for growing numbers of LEP undergraduates. These findings, therefore, are preliminary; in no way are they intended to suggest that the following material is comprehensive nor that one model is better than another. Certainly, what works best would vary considerably depending on the size of the college, the number of LEP students studying science, the degree of cooperation between science and ESL faculty, the extent of institutional commitment to recruiting and retaining LEP undergraduates in the sciences, and on the availability of resources. Although some of what follows is described in the literature, much is taken from the notes of the author who recently spoke to faculty, staff, and administrators at various colleges.

1. **The Adjunct Model** - The Adjunct Model involves pairing a content and an ESL course and requires that the two instructors work closely together (Snow and Brinton, 1988; Snow and Brinton in Benesch (Ed), 1988). The students in the content course may all be non-native speakers of English or a mixture of ESL and native

English speakers. In either case, the subject matter instructor focuses on providing comprehensible input by selecting appropriate reading materials, presenting well organized lectures, using simplified sentence structure, avoiding slang and idioms, and by establishing a classroom climate that stimulates learning. The ESL component of the course pairings allows the non-native speakers to use ESL techniques involving writing, reading, and speaking as well as cooperative learning groups to work with and to manipulate the subject matter taught in the content course. The end result is that students not only learn the subject matter but also increase their proficiency in English.

Clearly, the adjunct model could be used to teach science to LEP undergraduates, yet published descriptions invariably involve the humanities and business. However, at Union County College (Union, N.J.), the adjunct model has been used successfully for several years. In this case, a pre-allied health anatomy and physiology course is paired with an upper-intermediate level ESL course. All the students enrolled in the biology course are non-native speakers of English. They meet 3 hours a week to study anatomy and physiology and another 3 hours a week to go over the biology materials in their ESL course. The two instructors work together "down to the detail". Their goal is not only to ensure that the students do well in these two paired courses but also to prepare these ESL students to move into "less friendly", mainstream, science courses in the future.

2. **The Tutorial Model** - The Tutorial Model (Hirsch in Benesch (Ed), 1988) recognizes that students who have successfully

completed an ESL program still have difficulty competing in the mainstream classroom. For example, they have trouble understanding the lectures and the reading materials, and as a result do poorly or may fail. Clearly, the goal of the Tutorial Model is to prevent the latter from occurring.

In the Tutorial Model, ESL students enrolled in English-language content courses are assigned to tutor-led groups attached to specific content courses. The tutors are graduate or undergraduate students who are good writers and who know the content area well. Nevertheless, they undergo training in preparation to meeting weekly with their study groups. Tutors also are required to attend the students' content course once a week so that they are familiar with both the subject matter and the professor's expectations. The tutoring session is not a repeat lecture. Rather, the students, under the guidance of the tutor, talk and write about the content course subject matter and in this way learn the material. As in the Adjunct Model, the end result is that students not only better comprehend the content material but also improve their English language skills.

The Tutorial Model was developed at Hostos Community College in the Bronx, N.Y. where it has been applied to a variety of subject areas including General Biology. Evaluation of the Tutorial Model has shown that ESL students who participate in the tutor-guided study groups receive higher final grades in the content courses when compared to a control group of ESL students who did not have the tutorial assistance. In addition, both student participants and their content faculty instructors evaluate the program very favorably.

3. **"Sheltered" or "Bridge" Science Instruction** - In this model, enrollment in a particular section of a content course is limited to ESL students who have reached an intermediate level of English proficiency. Content professors who participate in such programs generally undergo training to learn more effective ways of teaching ESL students. Their students, in turn, receive some type of academic support which might include additional readings or exercises in their native language, weekly tutorial sessions, study skills development, or help with new vocabulary and reading assignments.

Sheltered or Bridge science instruction is being used at Hostos Community College (Bronx, NY) and at the Borough of Manhattan Community College (New York City).

4. **Focus on science faculty development** - Although some colleges do not offer any special type of science instruction for LEP undergraduates, they do make efforts to prepare faculty members across the curriculum to more effectively teach non-native English speaking students who are enrolled in mainstream courses. What typically happens is that members of the ESL faculty or outside consultants who specialize in areas such as content instruction of LEP students or second language acquisition may provide one-time workshops or weekly training sessions for interested faculty members. In this way, content faculty can learn about alternative ways of teaching, student learning styles, and about ESL techniques that can used in their classes. It is the distinct impression of this author, however, that science faculty are among the last to get involved in such training and that those who do participate are generally from biology or environmental

science and not chemistry or physics.

5. **Science instruction in the students' native language** - Several colleges offer native language (Spanish) instruction in introductory science courses to students who are simultaneously enrolled in ESL. For example, at Kean College of New Jersey (Union, NJ), students can take basic biology or chemistry in Spanish for academic credit. At Hostos Community College (Bronx, NY), general biology, environmental science, and a developmental chemistry course are taught in Spanish while at Erie Community College (Buffalo, NY), human biology, environmental science, and chemistry are offered in Spanish. Depending on the program, the text may be in Spanish or English. It is interesting to note that other colleges offer bilingual education of this type but not in science; the problem they face is finding Spanish speaking science professors.

While "bilingual" higher education surprises many U.S. academics, it is an extremely effective way to retain language minority students in college. It allows them to begin their academic coursework and to start working toward a college degree while simultaneously enrolling in an ESL program. In bilingual programs, as the students' proficiency in English increases, so does the amount of coursework taken in English. In other words, a student who doesn't know any English can take several content courses in Spanish and begin his or her ESL studies. Then, as the student progresses through the ESL course sequence, the proportion of content courses taken in Spanish decreases until the student is finally mainstreamed.

CONCLUSION

The U.S. college classroom is unquestionably becoming more diverse both ethnically and linguistically, yet proposals for science education reform do not pay much attention to these changes. How science is taught, the nature of the undergraduate student population, and language considerations are often viewed as peripheral issues. Yet, unquestionably, English is rapidly becoming the international language for communication in science. This paper is recommending that steps must be taken to make sure that the same language does not become a barrier to entry into the world of science for LEP undergraduates in U.S. colleges.

The science community needs to begin building bridges to those organizations such as TESOL (Teachers of English to Speakers of Other Languages) and NABE (National Association for Bilingual Education) which have years of experience and expertise in working with LEP students.[2] Additional resources are also available from the National Clearinghouse for Bilingual Education (NCBE) and the ERIC Clearinghouse on Languages and Linguistics.[3]

Any plans to reform science education, including those at the college level, must take into consideration the characteristics and needs of students of limited English

---

[2] Teachers of English to Speakers of Other Languages (TESOL), 1600 Cameron St., Suite 300, Alexandria, VA 22314 (phone 703-836-0774); National Association for Bilingual Education (NABE), Union Center Plaza, 810 First St., N.E., Third Floor, Wash., D.C. 20002 (phone 202-898-1829).

[3] National Clearinghouse for Bilingual Education (phone 202-467-0867 or 1-800-321-NCBE) and the ERIC Clearinghouse on Languages and Linguistics (phone 202-429-9551): The George Washington University/Center for Applied Linguisitics, 1118 22nd St., N.W., Wash., D.C. 20037.

proficiency. Just describing the changing U.S. demographics is not enough. Much more can be done than has been done to improve science instruction for LEP undergraduates.

(5392 words to here)

REFERENCES

A Report of the Carnegie Commission on Science, Technology, and Government (1991). *In the National Interest: The Federal Government in the Reform of K-12 Math and Science Education;* Carnegie Commission on Science, Technology, and Government,N.Y.

American Association for the Advancement of Science (1989). *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology;* AAAS, Washington, D.C.

American Association for the Advancement of Science (1990). *The Liberal Art of Science;* AAAS, Washington, D.C.

Banks, J.A. (1988). *Multiethnic Education*, Allyn and Bacon, Inc., Boston, MA.

Bennett, C.I. (1990). *Comprehensive Multicultural Education*, Allyn and Bacon, Inc., Boston, MA.

California Department of Education (1990). *Bilingual Education Handbook: Designing Instruction for LEP Students;* Bilingual Education Office of the California Department of Education, Sacramento, CA.

Cantoni-Harvey, G. (1987). *Content-Area Language Instruction,* Addison-Wesley, Reading, MA.

Carrasquillo, A. (1991). The Role of Native Language Instruction in Bilingual Education Programs. *NABE NEWS* 14: 1 and 20-22.

College Enrollment by Racial and Ethnic Group, (March 18, 1992) *The Chronicle of Higher Education*, A35.

Collier, V.P. and Thomas, W.P. (1989). How Quickly Can Immigrants Become Proficient in School English? *The Journal of Educational Issues of Language Minority Students* 5: 26-38.

Crandall, J. (Ed.) (1987). *ESL Through Content-Area Instruction: Mathematics, Science, and Social Studies*, Prentice Hall Regents, Englewood Cliffs, N.J.

Cummins, J. (1980). The Cross-Lingual Dimensions of Language Proficiency: Implications for Bilingual Education and the Optimal Age Issue. *TESOL QUARTERLY* 14: 175 - 187.

Cummins, J. (1981). Age on Arrival and Immigrant Second Language Learning in Canada: A Reassessment. *Applied Linguistics* 11: 132 - 149.

Cummins, J. and Swain, M. (1986). *Bilingualism in Education*, Longman, N.Y.

Gonzales, P.C. (1981). Teaching Science to ESL Students. *The Science Teacher* 48: 19 - 21.

Green, K.C. (1989). A Profile of Undergraduates in the Sciences. *American Scientist* 77: 475-480.

Harley, B. (1986). *Age in Second Language Acquisition*. College-Hill Press, San Diego, CA.

Hirsch, L. (1988). Language Across the Curriculum: A Model for ESL Students in Content Courses. In Benesch, S. (Ed.), *Ending Remediation: Linking ESL and Content in Higher Education*, TESOL, Washington, D.C. pp. 67-89.

Krashen, S.D. (1981). *Second Language Acquisition and Second Language Learning*, Pergamon Institute of English, Oxford.

Krashen, S.D. (1987). *Principles and Practice in Second Language Acquisition*, Prentice-Hall International, U.K.

Larsen-Freeman, D. (1991). Second Language Acquisition Research: Staking Out the Territory. *TESOL QUARTERLY* 25: 315-350.

Mason, C.L. and Barba, R.H. (1992). Equal Opportunity Science. *The Science Teacher* 59: 22 - 26.

Miller, G.A. (1988). The Challenge of Universal Literacy. *Science* 241: 1293 - 1299.

National Clearinghouse for Bilingual Education (1987). Teaching Math and Science to Limited-English-Proficient Students: Some Notes from the Literature. *NCBE Forum* X: 1 and 3.

Ostler, S.E. (1980). A Survey of Academic Needs for Advanced ESL. *TESOL QUARTERLY* XIV: 489 - 502.

Project Kaleidoscope (1991). *What Works: Building Natural Science Communities, Vol. One*. Project Kaleidoscope, Washington, D.C.

Reilly, T. (1988). ESL Through Content-Area Instruction. ERIC Clearinghouse on Languages and Linguistics, Washington, D.C.

Rendon, L.I. and Triana, E.M. (1989). *Making Mathematics and Science Work for Hispanics*, AAAS, Washington, D.C.

Rosenthal, J.W. The Limited English Proficient Student in the College Science Classroom. (accepted for publication in the *Journal of College Science Teaching*)

Santos, T. (1988). Professors' Reactions to the Academic Writing of Nonnative-Speaking Students. *TESOL QUARTERLY* 22: 69 - 90.

Scarcella, R. (1990). *Teaching Language Minority Students in the Multicultural Classroom*, Prentice Hall Regents, Englewood Cliffs, NJ.

Secada, W.G. (1991). Teaching Math and Science to Limited English Proficient Students. *NABE NEWS* 14: 15 - 16.

Seymour, E. (1992a). 'The Problem Iceberg' in Science, Mathematics, and Engineering Education: Student Explanations for High Attrition Rates. *J. of College Science Teaching* XXI: 230 -238.

Seymour, E. (1992b). Undergraduate Problems with Teaching and Advising in SME Majors - Explaining Gender Differences in Attrition Rates. *J. of College Science Teaching* XXI: 284-292.

Smoke, T. (1988). Using Feedback from ESL Students to Enhance Their Success in College. In Benesch, S. (Ed.), *Ending Remediation: Linking ESL and Content in Higher Education*, TESOL, Washington, D.C., pp. 7 - 19.

Snow, M.A. and Brinton, D.M. (1988). The Adjunct Model of Language Instruction: An Ideal EAP Framework. In Benesch, S. (Ed.), *Ending Remediation: Linking ESL and Content in Higher Education*, TESOL, Washington, D.C., pp. 33-52.

Snow, M.A. and Brinton, D.M. (1988). Content-Based Language Instruction: Investigating the Effectiveness of the Adjunct Model. *TESOL QUARTERLY* 22: 553-574.

Spener, D. (1988). Transitional Bilingual Education and the Socialization of Immigrants. *Harvard Educational Review* 58: 133 - 153.

Sutman, F.X., Allen, V.F. and Shoemaker, F. (1986). *Learning English Through Science*, National Science Teachers Association, Washington, D.C.

The Final Report of the Task Force on Women, Minorities, and the Handicapped in Science and Technology (1989). *Changing America: The New Face of Science and Engineering*; NSF, Washington, D.C.

The States, (August 26,1992) *The Chronicle of Higher Education*, 39 - 112.

Tobias, S. (1990). *They're Not Dumb, They're Different*, Research Corp., Tucson, Arizona.

Tobias, S. (1992). Science Education Reform - What's Wrong with the Process? *Change* 24: 13 -19.

U.S. Bureau of the Census (1990). *Statistical Abstracts of the United States, 1990, 110th Edition.* Table No. 85, Projected Fertility Rates, by Race and Age Group: 1990 to 2010 (p. 65) and Table No. 87, Live Births, by Race and Type of Hispanic Origin - Selected Characteristics: 1985 and 1987 (p. 66). U.S. Bureau of the Census, Washington, D.C.

U.S. Dept. of Education, Office of the Secretary (June 30, 1991). *The Condition of Bilingual Education in the Nation: A Report to the Congress and the President;* U.S. Dept. of Education, Washington, D.C.

U.S. Immigration and Naturalization Service. Table 2, Immigration by region and selected country of last residence, fiscal years 1820 - 1990. U.S. Immigration and Naturalization Service, Washington, D.C.

(6361 words, text plus references)