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What subject most intrigues young high ability learners? What subject is still rated highly by middle school academically talented learners? Interestingly, the answer is science even though it is taught less frequently than any other subject prior to middle school. Clearly, we need to ensure that appropriate curriculum is in place for such students from K-12. In a time of curriculum reform and a national goal of becoming Number One in the world by the year 2000, movement on this issue should be compelling to all educators.

SCIENCE REFORM RECOMMENDATIONS

Based on reports over the past 12 years, it is clear that students have not been achieving well in science (National Commission on Excellence in Education, 1983), advanced courses have been poorly subscribed to or not offered by many secondary schools (National Science Board, 1983; Bybee, 1993), and girls and minority students have been dropping out of the science track as early as possible (Hilton, Hsia, Solorzano, & Benton, 1989). On the instructional side of science, it has become evident that elementary teachers were not teaching science because they did not know the content nor feel secure with it as a subject area (Rutherford & Ahlgren, 1989); little instructional time in elementary schools was devoted to science (NAEP, 1988); and where science was taught, basal texts that emphasized reading and canned experiments were preferred and used over active learning (Lockwood, 1992a; 1992b).
In order to address the problems of science teaching and learning, key national groups including scientists and science educators collaborated on a set of science concepts and processes deemed essential for K-12 learners to understand and master (Rutherford & Ahlgren, 1989). Other groups such as the National Science Foundation, the National Academy of the Sciences, and the National Science Teachers Association have responded through the development of teacher enhancement programs and curriculum development recommendations. Project 2061 (1993) has published benchmarks of science literacy goals that concentrate on a common core of learning. More recently, the National Research Council (1996) has also published a set of national science standards. In this climate of education reform, the role of exemplary curriculum becomes a primary consideration in the attempt to improve both gifted and science education.

RESEARCH ON GIFTED LEARNERS IN SCIENCE

The research literature also contains many ideas for improving science education. The Third International Math and Science Study (TIMSS), which ranks the United States in the top half of participating nations at grades 4 and 8, suggests that more instructional time on experimental science activities would be useful, as would a focus on correcting misconceptions in science learning (U.S. Department of Education, 1996).

Moreover, opportunities for earlier access to advanced content need to be available to gifted students in science. Cross and Coleman (1992) conducted a survey of gifted high school students, finding that their major complaint about science instruction was the frustration of being held back by the pace and content of courses. In a 6-year study of middle school age gifted learners taking biology, chemistry, or physics in a 3-week summer program, these younger learners outperformed high school students taking these courses for a full academic year (Lynch, 1992). Follow-up studies documented continued success in science for these students, suggesting a need for academically advanced students to start high school science level courses earlier and be able to master them in less time. Evidence also suggests that advanced study in instructionally grouped settings based on science aptitudes promotes more learning for all students (Hacker & Rowe, 1993).

Data from several summer Governor's School programs in science have demonstrated the positive impact of such programs on students' continuing with the scientific enterprise in college (Enersen, 1994). The major impacts from the experience appeared to center around the collaborative opportunities to work with talented faculty and a highly able peer group. Such reports point to a continued need to provide and structure collaborative opportunities for these learners.

Recent work in using problem-based learning in teaching science to high ability learners at the elementary level suggests the efficacy of the approach in enhancing student and teacher motivation (VanTassel-Baska, Bass, Ries, Poland, & Avery, 1998); in improving problem-finding abilities (Gallagher, Stepien, & Rosenthal, 1992); and in promoting intra and interdisciplinary learning (Stepien, Gallagher, & Workman, 1993). Recent studies have also identified the materials that are most appropriate for use with high ability students in elementary science programs (Johnson, Boyce, & VanTassel-Baska, 1995), citing those that provide a balance of content and process considerations, including an emphasis on original student investigations, concept development, and interdisciplinary applications. Other studies suggest the importance of science mentors and more emphasis on laboratory-based science as central tenets of providing high-end learning opportunities in science at all levels.

WHAT SHOULD A SCIENCE CURRICULUM FOR GIFTED STUDENTS INCLUDE?

At the Center for Gifted Education at the College of William and Mary, the past six years have been spent addressing issues of appropriate science curriculum and instruction for high ability students as well as melding those ideas to the template of curriculum reform for all students in science. Consequently, the elements essential for high ability learners also have saliency for other learners as well. The most important include the following elements.

--An emphasis on learning concepts.

By restructuring science curriculum to emphasize those ideas deemed most appropriate for students to know and grounded in the view of the disciplines held by practicing scientists, we allow students to learn at deeper levels the fundamental ideas central to understanding and doing science in the real world. Concepts such as systems, change, reductionism, and scale all provide an important scaffold for learning about the core ideas of science that do not change, although the specific applications taught about them may.

--An emphasis on higher-level thinking.

Students need to learn about important science concepts and also to manipulate those concepts in complex ways. Having students analyze the relationship between real world problems, like an acid spill on the highway, and the implications of that incident for understanding science and for seeing the connections between science and society provides opportunities for both critical and creative thinking within a problem-based episode.

--An emphasis on inquiry, especially problem-based learning.

The more that students can construct their understanding about science for themselves, the better able they will be to encounter new situations and apply appropriate scientific processes to them. Through guided questions by the teacher, collaborative dialogue and discussion with peers, and individual exploration of key questions, students can grow in the development of valuable habits of mind found among scientists, such as skepticism, objectivity, and curiosity (VanTassel-Baska, Gallagher, Bailey, & Sher, 1993).

--An emphasis on the use of technology as a learning tool.

The use of technology to teach science offers some exciting possibilities for connecting students to real world opportunities. Access to the world of scientific papers through CD-ROM databases offers new avenues for exploration. Internet access provides teachers wonderful connections to well-constructed units of study in science as well as ideas for teaching key concepts, and e-mail allows students to communicate directly with scientists and other students around the world on questions related to their research projects.

- --An emphasis on learning the scientific process, using experimental design procedures.

One of the realities we have uncovered is how little students know about experimental design and its related processes. Typically, basal texts will offer canned experiments where students follow the steps to a preordained conclusion. Rarely are they encouraged to design their own experiments. Such original work in science would require them to read and discuss a particular topic of interest, come up with a problem about that topic to be tested, and then follow through in a reiterative fashion with appropriate procedures, further discussion, a reanalysis of the problem, and communication of findings to a relevant audience.

WHAT CAN TEACHERS DO TO MAKE THESE REFORM EFFORTS SUCCESSFUL?

In order to ensure that science reform is successful, administrators, teachers, and parents need to consider the following approaches to help the reform effort succeed.

- --The selection of modular materials rather than basals for classroom use.

There are excellent science materials available that will promote the teaching described here (Johnson, Boyce, & VanTassel-Baska, 1995). However, districts must be willing to use such materials rather than insisting on the purchase of basals which do little to promote the desired kind of science learning. Moreover, there are excellent supplementary materials also attuned to the new science agenda that can augment any school science program.

- --The training of teachers in content-based pedagogy.

If we wish to improve teaching and focus on student learning, then teachers need help in teaching for understanding (Cohen, McLaughlin, & Talbert, 1993). In order to do that, we need to emphasize strategies and instructional approaches in the context of content rather than separate from it. One good way to approach such training is to use high-quality materials as the basis for the training sessions to ensure the integration of content and pedagogy. Skills needed then by teachers of high ability learners in science include strong content knowledge and skills in teaching it, flexibility in classroom management, and the capacity to question student understanding through metacognitive and assessment techniques.

--The employment of curriculum monitoring processes in schools.

No matter what new emphasis schools wish to see implemented, there is a need to ensure that the innovation has been implemented faithfully. Where that is not happening, suitable measures may be employed to ensure that such change will occur in the future. Research on staff development as well as effective teaching demonstrates the need to provide systematic follow-up procedures to ensure teacher action (Joyce & Showers, 1995). Whether such monitoring occurs through peer coaching programs, supervisory procedures of the principal, or curriculum specialists is not as important as the fact that it occurs at all.

CONCLUSIONS

Appropriate science curriculum that promotes high quality learning is desirable for all learners. Access to such learning is mandatory for students demonstrating a strong yearning for substantive and challenging science curriculum in schools. Teachers and administrators alike need to recognize that gifted learners must be challenged in their area of greatest interest and potential expertise. The world can only benefit from motivating the future Marie Curies, Booker T. Washingtons, and Michael Faradays.

CURRICULUM REFORM CLASSROOM INDICATORS

Do our classrooms contain the following elements? Answer yes or no.
__Curriculum focuses on important concepts (e.g., systems, change, patterns, models).

__Curriculum emphasizes the research process within an integrated framework (e.g., exploring a topic, planning how to study it and carrying out a study, judging results, and reporting).

__Curriculum focuses on substantive content.

__Instruction is inquiry-oriented, using strategies like problem-based learning and higher level questioning.

__Instruction is activity-based, engaging students in the doing aspect of learning.

__Assessment of learning includes performance-based approaches such as use of real-world problems for students to demonstrate understanding and transfer of key ideas and processes.

__Assessment of learning includes a portfolio of student work including individual logs, reports, and other work.

Students engage in planning and carrying out original research. (Teachers instruct student in experimental design.)

__Students actively discuss real world problems and issues in relationship to societal implications. (Teachers present issues and ask high level questions about them.)

__Students demonstrate thinking processes necessary for doing work in a given discipline; e.g., inference, deductive reasoning, evaluation of arguments. (Teachers ask higher level thinking questions in classroom discussion and activities.)

__Curriculum materials are appropriate for high ability learners in that they reinforce Items 1-10 above.

__Curriculum materials promote student engagement in learning.

__Classroom instruction incorporates appropriate technology as a tool in learning.

__Classroom instruction attends to individual differences in rate of learning.

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