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We present our studies of the transitions of Iowa science students from high school to post-secondary colleges. Our report summarizes information and impressions from dealing with thousands of new students arriving at our six colleges, along with meetings and discussions with high school science teachers to add their viewpoints into our considerations. Feedback from community college, four year college, and high school science teachers highlighted the following five study issues and needs for improving student transitions from high school to college science: 1) Better math preparation is needed; 2) More work with inquiry-based learning rather than with facts and memorization is needed in both secondary and post-secondary courses; 3) Students must become aware of career choices earlier; 4) Misconceptions by teachers at both levels must be minimized; and 5) High school and college science educators must improve intercommunication. To address these issues differently, our team invited Nobel Laureate Leon Lederman to be keynote speaker at the Iowa Science Teachers Fall Conference in October 2004. Dr. Lederman has campaigned for revamping the high school curriculum to have mathematics and the sciences integrated into a coherent, logical, interconnected whole, with conceptual physics first, to enable students to learn with a minimum of memorization. Feedback from high school science teachers has been very positive. Several Iowa high schools expressed interest in adopting this approach, and one Iowa high school has incorporated, at submission time, this innovation into their high school curriculum.

INDEX DESCRIPTORS: science education, success in college, high school curriculum.

Learning how high school graduates make the transition to college is an important contribution towards solving our national education dilemma. Educators at all levels have struggled with this dilemma as they address recent reports on the dire science literacy situation in our country and in our state. We first review several of the relevant reports, keeping our view on Iowa. Strong impetus for serious study of Iowa science education is given in national newspapers, e.g., the *New York Times* (2005a, 2005b) and *USA Today* (2006) which report that the U.S. education system is not producing enough scientists to satisfy our economic needs for the near future. Broder (2005) of the *Washington Post* summarized this situation, suggesting that enhancing science literacy would be a very positive and beneficial strategy for President Bush to declare (as he did) in his State of the Union address in January, 2006. The need to fix our educational system is now economically especially urgent as the U.S. world leadership in manufacture and sales of electronics and microelectronics was eclipsed in 2005 by China (CBS Evening News, December 16, 2005).

Worldwide, all countries whose education processes we know, as well as all states in the United States, have standards and/or graduation requirements (*Des Moines Register* 2004a, abbreviated as DMR 2004a). In contrast, Iowa law allows local school districts more freedom than any other state in determining what students need to know in order to graduate and the power to implement school changes is in the hands of each local school board. This situation resulted in the F grade given by *Education Week* to Iowa, in Standards & Accountability (DMR 2005a) and the C in Efforts to Improve Teacher Quality. Judy Jeffrey, the state Department of Education Director, is quoted as saying, "There aren't really any surprises for us. In a couple of the measures, we simply will not get a higher grade because the state policy is different from other states." (DMR 2005a).

Critical observations from outside of educational governance include a report from the Manhattan Institute, (DMR 2004b) which says Iowa's education system is in need of drastic reform. Report coauthor Jay Greene notes "Iowa schools don't do well considering they're already starting with some very exceptional students." Additionally, the conclusion of a report to the Legislature's House Education Committee by Richard Ferguson, the chief executive of the American College Testing (ACT) Service, is summarized by the *Des Moines Register* header: **Schools in crisis, ACT chief cautions** (DMR 2005b). Ferguson reported that only 29% of Iowa students taking the ACT passed all three college readiness benchmarks in science, math, and English. Further, only 35% of the students had sufficient command of their high school core courses to handle the biology portion of the exam and thus would be reasonably able to make the transition from high school to college biosciences (WOI 2005).

{As an update, we remark that essentially nothing said above has changed between submission and publication dates of this paper. Successive *Education Week* report cards for Iowa are essentially unchanged. Iowa is given a C grade on its 2008 report card and is in the same average group of states as Louisiana and Kentucky. In producing this grade, they were aware of our state's plans for a state-wide model core curriculum plan (CCP) for all high schools, which was put together after the Department of Education visited each high school. Senate file 245, discussed below, was to become state law in the near future when the lawmakers in Des Moines set an 80% high school compliance requirement with CCP. But, this was removed from state law last year. It now (January, 2008) appears certain that all present students in high school will graduate before the CCP requirements will be imposed on any student's program.}

Much more information on the ACT tests and results can be found on the ACT web page (http://www.ACT.org), including a discussion of the work of the Education Trust. The Director of the Education Trust, Kati Haycock, addressed the question of statewide education requirements at a meeting in Des Moines (DMR 2004a). She said some states, e.g., Texas, have successfully adopted a standard, statewide curriculum that is rigorous and designed to prepare all high school students for college. She said students who take a challenging curriculum "learn more, fail less, and will be more prepared in college and the workplace." Although test scores in Iowa and nationally show students are entering high school better prepared than were students 20 years ago, they are leaving high school less ready for college and the work force.

In Iowa, former Governor Vilsack expressed concern about the downturn in Iowa education and concluded that the high schools need to become more rigorous (DMR 2005c). The state education officials emphasize that school administrators need to create high schools that are more individualized, relevant and rigorous (DMR 2004a, DMR 2005d). To move forward on this issue the Iowa Legislature passed Senate File 245, Iowa Law section 256.7, subsection 26 in June, 2005, which directs schools to develop a high school core curriculum plan for eighth grade students and to report student core curriculum progress annually (State of Iowa Code 2005).

Low teacher pay contributes to deteriorating secondary education. The average Iowa teacher salary, relative to other states, ranked 41st in the U.S. in 2005. Soon after, the 2006 legislature approved a raise of about $1000 per year to bring Iowa's ranking up to 40th. (A legislator is quoted as saying they treated Iowa teachers well.) Consequently, other states have successfully recruited Iowa's graduating teachers, e.g., with initial salaries typically $15,000 (including a signing bonus) above Iowa's beginning salary was $25,000, slightly above the poverty line of $21,400. Fortunately, the 2007 legislature approved a pay increase bringing teacher salaries up to 25th for next year.

The next section discusses the Transitions Team objectives and findings in some detail. One of our main conclusions is that a mechanism must be introduced to convince a high school student to learn and understand concepts thoroughly so as not to rely on memorization. Section 3 discusses the Transitions Team's work with an alternative approach in high school science education that will emphasize and enforce learning for understanding. This involves a curriculum change that places conceptual physics as the first high school science course. The last part of Section 3 emphasizes the positive results following from such an adaptation, a main point being that the transition to college will be easier. The final section states our conclusions on making high school science courses more rigorous and smoothing the transition from high school to post-secondary education.

TRANSITIONING FROM SECONDARY TO POST SECONDARY EDUCATION

Nearly a year before concerns discussed above made headlines, the authors, committed educators who teach Iowa high school graduates at the next level in science, were studying high school students' transitions to post-secondary education. We first explored our different experiences with new students at our six different colleges by cataloging common problems high school graduates have in making the transition from high school to college.

The Transitions Team gathered data by first examining characteristics of freshmen college students in our respective science courses. We recorded a large number of specific and sometimes interrelated non-science issues that commonly clouded the approach of our students to learning new material. For discussion and exploration purposes, we divided these into three groupings or sets. The Team identified the first set of problems as arising from: (1) indiscriminant computer, or electronic gadget, and TV usage, (2) mistaking memorization for true learning and understanding, (3) attitude and motivational problems, and (4) a lower literacy level honed by these issues. The second grouping included difficulties related to students' preparedness often arising because a student (1) might not have grasped concepts but seems to have gained content by rote applications, (2) might not have any depth of knowledge even though s/he exhibits considerable, but superficial, breadth, or (3) might not be able to make progress because of lack of math or computer skills. Finally, other contributing factors to a difficult transition could be (1) student expectations, (2) the influence of high school teachers, and (3) parental pressure. Much of the students' high school experience tends to make their approach to learning very content-, vocabulary-, and fact- oriented, which has them leaning heavily on memorization. We feel this isolates the major contributions explaining the ACT attrition rate (DMR 2004c): one out of every four college students do not return for their second year. One might expect a large attrition rate since the ACT test results (DMR 2005b) show that only 29% of the students passed college readiness benchmarks.

The Team discussed how we could improve the situation and why this transition was so difficult for so many new students. It appeared very likely that the brunt of these negative influences could be countered with more concept- based high school work, emphasizing inquiry and exploratory approaches and processes in class.

We concluded that the main objective of our Team was to examine ways to strengthen and sustain student success in science. We needed to further explore characteristics of students leading to success in science in post-secondary education, and to determine problems in transitioning from high school to community college or university courses in math and science. To do this we needed to enlist the assistance of high school science teachers. All of us had contact with high school teachers in his/her area of teaching or research and invited teachers to one of our Transitions Team conversations. In addition, two concurrent sessions were scheduled at the Iowa Science Teachers Fall 2004 conference to gather ideas from secondary science teachers on these same objectives.

High school teachers came up with many factors regarding the students' lack of interest in planning for science, technology, engineering, and mathematics study. In the area of careers, there is a perception of high paying jobs; however, coupling good pay without too much effort is often most important to individual student choices. Attitude toward science is important.

A broader category of issues relates to the revision of high school, community college, and university math and science curricula. High school teachers saw a need for better preparation in mathematics and in study skills. They considered the idea of rearranging the order of basic science courses and what advanced course should be offered. They cited a need to examine national science standards for process-based curricula, and to consider what precedent there is for changing our curricula. Many teachers said it was better for students to understand the process of science, not just facts, and to be able to reason. This could be carried out by more work on conceptual understanding via inquiry and exploration rather than didactic content and vocabulary. Teachers questioned what courses were available for high school students who have already had college level science in high school, then voiced the alternative view that not enough basics were taught in high school.

It seemed that the bottom line was that both high school and college teachers held misconceptions about what the other was doing. Some wondered if high school teachers believed college teachers want more content at the high school level, when in fact college instructors want more processing ability and less content. This points to a huge lack of communication between high school, community college, and university science instructors.

Our Team turned to what could be done in high school to dramatically improve the students' chances of success in college science courses. It appears that only a very small fraction of students have made the necessary mindset and scholarship adjustments during high school so as to not suffer "cultural" shock in college. By this we mean that their high school courses did not sufficiently emphasize developing reasoning skills. This is reflected in a typical new college student comment, such as "I know this topic; give me the formula and I can use my calculator to get the answer."

Quite possibly, the typical high school curriculum, if modified, would better prepare students for education beyond high school. One way to influence the views of science teachers in the state was to expose them to an alternative view of teaching high school science. Thus, we invited Nobel Laureate Leon Lederman to speak at the Iowa Science Teachers Fall Conference, October 2004.

A DIFFERENT VIEW OF SCIENCE EDUCATION

Dr. Leon Lederman, 1988 Nobel laureate in physics and internationally renowned high energy physicist, gave two lectures on science education on October 21, 2004, and held small discussion group meetings with members of our Transitions Team and interested high school teachers. The lectures and small group sessions were of special significance because Lederman (1999) advocates an approach to teaching secondary science that promotes very effective student transition from high school to college in the science areas. His first presentation was "Project ARISE: A New Way to Approach Science Sequencing". He elaborated further on science education in an afternoon question and answer session with high school science teachers. Finally, he presented a colloquium at Iowa State University in Ames, on "A Radical View of 21st Century Science Education." The response to each session was enthusiastically positive and useful in touching on some new dimensions that add clarity to the transitions problem as it affects Iowa.

The tradition of teaching biology before chemistry and physics in Iowa is quite likely over 80 years old, dating to the era of progressive education and the advent of a general science course by the 1920s. General science was followed by biology, with those going on to college pursuing chemistry and physics (DeBoer 1991). This order of science courses has resulted in discrete content courses, more related to differentiating college-bound from non college-bound students and those with higher-level math skills from those with lower skill levels. Additionally, this traditional science curriculum and pedagogy continues to be based more on memorization than conceptual understanding.

Dr. Lederman (1999) pointed out that our knowledge is growing very rapidly: The world's knowledge base now doubles every eight years. Because of such rapid growth, a high school education based on memorization is not serving our youth very well; true learning to encourage mental processing ability is essential. The student will then develop the flexibility to understand how sciences are expanding as old distinctions between areas disappear and interdisciplinary knowledge grows. The economic and societal consequences of such growth and expansion of knowledge are hard to predict, but it seems likely that biotechnology may exceed the impact of microelectronics as an engine of change. Students in high school courses emphasizing memorization will fall farther and farther behind in their ability to stay close to scientific literacy in a period of rapid knowledge expansion. Such students will not be able to contribute to the economic wave developing from new science and technology growth. The status quo educational situation will cause the exodus of brainpower and creativity to become more pronounced and will continue to erode the huge yearly economic impact of $3.6 billion that our colleges and universities have on our state (Doak 2005).

The above dilemma is addressed in a quote from Lederman (1999): "A 21st-century person must be armed with a science overview to be able to adapt to these extraordinary events, to be employed by or otherwise profit from the new industries that will emerge, and to participate in the decisions that society must make as to the pace and direction of this revolution." There are always problems when new technology develops, but equal access to knowledge, which our schools must give to all students, would seem to be essential to address these. Accordingly, Lederman advocates that **all** students be required to take a conceptual physics course first, as freshman, which would emphasize general principles true of all everyday phenomena and equally true for molecular behavior in life processes. Such a course would be followed in the next year by chemistry when the student has knowledge of basic charge interactions and memorization requirements in chemistry would be replaced by understanding. Only then is the student ready to take biology, taught as a logical body of knowledge incorporating the principles of physical science.

The first physics course would be taught quite differently than past physics courses. It would emphasize familiar phenomena apparent in all our everyday lives, building from principles that are logical and do not need to be memorized. These include conservation of energy, conservation of momentum, conservation of angular momentum, gravity with its effects in planetary and spacecraft motion, charge interactions, etc., and these principles will be emphasized concurrently in a lab. The freshman mathematics course, taken simultaneously, will be kept meaningful by correlating it with the physics lab and homework. The aim is to produce a coherent, meaningful introductory picture of science and math as a whole. The teachers must necessarily talk in detail with one another to correlate math with the science sequence, a requirement that will immensely benefit students. The correlation of mathematics with the three year science sequence will make mathematics courses explicitly relevant (ASCD 2004). And, more importantly, it will give all students the opportunity to develop thinking and reasoning skills, as the approach is designed to minimize the necessity to memorize terminology.

Compelling arguments for instituting the above math-science sequence correlation in high school are obtained from pre-entrance questionnaires for thousands of high school graduates entering the algebra course at the Des Moines Area Community Colleges (Trumpy 2006). Among the misconceptions found: about three of every four students did not understand the relationship of the minus sign in the algebraic expression $(a-b)^2$ to the similar expression with a "+" sign $(a+b)^2$. This, and several other understanding problems, could be made clear in conceptual physics when distances (e.g., in driving), negative velocities, and negative acceleration (deceleration) are discussed in terms of automobile motion. Additionally, a random sampling of 118 new students enrolled in first year non-calculus physics at Iowa State University found that about 20% said their high school physics course was of no use in preparing them for college physics (Lassila 2005).

After the freshman through junior physics, chemistry and biology sequence, various electives, including earth science, AP physics, etc., may be taken in the senior year, or earlier. This enhanced curriculum will maximize each student's opportunity to understand the new developments in molecular biology and biotechnology and all will have been given the possibility of contributing to the discipline that appears very likely to dominate our country's future economy.

As Director of the Fermi National Accelerator Laboratory (Fermilab) near Chicago, Dr. Lederman initiated enhanced science courses at Fermilab for gifted students from suburban high schools. He also did considerable science work with the Chicago inner city schools. As Emeritus Director, he has strongly supported restructuring of the high school science curriculum (Lederman 2004a). The high school founded by Dr. Lederman, the Illinois Mathematics and Science Academy in Aurora, had the highest average ACT exam score in 2004 in the US.

This new science sequence in high school has produced a number of success stories. About 700 out of roughly 24,000 US high schools and some countries (e.g., Finland, decades ago) have made this change and report success with this new course sequence. Thus, it is not surprising that the present-day cell phone technology originated with the Nokia phone invented by two Helsinki University of Technology students soon after graduation. Of special interest is the result reported by a New Jersey high school (Palma 2000) that has used the Physics First sequence for over 15 years. Since all high school freshmen automatically take physics, the science course phobia of students and the labeling of science as something for nerds, has disappeared. These same students took the SAT physics exam after completing their freshman year conceptual physics course and remarkably received the same average score as graduating seniors in high schools that had the US traditional approach. Other similar schools have reported dramatic increases in female and minority enrollment in advanced science courses and in their pursuit of science, math and technology careers (Lederman 2004b).

Though the Price Laboratory School at the University of Northern Iowa has offered its chemistry course before biology for at least twenty years, to the best of our knowledge, only one high school (Fletcher 2006) in Iowa had completely adopted physics first by 2005–2006. Two schools are discussing how to make this major change in their curriculum. Several schools have adopted an elective conceptual physics course and we know of two other schools that have instituted a required combined physics and chemistry conceptual-survey course for freshmen. The model school for our Transitions Committee work is the Earlham Community High School, which converted their curriculum to have Physics First for all freshmen, beginning with the 2005–2006 academic year with the consent of the superintendent and full support of the School Board. Chemistry, based on physics, is scheduled for the 2006–2007school year and biology, based on physics and chemistry, is set for year 2007–2008. The freshman course uses the text *Conceptual Physics* (Hewitt 2006); this newest edition has concise text and numerous illustrations. Of special interest is the Earlham reorganization of the middle school curriculum to build student foundations for the new science sequence that they will begin in ninth grade. This will give eighth grade a positive purpose and eliminate the goof-off attitude described by the *Des Moines Register* stemming from the perpetuated view in Des Moines that Middle School records do not matter as they will not appear on students' transcripts. (DMR 2005f) As the first example of a coherent, reasoning science sequence, Earlham will be in the limelight and should serve as a good model for other schools to follow.

SUMMARY AND CONCLUSIONS

The first step in strengthening the science capabilities of students for careers in science and technology is to identify the difficulties in becoming scientifically knowledgeable. Another crucial step is to get high school and post-secondary teachers talking to each other. The Transitions Team achieved both of these goals with the help of several small groups of other educators, and paved the way for more and larger discussion and problem resolution.

An open minded look at restructuring high school science courses should be in order for a state that wishes to be rated at the top of the United States in education. As a result of attending Dr. Lederman's lecture and gathering data from high school and post-secondary science teachers, more science educators in the state are considering the issue of student transitions from high school to college and more high school physics teachers are now considering a change in their school science sequence to physics, chemistry, and then biology.

All changes made in our state's education process that will increase the transition probability for a high school student to be a success in college is good for all Iowans. The physics-first curriculum change for all students has immense benefits for the state because it raises the reasoning base level of each entire graduating class and, in turn, will lead to more college degrees than the present one per four adults in Iowa. After we submitted this report to JIAS, we learned Des Moines was introducing physics for freshman in high school, including at Central Academy. We talked with some of these freshmen who took and enjoyed the course. But, these conceptual physics courses have now been discontinued due to "lack of teachers" which we interpret as lack of funds to pay such teachers.

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