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ABSTRACT

This document reports on a workshop entitled "Articulation, Equity, and Literacy Issues" hosted by the College Level One (CL-1) project of the National Institute for Science Education (NISE). CL-1 identifies important issues in undergraduate education and determines the best strategies for addressing them. Workshop discussions examine curriculum content and delivery practices within disciplines and explore the cross-cutting themes of articulation, equity, and literacy. The CL-1 team answers the following questions: (1) What are the most strategically valuable research questions?; (2) What are the most appropriate research methodologies?; (3) What is the original mix of research expertise?; and (4) What other considerations might there be? (Author/KHR)

Workshop Report No. 1

College Level One: Articulation, Equity, and Literacy Issues

Søren Bisgaard, Lia V. Brillhart, Ann B. Burgess, Jane Harris Cramer, Denice D. Denton, Janice D. Downer, Sharon L. Dunwoody, Arthur B. Ellis, Peter W. Hewson, Walter G. Secada, and Sheila Tobias

National Institute for Science Education (NISE) Publications

The NISE issues papers to facilitate the exchange of ideas among the research and development community in science, mathematics, engineering, and technology (SMET) education and leading reformers of SMET education as found in schools, universities, and professional organizations across the country. The NISE Occasional Papers provide comment and analysis on current issues in SMET education including SMET innovations and practices. The papers in the NISE Research Monograph series report findings of original research. The NISE Conference and Workshop Reports result from conferences, forums, and workshops sponsored by the NISE. In addition to these three publication series, the NISE publishes Briefs on a variety of SMET issues.

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National Institute for Science Education
University of Wisconsin-Madison

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Executive Summary

A part of the National Institute for Science Education (NISE), the College Level One (CL-1) Team was established to examine first-year postsecondary courses in science, mathematics, engineering, and technology (SMET). These courses represent curriculum "pressure points" in that they greatly influence student career trajectories and attitudes, and they have a strong effect on the courses that follow them. CL-1 will work with the Institute's partners, the National Science Foundation (NSF) and the National Center for Improving Science Education (NCISE), to characterize these courses and suggest strategies that will add value to them.

As a first step in this process, CL-1 hosted a workshop entitled "Articulation, Equity, and Literacy Issues" to obtain diverse perspectives on these courses from representatives of various stakeholder groups. Outcomes sought were feedback on an initial set of objectives for year one efforts; acquisition of baseline information on relevant literature, statistics, and "best practices"; and an expanded network of participants.

After introductions, the workshop centered around four disciplinary breakout groups (mathematics, physics/engineering/technology, chemistry/biology, and alternate/integrated SMET courses) and, subsequently, three cross-disciplinary breakout groups (literacy, equity, articulation).

Within disciplines, discussions centered on what knowledge and skills students should learn as a result of being in SMET courses and how to assess mastery. Although a few disciplines have attempted to address these issues, most have not. There is a general recognition that the clientele of these courses should be better identified and their needs more specifically addressed. Standards currently being developed for the precollege curriculum must be considered in designing SMET courses. A number of innovative effective approaches to both content and pedagogy have been implemented in college level one SMET courses, and these best practices are worth examining in more detail for characteristics that permit transportability.

Cross-disciplinary discussions on literacy identified various audiences–SMET majors, non-SMET majors, and future teachers, for example–who need to be served by these courses and the importance of finding engaging approaches that convey a sense of the method and content of science and its application to the real world. Equity discussions considered the effect of present instructional practices and new technologies on various population groups and their effect on the recruitment and retention of underrepresented groups in SMET-related courses; socioeconomic factors and the sensitization of faculty were other issues that were considered. Articulation discussions highlighted the need to raise awareness of the difficulties associated with transferring knowledge, skills, and credits within and between institutions. New technologies like the Internet and World Wide Web offer the potential to facilitate these transitions for students and teachers and may become especially important as new approaches to teaching SMET courses are implemented.

The workshop substantially sharpened the focus of the College Level One Team. The Team has now identified three areas for the first-year research effort:

- Pathway Studies

  We will identify the pathways through first-year college SMET courses that were taken by individuals who subsequently entered four career areas: social leadership, business, teaching, and SMET-related fields. Toward this goal, we will conduct analyses of large-scale databases of individuals as a function of their initial careers to see whether they had enrolled in distinctive course sequences. Examples of appropriate resources are "High School and Beyond" and "National Longitudinal Study." Results of this study may be of particular help to NSF's programs in teacher preparation, such as the Collaboratives for Excellence in Teacher Preparation.

- "Best Practice" Programs

  We will identify outstanding, effective SMET programs being used in the first-year courses in two-year and four-year institutions. These may exemplify new instructional methods, new technologies, and/or new curricula. We will choose a small number of these programs for detailed case studies, including site visits, in year two. In making our selections, we will look at the impact of these programs on students and faculty, as well as the institutional structures and cultures that promote or inhibit reform. We will look at dissemination efforts and attempt to identify those factors that facilitate propagation of successful programs. Potential case studies may include projects supported by NSF under programs such as Course and Curriculum Development, Instrumentation and Laboratory Improvement, and Advanced Technological Education.

- Equity Issues

  Current practices and innovative reform efforts in SMET education may have a differential impact on women and individuals of color. For example, poor instructional practices may disproportionately contribute to loss of these underrepresented groups from SMET-based career paths. Similarly, introduction of new technologies may be less readily embraced by underrepresented groups who have not had prior exposure to these tools. A literature survey and statistical analysis will be conducted to address these issues, which may markedly affect retention of underrepresented groups. These results may be of interest to a variety of NSF efforts related to equity.

Introduction

Driven by many factors, the reform movement in undergraduate mathematics and science education in the United States is now at a critical stage. Changes in precollege education have altered the knowledge and expectations of entering students. College level SMET courses are expected to meet the multifold goals of enabling individuals to be scientifically literate in a technological society, training scientists to be analytical researchers and skilled technicians, and preparing teachers to be scientifically knowledgeable and pedagogically skilled. Finally, science education must be made more accessible and meaningful to all segments of our society.

The National Science Foundation, in pursuing its mission to initiate and support education programs, has funded many innovative college SMET programs at the local level. The time has come for broader-scale implementation. Challenges to change are complex, crossing disciplinary boundaries, involving both scientists and educators, and requiring adaptations at departmental and institutional levels. The NISE has been established with NSF funding to act as guide and partner to confront inadequacies in science/math education at all educational levels. The College Level One Team (CL-1) of the NISE is charged with identifying the important issues in undergraduate SMET education and determining the best strategies for dealing with them. Critical among these is how to progress toward systemic implementation and change.

CL-1 was designated as one of the projects within the NISE because of the conviction that college entry level courses represent a curriculum "pressure point," strongly influencing courses that succeed them and often determining student career paths. During the past few months the group has worked to define its field of investigation. The Articulation, Equity, and Literacy Issues Workshop, an outgrowth of those discussions, was organized to tap the knowledge and ideas of SMET education stakeholders, who represent a spectrum of disciplines and institutions.

In addition to examining curriculum content and delivery practices within disciplines, workshop discussions were channeled to the cross-cutting themes of articulation, equity, and literacy. Participants were asked to reflect on several questions: How effective are articulation mechanisms, i.e., transfer of knowledge and credits, both within and between institutions? Are all groups within our population being well-served by SMET courses? How can science literacy be taught and how can it be woven into courses that serve science majors, nonmajors, and future teachers?

As an outcome of the workshop, CL-1 requested advice on the following:

- What are the most strategically valuable research questions?
- What are the most appropriate research methodologies?
- What is the optimal mix of research expertise?
- What other considerations might there be?

Participants were reminded in closing that the NISE as a whole, and the College Level One project specifically, seek the broadest possible involvement from the science and education communities. The entire initiative is viewed as multidisciplinary, inclusive, and comprehensive. Workshop attendees, their colleagues, and their expanded network of contacts were invited to be involved in the effort.

Disciplinary Group Discussions

Mathematics

Participants: Cliff Adelman, Steve Bauman, Sharon Derry, Janice Downer, Robert Lopez, Walter Secada, Larry Suter, Sheila Tobias, Alan Tucker

The mathematics group discussion was wide-ranging, covering many themes and topics. As a basis for thinking about math education, the group emphasized the unique nature of mathematics because of its use in all other scientific disciplines. As a service subject, it needs to reflect the needs of those areas. Although "mathematics" is a plural word, it is a single discipline, hence easier to organize and reform. NISE efforts have the advantage of building on an eight-year history of reform founded on a comprehensive study of misconceptions and student reasoning in mathematics. The National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards* (1989) focused on precollege mathematics; college level activities have emphasized calculus reform and led to the creation of new texts and new uses of technology. Workshop participants directed their attention to the following issues: definition, content, and outcomes of college level one mathematics; curriculum pathways; and the current status of other reform efforts.

College level one mathematics: Definition, content, and outcomes. Workshop participants acknowledged that mathematics education is an integral part of postsecondary education options, many of them outside of the college context (for example, trade schools, union apprenticeships, and military service). However, given its background and resources, the NISE would be best directed to studies of college mathematics. The definition of college here includes technical, community, and four-year liberal arts colleges and universities.

The group was split on the issue of defining content for college level one mathematics, i.e., whether it should encompass everything taught during the first year of postsecondary education or whether it should include only nonremedial information. On the one hand, to exclude all remedial content is to omit an ever-increasing area of college mathematics teaching. (Note, however, that data from the "High School and Beyond" study suggest that the increase results not so much from continual entry of new students into remediation but from repeating students who never successfully complete the courses.) On the other hand, participants argued, content for remedial college courses is already defined by the NCTM *Standards*, which specify what students should know prior to postsecondary education. Thus, the important issues are related to implementation rather than desirable content, teaching practice, and assessment. The Institute should focus its attention on conceptual work, that is, on nonremedial content.

Outcomes for first-year courses are two-fold: mathematical literacy for applications in real life and appropriate knowledge for pursuit of higher level courses in mathematics or other disciplinary areas.

Curriculum pathways. Any reform measure at college level one must take into account the pathways into and out of mathematics at this stage. The classical pattern goes from precalculus to calculus to advanced calculus. The effect on transitions to other courses such as finite mathematics, statistics, and more general quantitative reasoning courses must be considered. In addition, the reliance on first-year mathematics as a prerequisite for other disciplinary studies will drive the need for change in other course offerings.

Mathematics reform: Current status. Efforts such as the NCTM *Standards* and the calculus reform movement have significantly altered the view of mathematics education at the secondary and postsecondary levels. Moreover, many individual colleges have taken great strides in implementing their own reform efforts. There is not, however, universal consensus that these initiatives are channeling mathematics education in the proper direction. What is more, the vast majority of students have not been taught in a manner consistent with the proposed changes.

Workshop participants expressed concern about the increased use of technology (computers, graphing calculators, etc.) as a tool in the mathematics curriculum. Although they agreed that computational facility should receive less emphasis than in the past, they stressed that teaching/understanding concepts and principles could not be compromised. At present it is unclear whether students who rely on technological tools are properly learning underlying concepts. Graphing calculators, for instance, can support the development of deep misconceptions about graphs and their translations. Moreover, access to technology is in danger of becoming a social class issue. Individuals who, for economic or other reasons, are unable to access technological tools, will find their ability to pursue mathematics impaired.

The group's overall recommendations were straightforward. Without question, the NISE should build on prior reform efforts and not reinvent the wheel. Furthermore, close ties should be built with the Mathematical Association of America and its reform initiatives. Specifically, the NISE should assess the spread and impact of calculus reform. An important measure of success will be students' ability to apply calculus concepts in subsequent courses, e.g., economics, engineering, physical chemistry. In addition, the Institute needs to examine factors that promote change at the departmental and college levels identifying institutional characteristics as well as faculty beliefs and behaviors that stimulate or impede mathematics reform.

Physics, Engineering, and Technology

Participants: Wilmer Anderson, Søren Bisgaard, Lia Brillhart, Carole Goodson, Peter Hewson, Wilfred Kenney, Jose Mestre, Michael Neuschatz

The discussion centered on issues related to introductory courses in physics, engineering, and technology. Discussion was organized according to discipline and focused specifically on how to improve curriculum. A number of relevant programs and resource materials were identified and are noted below.

Physics. At least three levels of introductory physics courses, differentiated by the degree of prerequisite mathematics, are offered: calculus-based physics for physics and engineering majors, algebra-based physics for other science majors and students in technical programs, and descriptive (conceptual) physics designed for nontechnical majors. Irrespective of the mathematical framework, there are content areas and learning objectives that should be common to all entry level courses. For example, students should be able to articulate the concepts and principles of physics and to apply the scientific method as a problem-solving procedure.

Some participants advocated a process to identify, review, and evaluate existing materials in physics. Others, however, believed that it was more important to encourage the development of new teaching methods rather than the recycling of traditional approaches, because they did not view specific content as the primary concern. Attention was subsequently directed to course construction and design considerations, resulting in the following suggestions.

1. The process of scientific discovery should be addressed, keeping in mind that principles obvious to scientists are not necessarily obvious to college level one students.
2. Students' interest and imagination should be captured through the use of innovative teaching technology, including multimedia, computer software, cooperative learning, real world applications, and demonstrations.
3. Bridges must be built between understanding that results from physical observation and the mathematical principles that are used to represent this understanding.
4. Laboratory experiences are essential.
5. Writing assignments should be an integral part of the curriculum so that students learn to communicate their understanding of concepts and of the problem-solving process.

The group emphasized that, although introductory courses should reflect the need to train career physicists, the primary "consumers" of these courses are not physics or engineering majors, and curricula must be developed to address the needs of nonphysics majors. Such efforts may actually draw more students to scientific disciplines. Continued attention should be given to attracting more women and minorities. Furthermore, the needs of preservice teachers must be given special and separate consideration. (The group noted that a change in the valuation and rewards for teaching vs. research by major funding agencies such as NSF would help to drive corresponding changes in institutional priorities.)

Engineering. Limited time was available for the engineering and technology discussions. However, many of the physics themes were reiterated, e.g., the need to emphasize problem solving and to show relevance to real world issues. An example of programming that creatively relates engineering/technology to humankind's development is the radio program "Engines of Our Ingenuity," developed by John Linehart, University of Houston.

Technology. Technology-oriented programs continue to emerge and to attract growing numbers of students, in part because of Tech Prep initiatives nationwide. (*The Neglected Majority* by Dale Parnell, which served as an impetus for this movement, was recommended as a reference.) These programs should be investigated for content and long-term impact. In addition, the National Science Foundation's Advanced Technology Education program includes applied technology projects for development of curriculum and learning delivery systems that will impact students in introductory college courses.

In addition to the points listed above, participants identified as priorities the need to determine what makes good programs portable so that they can be disseminated and the need to determine criteria for proper evaluation of goal attainment.

Additional Resources, Physics

* American Association of Physics Teachers (workshops and programs held at annual meeting)
* American Institute of Physics
    Introductory University Physics Project (course models that differ from classical courses)
    Michael Neuschatz (statistics on women, minorities in physics)
* Berkeley Physics Course series
* Mestre, Jose (references on problem-solving in physics)
* Physics Academic Software (North Carolina)
* Workshop Physics (Priscilla Laws, Dickinson College, Pennsylvania)

Additional Resources, General SMET

* "High School and Beyond" studies (statistical data)
* Seymour, Elaine (references on college students switching into or out of science majors)

Chemistry and Biology

Participants: Ann Burgess, Arthur Ellis, Don Emmeluth, Jo Handelsman, Jann Joseph, Eileen Lob Lewis, Michael Patrick, Senta Raizen, Hal Richtol, Ray Turner

The chemistry/biology disciplinary group discussion focused on (1) the knowledge and skills that should be acquired in first-year college level biology and chemistry courses and (2) appropriate ways to assess mastery of these goals. Although there is a body of background work on some aspects of these topics, participants also noted the absence of appropriate information in other areas and highlighted those for the group's consideration as noted below. With regard to the biological sciences, several initiatives and coalitions (e.g., Biological Sciences Curriculum Study, Science as a Way of Knowing, Coalition of Education in the Life Sciences) have already invested considerable effort in identifying content areas, ways of thinking, and goals for biology education. In contrast, the same level of analysis has not been done, to the group's knowledge, for first-year college chemistry courses. Exceptions are the American Chemical Society's Task Force on the General Chemistry Curriculum and the Society's project to define educational guidelines for students preparing to become chemical technicians (Foundations for Excellence in the Chemical Process Industries).

In identifying learning objectives for first-year college biology and chemistry courses, national standards for precollege science courses being developed through Project 2061 (American Association for the Advancement of Science) and through the *National Science Education Standards* (National Research Council), as well as existing frameworks at the state level, must be taken into account and should be treated as a foundation on which college courses should build. However, these standards provide a only a frame of reference, and the group noted that they are an ideal that is seldom reached even at the first-year college level at the present time. Important objectives for these courses include relating subject matter to "real world" problems or situations, motivating students to develop a lifelong interest in science, and enabling students to understand the scientific method, viz., the ability to pose questions, design experiments, assess data, and draw conclusions.

In defining content/outcomes for college level one courses, considerations of the student audience and the teaching format should be addressed. Key audience-related questions include: Should majors and nonmajors take the same courses? How are teachers best trained? What differences are required in the science training of primary and secondary teachers? Each of these student audiences will apply the knowledge gained from their biology and chemistry courses in different ways. Pedagogical style is an important factor in achieving successful outcomes. Alternatives to the traditional, exclusively lecture-based format may be more effective. In addition, topic-oriented approaches that introduce concepts and facts on a need-to-know basis are currently being implemented and should be examined. These strategies could potentially make courses more stimulating and engaging for a wider spectrum of students.

Workshop participants agreed that the issue of assessment is extremely important and complex and will require careful attention. Testing of general concepts, albeit important, is difficult. Furthermore, appropriate measures of acquired knowledge and skills will vary depending on the content of these courses.

Alternative/Integrated SMET Courses

Participants: Richard Brualdi, Denice Denton, Michael Finn, Eli Fromm, Dave Jenness, Gretchen Kalonji, Holly Walter Kerby, Susan Millar, Terry Russell, Norm Webb

This group discussed a wide variety of models and implementation schemes for alternative SMET education (e.g., knowledge, skills assessment, relevant literature and statistics innovation, clientele, collection of information). The group acknowledged the major differences in constraints associated with community colleges, vocational technical schools, liberal arts institutions, and research universities. However, it identified a number of innovative pedagogical approaches that can be implemented in all these arenas.

The group's findings are summarized in two categories: "models for integration" and "research questions." The research questions will help guide the planning for the College Level One Team.

Models for Integration

1. Faculty and curriculum are fully integrated: Focus is professional and career interest area (e.g., Drexel's E4)
2. Integration around a single course
   A. "Big Idea" integration
   B. Interdisciplinary subject
3. Topic-oriented approach
4. Institutional or departmental integration

Research Questions

1. Assessment of student learning in integrated approach vs. traditional. Which approach is more successful?
2. Skills/knowledge. What is the appropriate mix?
3. Identify successful models–define success. What defines best practice in the different arenas?
4. Longitudinal issues: retention, demographics, employer satisfaction
5. What is the most feasible and economical way to implement longitudinal studies?

Cross-Disciplinary Group Discussions

SMET: Literacy and Careers

Participants: Wilmer Anderson, Steve Bauman, Søren Bisgaard, Ann Burgess, Peter Hewson, David Jenness, Eileen Lob Lewis, Susan Millar, Terry Millar, Michael Neuschatz, Senta Raizen, Terry Russell, Sheila Tobias, Alan Tucker, Paul Williams

College level one SMET courses often determine a student's future career path and life-long attitude toward science. How can we create scientifically literate citizens, realizing that many students will not take additional science courses after their first year in college, and at the same time meet the needs of SMET preprofessionals? It is vital to keep all types of students engaged with science at this

level, because many have not yet decided on their future careers. The SMET Literacy-Careers group identified four key points:

College level one SMET courses reach a complex audience. The needs of at least four different groups of students must be met by entry level science and math courses: (1) science majors who plan to become science professionals (including future secondary school science teachers, who may eventually be teaching multiple disciplines); (2) science majors or nonmajors who will find science an integral component but not the major focus of their careers (e.g., policymakers, journalists, business people); (3) future elementary school teachers; and (4) all others, who will require an understanding of science to make informed decisions in their daily lives. Thus, course content and design must serve a number of different functions. For example, skills required for career success may be different from information taught as part of specific major. Employers may be more concerned with a person's ability to think quantitatively than whether she/he majored in math, physics, or engineering. Workshop participants particularly noted the need for educating people to be effective communicators about science. They also stressed the importance of developing an understanding and enthusiasm for science among future leaders and policymakers. In thinking about science literacy, relevant issues are the level (e.g., "high level" for leadership positions and "low level" for citizenship); and how much exposure is optimum.

Although most science courses are restricted to a specific audience, there are notable exceptions that are more flexible in design and appeal. An introductory chemistry course for nonscience majors at the University of California-San Diego offers special sections with increased emphasis on chemistry, followed by a "bridge course" to organic chemistry for students who decide to pursue a more rigorous chemistry curriculum. Tufts offers an engineering design course in which beginning engineering students and elementary education students collaborate. NISE should identify additional examples of these types of programs.

In-depth experience with the process of science is more important than broad but superficial knowledge. Workshop participants concluded that acquiring science literacy revolves around understanding how scientists view the world, how they frame questions, and how they address problems, i.e., "science as a way of knowing." Science literacy is also characterized by attitude: curiosity, enthusiasm, and a willingness to become engaged with science. The group felt that these characteristics were best developed through process-oriented immersion in science and that all students should have direct experience with scientific experimentation. Individuals should learn by addressing problems and determining what they must learn in order to solve them. These experiences will teach students to identify and use resources, think critically, and evaluate information, providing them not only with a knowledge of the scientific reasoning process but also with skills for life-long learning. This training is particularly critical for preservice teachers, because the factual content of what they teach will probably change radically over time. The group made the analogy that performing in a Shakespeare play in high school has the potential to keep one attuned to the theater for life. Performing one entire play is more valuable than learning 15 lines from each of 20 different plays.

Workshop members recognized that focusing on in-depth experience fails to provide students with an overall framework for the different science disciplines and an understanding of how paradigms have changed over time. This information is also necessary, but carries a lower priority than the experiential component described above.

"Connections" are essential: Connections between curriculum content and real world applications as well as connections between disciplines. Most science and math courses are ineffective in relating the science learned in class to real-life applications. In addition, most scientists confine themselves to their own specific field, failing to make connections with other sciences, let alone humanities or social sciences. Even where integrated science curricula have been successfully implemented, sustaining these initiatives has been difficult because of the inertia of the status quo and the discipline-oriented training that the teachers themselves have had. Several ideas for integrated curricula were promoted. Some group members felt that mathematics could serve as the "glue" to hold many disciplines together. Others suggested focusing on the relationship between science and world issues to stimulate student interest. NISE should review examples of successful integrated courses and determine what themes are important in initiating and sustaining them.

Mechanisms for promoting change must be identified. Although it is important to identify successful innovative programs in two- and four-year colleges, the NISE should also find "levers" for implementing change. The group discussed a number of entities that have the potential to promote reform: accrediting and licensing boards (such as those for nursing, medical technology, and the broad range of other professions), national disciplinary coalitions (e.g., the NSF engineering coalition), professional societies (the American Chemical Society has developed *Chemistry in Context*; the American Statistical Association has played a major role in the way statistics is taught), federal agencies, etc. Publishing houses are an important link in the dissemination process, and the impact of new textbooks in promoting reform should be examined. Additional contacts and avenues for implementation should be developed and promoted.

Equity: Access, Retention, Diversity, and Remediation
Participants: Cliff Adelman, Denice Denton, Janice Downer, Don Emmeluth, Michael Finn, Jo Handelsman, Wilfred Kenney, Jose Mestre, Hal Richtol, Larry Suter, Ray Turner

The role of the NISE, in the context of equity, is to address issues of access, retention, diversity, and remediation as they relate to college level one SMET courses. The field of interest includes two-year technical and community colleges, four-year liberal arts institutions, and four-year institutions with professional degree programs. Group members turned their attention to retention of students already in the SMET pipeline rather than to recruitment. Ways to measure the retention rates of women and students of color in these programs should be identified and mechanisms to enhance success developed. Recruitment of preservice teachers into SMET pipeline courses is a related matter and has been targeted as a high priority for the National Science Foundation.

A variety of supportive measures were discussed as being important for the retention of potentially at-risk students:

Skills assessment/remediation. Workshop participants recommended that the NISE research the fundamental question of whether a relationship exists between academic readiness at the beginning of college level one and successful completion of a degree. Discussion also focused on appropriate corrective measures when precollege training is inadequate. Many students, particularly those representing minority groups, are unprepared for entry-level SMET courses. The key to successful remediation practices will be, first, to use assessment techniques that *accurately* determine incoming students' math/science knowledge and skills, then to deal effectively with academic deficiencies. The

group specifically identified computer literacy as requiring attention, because lack of skill in this area leads to significant feelings of frustration, isolation, and failure. Collaboration between two- and four-year institutions was suggested as a potential avenue for addressing remediation needs. Community colleges may be more successful at remediating students and preparing them for the four-year college. Under such an arrangement, ease of credit transfer was cited as a critical factor.

Formal/informal support structures. All students require some kind of support structure for success. Recent studies (see, in particular, Elaine Seymour and Nancy Hewitt's report "Talking about Leaving: Factors Contributing to High Attrition Rates among Science, Mathematics & Engineering Undergraduate Majors") have concluded that the main difference between students who complete SMET majors and those who leave is not the difficulties that they encounter but rather the existence of mechanisms that enable them to surmount these challenges. Various types of support can be effective and their relative importance differs, depending on personal and institutional circumstances.

Formal advising and personal interactions with faculty/staff can be crucial, particularly in large institutions or those with large commuting student populations, where students may not have the opportunity to interact with their peers. Ideally, individuals who assume advisory duties should be properly trained, have the support of their institution, and view their role as an important mission. Effective institutional support is also dependent on student perception of attitudes. If faculty/staff demonstrate hostility, indifference, or reduced expectations toward women or students of color, feelings of isolation or failure are reinforced, increasing the probability of attrition. Academic practices need to be reviewed to eliminate these types of behaviors, which are often subtle and unintentional.

Minorities and women students must have access to experiences, both in the classroom and outside, that enable them to gain ownership of their studies, to link with other students, and to see relevance of academic content to their lives. Working as part of a research group, for example, helps students make connections and feel that they are contributing members of a team. Formation of peer support systems that allow good information exchange and academic support can often take the place of a strong institutional advisory system. (An example of successful peer support is the Treisman model initially used with African American students in calculus at Berkeley.)

Support systems may need to extend beyond academics. In certain cases, socioeconomic concerns are the major reason for students leaving SMET programs. Although the education community can not solve these problems directly, ways of integrating academics with social support systems should be actively sought. For example, programs have been adopted that provide child care coupons to students. Offering lectures at more convenient times, providing videotapes for review, and implementing experimental/alternative classrooms are all potential mechanisms for alleviating socioeconomic stress factors.

Workshop participants emphasized the need to support students who make a conscious effort to succeed in SMET disciplines. Existing databases that include high school and college transcript information should be used to research the factors (academic preparedness, internal motivation, external support, mentoring, advising, etc.) that determine whether students pursue or abandon programs. Quantitative, statistical studies should be supplemented by descriptive analyses designed to reveal more qualitative factors governing student attrition. NISE should also scrutinize the approximately 20 percent

of successful students to identify the practices that distinguish programs that succeed from those that do not.

Articulation: Transfer of Knowledge and Credits

Participants: Lia Brillhart, Sharon Derry, Art Ellis, Carole Goodson, Holly Walter Kerby, Robert Lopez, Norm Webb

Three major topics were discussed as part of this workshop session: articulation of SMET courses between institutions, articulation between SMET-related departments within an institution, and articulation with teacher education departments. *Articulation* was broadly defined to include courses, the scope of their content, and the pedagogical strategies.

Discussion regarding arrangements between institutions was subdivided according to type of school. Articulation between high schools and colleges, usually community colleges, has been mandated by Tech Prep initiatives in high schools. This format is currently being extended by the development of 2+2+2 programs (two years in high school followed by two years at a community college and then by two years at a four-year institution). Implementation of this type of plan varies considerably from state to state.

Articulation between colleges, either two- or four-year institutions, was the major topic of discussion. Theoretically, a student who starts at one institution and transfers during the first two years without a change in major should be able to complete a baccalaureate degree in a total of four years. This four-year completion time is, however, an ideal, since many college students who change neither institution nor major require more than four years to graduate. Although many states already have articulation agreements, they are highly variable with respect to detail. Some are limited to public institutions; others are for all community colleges, colleges, and universities. Some states operate on a course-by-course basis, while others include programmatic issues to determine transferability. Most transfer students remain within their state. However, for those who choose to move elsewhere, the absence of any type of interstate agreements, except in rare instances between individual institutions, causes major difficulties.

Workshop participants identified a number of emerging issues that will affect articulation. Radical changes in curricular content and style as a result of current education reform efforts will cause major difficulties in transcript evaluation. The rapid evolution of program content in science and technology programs presents a continual challenge, particularly for part-time students who may begin under one set of program guidelines and later find that requirements and/or courses have changed. Transfer standards should be flexible and based on the criterion of actual student preparedness for a particular course or program, rather than simple topical relationship with previous classwork. Because almost one-quarter of all community college students who complete over 12 credit hours do transfer, these issues affect a large number of students. Also to be determined is whether those students transfer into SMET programs or pursue SMET-based careers.

Transfer of credits within an institution also raises challenges for students. Individuals who shift into math or science from another discipline often find that entry level SMET courses for nonmajors are not accepted as part of the major, resulting in loss of course credit and/or time. New initiatives to attract

nontraditional students into education majors are encountering problems with prerequisites for the education curriculum. Some schools require that students complete a major prior to admission to a college of education, while others integrate education courses during the first two years. Successful transfer between programs is dependent on adequate knowledge of program requirements.

Several specific recommendations were made for further study and for alleviation of current problems. Group members placed strong emphasis on the need for information gathering and dissemination. A comprehensive database of current articulation practices nationwide–to include community college systems, and vocational and technical schools–should be established. The favored mechanism for such a resource is an electronic bulletin board on the Internet or World Wide Web. The information would be invaluable not only to individuals researching articulation issues but to students, for personal program planning and college selection, and to SMET educators, for facilitating exchange of ideas about "best practices" and innovative curricula around the country. The group also recommended the preparation of a set of case studies, or "pathways," that highlight examples of successful transfer students. These histories would serve as a model for other students to follow and for institutions in developing policy.

Closing Discussion

The closing discussion dealt primarily with how innovative, effective college level one SMET programs develop and are disseminated and evaluated. A traditional role for the National Science Foundation has been to provide seed funding for new initiatives in SMET education. Mechanisms for nurturing the growth of reform programs will need to be identified and developed. As a partner of the NSF, the NISE is in a position to help evaluate the impact and growth of programs funded by the Foundation. In some cases this evaluation will involve working with groups that have already begun evaluations of existing programs, such as those supported by the Foundation's Division of Undergraduate Education (DUE).

A key contribution of the NISE to college SMET courses might be to develop working definitions of programs that are successful with respect to both general SMET literacy and preparation for SMET-related careers. A number of measures of success were discussed, including the number of institutions that adopt a program; long-term effects on student careers, attitudes, and critical thinking skills; and employer satisfaction with student performance.

Learning why students enter and leave SMET courses is a critical element in understanding why programs are and are not successful and underscores the importance of articulation and equity issues. Analysis should allow for identification of both practices in SMET education that have a differential impact on women and individuals of color and pathways through SMET courses that have proven effective in training key groups such as future teachers, social and business leaders, and individuals who pursue careers in SMET-related fields.

Identification of so-called best practices will require assessing the impact of programs and the departmental and institutional factors that help or hinder transportability. Studies of failed innovations may prove useful, too. Examples of factors that can affect development and use of new instructional materials and approaches are class size and resources. The outstanding success of small liberal arts

colleges in training scientists was given as an example of an outcome that may have been facilitated by small class size.

A concern was raised that many institutions lack resources to implement innovative practices. Some institutions lack computers and the capability for communication via electronic mail, for example. Opportunities for obtaining release time to further professional development need to be made available. The NSF programs that have provided research experiences for teachers at eligible postsecondary institutions were cited as having broadened the perspectives of many SMET faculty members. The NISE may be able to assist with identifying mechanisms for encouraging sustained professional development.

The session concluded with a discussion of the name Grade 13 Reform Group. There was sentiment that "grade 13" had a pejorative connotation, being viewed as an extension of K-12 rather than as an important transition year in a student's life. College Level One (CL-1) was felt by most workshop participants to be a better label for the group's focus, while continuing to embrace the full spectrum of institutions that are to be studied. Henceforth, we will use this designation.

References

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

Parnell, D. (1985). *The neglected majority*. Washington, DC: Community College Press.

Seymour, E., & Hewitt, N. M. (1994). *Talking about leaving: Factors contributing to high attrition rates among science, mathematics and engineering undergraduate majors* (Final report to the Alfred P. Sloan Foundation on an ethnographic inquiry at seven institutions). Boulder: University of Colorado.

Appendix A
Agenda
Grade 13: Articulation, Equity, and Literacy Issues

All meeting sessions will be held on the 13th floor, Educational Sciences Bldg.

Friday, June 23

8:00-8:30	Continental breakfast
8:30-9:00	Introductions Charles Read, Dean Designate of the School of Education, UW-Madison Denice Denton and Andrew Porter, Co-Directors of the National Institute for Science Education (NISE) Larry Suter, NSF, EHR Directorate, Division of Research, Evaluation and Dissemination Hal Richtol, NSF, EHR Directorate, Division of Undergraduate Education Art Ellis, NISE Grade 13 Reform project
9:00-10:00	Five-minute presentations by participants

Please tell the group in five minutes about the grade 13 activities in which you have been involved or have a specific interest and mention any ideas you would like to share with us as we begin the workshop.

10:15-10:30	Break
10:30-12:00	Five-minute presentations continued
12:00-1:30	Discussion continues over lunch
1:30-3:00	Disciplinary breakout groups

Participants will be organized into discipline-based working groups to discuss what skills and knowledge students should possess at the end of grade 13 courses in these areas; and how to assess whether the skills and knowledge have been obtained.

Group A. Mathematics
Group B. Physics/Engineering/Technology
Group C. Chemistry/Biology
Group D. Alternative/Integrated Grade 13 SMET courses

3:00-3:15	Break
3:15-3:30	Group reports written
3:30-4:30	Group reports presented and discussed
4:30-5:00	Wrap-up
6:00-7:00	Reception (cash bar), Madison Civic Center, Spotlight Room
7:00	Dinner at the Madison Civic Center
8:00	Banquet speech, Denice Denton, UW-Madison

Saturday, June 24

8:00-8:30	Continental breakfast
8:30-10:30	Cross-disciplinary breakout groups A. SMET: literacy vs. careers B. Equity: access, retention, diversity, remediation C. Articulation: transfer of knowledge and credits
10:30-10:45	Break
10:45-11:00	Group reports written
11:00-12:00	Group reports presented and discussed
12:00-1:30	Discussion continues over lunch
1:30-3:00	Defining the Priorities for the Grade 13 SMET Research Agenda What are the most strategically valuable research questions to ask? What mix of research methodologies would best help us move this agenda forward? What mix of participants would be optimal? What other considerations might there be?
3:00-3:15	Break
3:15-5:00	Continued discussion, report writing, and wrap-up

Appendix B

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