Achieving the Visions of the National Science Education Standards

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The Iowa Academy of Education
Occasional Research Paper #4
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National Science Education Standards

Robert E. Yager

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Abstract

A brief history of the emerging goals of science education culminating in the creation of the 1996 National Science Education Standards (NSES) is presented. The current realities of science education in classroom practice and teacher education programs are explored, indicating that science reform goals are rarely addressed. C*ontext* – rather than *concepts* and *process skills* – is identified as essential for learning science. Next, recommendations by the National Research Council (NRC) regarding how to improve science teaching by de-emphasizing certain traditional practices and giving added emphasis to new strategies are delineated. Exemplary science education programs are identified, and the Iowa Chautauqua Program is advanced as a staff development model that has succeeded in helping schools and teachers change in ways envisioned by NSES. Five reasons for optimism about the future of science education are offered along with a cautionary note that successful science education reform is dependent upon changes in the ways science is taught. Implications for science teachers are disclosed. It is concluded that further research, particularly action research conducted by practitioners, is needed.

Achieving the Visions of the
National Science Education Standards

The goals for science education have changed over the past several decades as reforms have suggested using current issues and other personal, relevant, or meaningful contexts for learning. As early as 1946, the American Association for the Advancement of Science (AAAS) (American Association for the Advancement of Science [AAAS], 1946) called for changes in science teaching that would provide functional (useful) learning for all students. This focus was altered in the 1960s with the scare provided by the Soviets with their space exploits. The U.S. moved to a focus on the constructs and skills known to scientists as appropriate for all learners (Harms & Yager, 1981). The 1970s resulted in disillusionment with the science "known to scientists" and the emergence of a new movement intended to affect the thinking and the lives of all. Project Synthesis (Harms, 1977) established the importance of four goals for science education, namely:

1) Science for meeting personal needs. Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.
2) Science for resolving current societal issues. Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.
3) Science for assisting with career choices. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.
4) Science for preparing for further study. Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

All but the fourth goal illustrate science *in context*. When science is studied in context, students are provided with a rationale and/or a situation illustrating the importance of the study. There is a reason other than "it has been assigned" or "it is the next chapter in a textbook."

Goals similar to those outlined in Project Synthesis became central to the National Science Education Standards (NSES) (National Research Council [NRC], 1996). However, the fourth goal – teaching science as preparation for further study – was dropped in favor of a new goal that encouraged every student to experience the kind of science *that is basic to the human enterprise*. The new goal became the first and most important goal – and yet one that is rarely apparent in typical K-12 programs.

Dropping academic preparation as a legitimate goal of science education was a major change because previously it had been the primary justification for the teaching of science. Teachers believed that their primary function was to prepare students for what was demanded/expected at the next academic level. Thus typical instruction served an administrative function (i. e., as gatekeeper for the best students who would study more science) – unrelated to the way students live or use their study outside of class.

The four goals basic to the NSES indicate that students should:

1) experience the richness and excitement of knowing about and understanding the natural world;
2) use appropriate scientific processes and principles in making personal decisions;
3) engage intelligently in public discourse and debate about matters of scientific and technological concern; and
4) increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.

The goals of the NSES concentrated on science education that is appropriate for all – not just for those pursuing additional formal science study.

Further, the NSES and the Science for All Americans Project: Project 2061 (AAAS, 1990a) embrace the joining of science and technology for school science. In fact, the merger of the natural world and the human-made world is considered fundamental to the development of solutions to science education problems. However, this merger is proving difficult because for the past forty years the focus in school science has been on "pure" science, separate from technology. Technology was left to vocational areas which rarely concentrated on preparation for college. Zuga (1996) has eloquently described how science and technology must be rejoined if real reforms in education are to occur.

Another area of debate revolves around the definition of science education. Too often science education has been defined as a two-dimensional enterprise. The first and most important dimension consists of *concepts*; i.e., the constructs generally accepted as explanations of the objects and events found in nature. The second consists of *processes*. For over a hundred years reformers have identified certain processes/skills used by scientists that should be considered in the study of science. Like concepts, these processes have been used to define school science – but often to a much lesser degree than the conceptual themes used to organize typical courses.

Some science educators still accept a two-dimensional view of science education with the concepts being taught (and learned?) in science courses and process skills being taught (and learned?) in education courses (Weiss, Banclower, McMahon, & Smith, 2001). Yet, to accept that science education consists only of the current constructs of the natural world accepted by today's scientists and the skills they have used in determining these constructs results in missing the essence of the enterprise (Yager, 2000).

While concepts and process skills are important in promoting learning, *context* is more important. Concepts and processes represent important outcomes for science teaching, but they do not help achieve understanding unless there is also a real world context for seeing, learning, and using the ideas and skills. Establishing an appropriate and relevant context for learning science is a prerequisite for learning concepts and processes. Further, the students must help develop the context if it is to be seen as important and useful. Often the best context for learning occurs when emphasis is given to questions, problems, concerns (e.g., technological advances) that students perceive are valuable.

The importance of context in science education was first realized after cognitive science research revealed the inadequacies of typical instruction (Organization for Economic Co-Operation and Development [OECD], 2000; Champagne & Klopfer, 1984; Resnick, 1987). When university science and engineering majors were studied, it was found that 85 to 90 percent of these students had no real understanding of the concepts and processes they had mastered in courses in which they had received high evaluations from their teachers. They could not use the information and skills to solve problems and were unable to connect the ideas and skills to anything else. They were merely conscientious students who committed important concepts and skills (often mathematical equations) to memory.

In fact, the minds of most of the science and engineering students in the study were not engaged. That is, they did not demonstrate the characteristics which Perrone (1994) reported to be indicators that students' minds are intellectually engaged. These include:

1) Students must help define the content – often by asking questions.
2) Students must be given time to wonder and to find interesting pursuits.
3) Topics often have "strange" features that evoke questions.
4) Teachers encourage and request different views and forms of expression.
5) The richest activities are "invented" by teachers and students.
6) Students create original and public products that enable them to be "experts."
7) Students take some action as a result of their study and their learning.
8) Students sense that the results of their work are not predetermined or fully predictable.

Once students' minds are engaged, Perrone posited that learning can and is likely to occur. Reinsmith (1993) has described contexts that determine real learning. Major factors include:

1) Real learning results from trial and error.
2) Students only learn when they have some success and interest in the field.
3) Students have to believe that they can learn.
4) Real learning connotes use.
5) The more learning is like play, the more absorbing it will be.
6) Time must be wasted, tangents pursued, side-shoots followed.
7) Learning never occurs outside an appropriate context.
8) Typical tests are very poor indicators of real learning.

This introduction to and background on science education is helpful for understanding current efforts in the field.

Current Realities of Science Education

Classroom Practices

Science educators tend to define science as the information found in textbooks for K-12 and college courses or the content outlined in state frameworks and standards. Such definitions omit most of what George Gaylord Simpson (Simpson, 1963) described as the essence of science:

1) asking questions about the natural universe; i.e., being curious about the objects and events in nature;
2) trying to answer one's own questions; i.e., proposing possible explanations;
3) designing experiments to determine the validity of the explanation offered;
4) collecting evidence from observations of nature, mathematics calculations, and, whenever possible, experiments carried out to establish the validity of the original explanations;
5) communicating the evidence to others who must agree with the interpretation of the evidence in order for the explanation to become accepted by the broader community (of scientists).

The elements of science identified by Simpson are rarely studied in schools. For example, science students seldom determine their own questions for study; they are not expected to be curious; they rarely are asked to propose possible answers; they seldom are asked to design experiments, and they rarely share their results with others as evidence for the validity of their own explanations (Weiss et al., 2001). One could argue that "real" science is seldom encountered or experienced in most science classrooms. The typical focus is almost wholly on what current scientists accept as explanations (Harms & Yager, 1981; Weiss et al., 2001). Competent science students only need to remember what teachers or textbooks say. Most laboratories are but verification activities of what teachers and/or textbooks have indicated as truths about the natural world. There is seldom time for students to design experiments that could improve human existence.

Science education should be about drawing people out in terms of engaging their minds. Instead, most science programs focus on directing students to what they should learn – i.e., the explanations of objects and events that scientists have accepted as truths or explanations of technological achievements (e.g., automobiles, airplanes, air conditioners) (AAAS, 1990a). Education has become *training*; i.e., getting students to accept and be able to recall explanations others have offered. This is often done under the guise that specific concepts and process skills are necessary prerequisites for understanding even though it is now apparent that such approaches are useless and not really understood until students see the importance and need for them (Resnick, 1987; NRC, 1999).

Science Teacher Education

Recently, two major research studies funded by the U.S. Department of Education – Salish I and Salish II (Salish Research Consortium, 1997; Robinson & Yager, 1998) – revealed the status of current programs for preparing new science teachers:

1) Most new science teachers use little of what teacher education programs promote during their initial years of teaching.
2) Few teacher education programs are utilizing what we know about science as envisioned by NSES.
3) Programs are poorly conceived in terms of sequential experiences with science teaching; these are unrelated to the general education and science courses that comprise most of a Bachelor's program.
4) There are few ties between pre-service and in-service efforts.
5) Support for teacher education reforms have been largely unrecognized and under-funded; only in the last few years has this situation been altered.
6) Changes in science instruction at colleges must be substantial if real improvements are to occur in schools.

From these studies, it is apparent that revisions are needed in the way new teachers are prepared. In fact, there is renewed interest in and funding for the preparation of new teachers as well as innovative staff development efforts for practicing teachers.

Recommendations for Improving Science Education

If learning is to occur, changes in the way science is taught must occur. The NSES have captured the essence of the changes needed in teaching. The following lists from the National Research Council (NRC, 1996) delineate current, typical teaching situations which should be de-emphasized (left column) and suggested reforms which merit emphasis (right column).

Less Emphasis On	**More Emphasis On**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following the curriculum	Selecting and adapting the curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding

Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Learning can also be encouraged with materials that are better designed to: (a) meet the NSES goals, (b) produce scientifically literate people, and (c) assist with the desired instructional strategies (NRC, 1999). Elementary school programs may be the easiest to improve for two reasons: (a) elementary teachers typically are not well-prepared to teach science (Raizen & Michelsohn, 1994); and (b) elementary teachers are often more aware than secondary and college teachers of how students learn since they focus on teaching and learning in many subjects across the curriculum and are usually with the same students throughout the school day. Middle schools are especially set for effecting change because the teachers represent a mix of those prepared for elementary teaching and those prepared for secondary teaching, and the philosophy for such schools encourages teams of teachers working with subsets of students (National Science Teachers Association [NSTA], 2000-2001; Berns, Kantrov, Pasquale, Makang, Zubrowski, & Goldsmith, 2000; Koballa & Tippins, 2000). This means there are teachers concerned primarily with content knowledge as well as those whose primary concern is pedagogy. In middle schools there is little focus on preparing students for higher education which is often the main goal for high school science teachers (Harms & Yager, 1981). There is also less parental concern when major changes are implemented in the middle school. Parents perceive four years of high school will be enough to prepare students for college. Hence, the high school program becomes more discipline bound where just half of the students prepare to study in college. And, college instruction is often provided in very traditional ways. Unfortunately, many high school teachers mimic the way they were taught content in college (Iowa Chautauqua Program, 1998).

Model Science Programs

Some of the most promising projects funded by the National Science Foundation (NSF) to provide help in meeting the NSES include:

Elementary School Projects

- Science and Technology for Children (STC), (1997), Carolina Biological Supply Company, 2700 York Road, Burlington, NC 27215-3398

- Education Developmental Center (EDC), (1999), Insights, Kendall/Hunt Publishing Company, 4050 Westmark Drive, PO Box 1840, Dubuque, IA 52004-1840

Middle School Projects

- Event-Based Science Project, (2000), Dale Seymour Publications, A Division of Scott Foresman/Addison-Wesley Publishing, 10 Bank Street, White Plains, NY 10602
- Science Education for Public Understanding Program (SEPUP), (1999), Lab-Aids, Ronkonkoma, NY 11779

High School Projects

- Chemistry in the Community, (2000), W.H. Freeman, 41 Madison Avenue, New York, NY 10010
- Active Physics, (2000), IT'S ABOUT TIME, Inc., Armond, NY 10504
- EarthComm, (2001), IT'S ABOUT TIME, Inc., Armond, NY 10504
- Leonard & Penick, Biology: A Community Context, (1998), Glencoe McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020

It is noteworthy that all the model high school programs – unlike typical science education programs – address the NSES goals, focus on concepts, and emphasize real world contexts.

Iowa Chautauqua Program

All of the model curriculum projects (cited above) have been and/or are in use in Iowa schools. Another model program for staff development, the Iowa Chautauqua Program (1998), has been in operation in Iowa since 1983 and has been transported to a dozen or more other states and to several other countries, including Estonia, Israel, Japan, Korea, and Thailand. The Chautauqua model consists of a series of activities for science teachers at elementary, middle, and/or high school levels over an entire summer and academic year. Figure 1 outlines and describes the yearly sequence. Leadership and mentoring of new teachers is continued with outside funding for a period of at least three years.

Twenty Iowa secondary school districts have used the Chautauqua staff development model for all science teachers in grades 6 through 10. The model, funded by NSF, promotes the new NSES teaching emphases through Science-Technology-Society (STS) approaches while using local issues and the NSF curricula as models. STS, one of the new science education movements, stresses changes in teaching, promotes the inclusion of technology, and emphasizes the importance of context.

Extensive evaluation data of the changes in student learning in multiple domains by teachers in Iowa schools have been collected. The most impressive results come from experienced Chautauqua teachers who are involved each summer in leadership training. Data from their students demonstrate impressive improvements in student learning. Figure 2 illustrates the content as well as the teaching and assessment domains used to structure the Iowa Chautauqua program and to assess its successes. Following the Figure is an elaboration of what is included in each of the six domains. For many students, the program begins and ends with the applications-connections domain.

The effectiveness of the Iowa Chautauqua Program – in terms of changing teaching and, more importantly, student learning – has been established by nearly 20 Ph.D. dissertations. The Dana Report (Iowa Chautauqua Program, 1998) also provides an overview of 15 years of successful staff development activities with the Iowa Chautauqua Model.

Figure 3 compares student achievement results in all six domains when classes are taught by Lead Teachers using traditional methods (see former listing of "less emphasis" on various teaching procedures) and by Lead Teachers using methods advocated by the National Science Education Standards (see former listing of "more emphasis" needed). There is little significant change in terms of the concept mastery domain. However, student achievement in all other domains is statistically significant at the 0.01 level of confidence in favor of the standards-based teaching approaches.

Reasons for Optimism for Science Education Reform

What do evaluation data of the Iowa Chautauqua Program and other model programs suggest? Emerging evidence indicates current reform efforts in Iowa and internationally are "on-the-mark" and succeeding. In fact, there are five primary reasons to be optimistic that the current reform efforts will succeed.

The first reason for optimism is that science educators now realize the power of collaboration and the importance of having all stakeholders involved in creating and implementing the visions for science education reform. This certainly was – and is – the approach of Project 2061 (AAAS, 1990a) and the rationale for systemic reforms in the teacher education collaboratives supported by the NSF. As more science educators establish systemic reform projects and as funding becomes available to support the reforms, change will occur more quickly. Furthermore, new initiatives will be guided by evidence designed to evaluate progress on all reform goals.

A second factor contributing to the likely success of realizing our immediate goals will be changes in teaching and the effects such changes will have on students. Currently, as was discussed earlier in this paper, the essential aspects of science are missing in most school programs. Evidence gathered by reform efforts demands changes in instruction that will help students become more scientifically literate and possess scientific habits of the mind (Yager, 2000).

One is reminded of Carl Sagan's comment: "Everybody starts out as a scientist. Every child has the scientist's sense of wonder and awe" (NRC, 1998). Teaching practice must change so that every teacher and every student will be empowered to wonder, to suggest explanations, to devise ways of testing personal and group hunches that are offered to explain the objects or events in question, to collect and analyze evidence, and to communicate the process and the results to others. Learning science means *engaging in it* as opposed to *learning about what others have done*.

A third reason for optimism that current science education reforms will succeed is the latest research on human learning. Our knowledge of how all people learn puts us in a powerful position to succeed in ways never before possible (NRC, 1999). Utilizing existing research on pedagogy, we can now focus more attention on teaching instead of merely transmitting concepts which scientists now accept as valid explanations. We want and need to develop students who can think, solve problems, and make decisions based on evidence and reasoning. The National Research Council's (NRC, 1999) book on how people learn includes an appropriate epilogue:

> Developments from a diverse array of sciences have altered conceptions of learning in fundamental ways. The cumulative knowledge from these sciences delineates the factors that contribute to competencies in reasoning and thinking. The new developments are ready to take learning science another step and focus on processes that promote learning with understanding.

As current research on teaching and learning is put to use by science teachers, we will succeed in developing a citizenry that is scientifically and technologically literate.

A fourth basis for optimism is the success of merging science education with computer technology. Computers allow us to locate information and analyze and report data with speed and efficiency; they also generate designs and make predictions based on given information. All in all, computers provide a way of experiencing science never before imagined. New computer technologies have been shown to assist in science instruction in five ways (NRC, 1999):

1) bringing exciting curricula based on real-world problems into the classroom;
2) providing scaffolds and tools to enhance learning;
3) giving students and teachers more opportunities for feedback, reflection, and revision;
4) building local and global communities that include teachers, administrators, students, parents, practicing scientists, and other interested people;
5) expanding opportunities for teacher learning.

As computer technology advances, the future will be shaped in ways that allow everyone to do more than is possible using only the human brain. Our imaginations have only begun to tap the potential of this technological achievement.

A final factor that provides optimism for meeting the goals of scientific literacy is an enhanced focus on science teacher education. NSF has begun to fund centers for science and mathematics learning and teaching that reflect and implement what is now known about effective teacher education. In addition, each center funded will serve as a research center — producing more information that can be used to speed the needed changes in teaching, curriculum, and assessment of learning (NSTA, 2002).

Implications for Science Teachers

Continuing efforts to evaluate and improve science education programs suggest that the next several years will be exciting ones. The climate has never been better for realizing current reform visions. Funds are available; National Standards are in place; state leaders have endorsed the new directions, and international attention and efforts are in concert with national initiatives (Yager & Weld, 1999).

However, science teachers must assume major responsibility for changing their teaching. They must ask questions about science, about processes, and about varied contexts for learning. They must help students question better, propose ideas that encourage student questions, help students establish the validity of their explanations, and teach students to interpret and communicate effectively the results they offer as evidence. In order to provide strong evidence that learning has actually occurred, science teachers must develop and use more accurate and complete assessments. And most importantly, they must focus on context, ensuring that teaching begins with a situation that is local, personally relevant, and current.

Future Research

In addition to providing support for science education reforms, current research results also raise questions and indicate areas for follow-up research, e.g.:

1) How do students respond to free-choice learning – i.e, how do students respond when they have more choices to explore?
2) What can teachers do to ensure that free-choice learning results in clear understanding of what experts view current concepts to be?
3) If learning became student-centered, how must teaching change?
4) How can science teaching be transformed into lifetime learning?

5) How can teacher-initiated contexts be transformed into contexts that students internalize?
6) Is the apparent learning that students achieve in the reform classrooms permanent and transferable to new situations?
7) How can college science programs be changed to reflect the reform conditions envisioned for K-12 schools? (AAAS, 1990b; Iowa Chautauqua Program, 1998)

The National Research Council (NRC, 1999) has also provided a listing of broad based research questions that will affect the future of science education. The following eight questions (modified to focus on science) indicate some immediate research needs that will hasten the reforms in science education:

1) How can science education "scale up" successful demonstrations of research-based curricula so that they can be implemented in many diverse settings under the guidance of many different kinds of teachers?
2) Which factors influence the conversion of research knowledge about science teaching into effective instructional methods in real settings?
3) Do strategies that work for science education also work to improve instruction in other subject areas?
4) How can preschool children be assisted in developing representational structures so that there are bridges, rather than gaps, between early and later science learning?
5) How can collaborative learning environments be organized in ways that counteract societal stereotypes and tap diversity as a positive resource for science learning?
6) Which kinds of assessments can effectively measure new kinds of science learning?
7) How do the features of a constructivist curriculum interact with other social factors in science classrooms?
8) What is the impact of new technologies on school performance in science?

It should be remembered that research cannot be left only to the professionals. All involved in science teaching need to be a part of the search for answers. Action research that focuses on the daily lives of students needs to be central to science teaching and learning (Riding, Fowell, & Levy, 1996). Teachers need to ask questions about their teaching. Students should be involved with new efforts that will improve their learning. The resulting evidence – provided by teachers and students – will help shape the science reform process.

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Figure 1

The Iowa Chautauqua Model

CHAUTAUQUA LEADERSHIP CONFERENCE

LEAD TEACHERS FOR THREE 3-WEEK WORKSHOPS MEET TO:

- Plan summer and academic year workshops
- Enhance instructional strategies and leadership skills
- Refine assessment strategies
- Plan and execute 3-day workshop for scientists who will be part of the site staff teams

3-WEEK SUMMER WORKSHOPS

3-4 LEAD TEACHERS, UNIVERSITY STAFF, AND SCIENTISTS WORK WITH TEACHERS IN LOCAL/REGIONAL WORKSHOP SETTINGS

Teacher leaders from each building are introduced to constructivist teaching with NSF target curricula as models. Teachers:

- Participate in activities and field experiences that integrate science concepts and principles from all eight facets of science content defined in the *NSES*
- Make connections between science, technology, and society in the context of human experiences
- Adapt the target curriculum projects to relate them to local conditions, current events, and the lives of students
- Use local questions/problems/issues such as air quality, water quality, land use and management as the context for conceptual development
- Reflect and create a 5-day lesson plan from the target national program

5 DAY CLASSROOM TEACHING TRIAL

Teacher leaders from each building involved in summer workshops teach and assess a 5 day lesson plan using constructivist practices and in ways modeled in the summer workshop

ACADEMIC YEAR WORKSHOP SERIES

3 LEAD TEACHERS, UNIVERSITY STAFF, AND SCIENTISTS WORK WITH TEACHERS AND TEACHER LEADERS INVOLVED DURING THE SUMMER

Fall Short Course

20 hour Instructional Block

Activities include:

- Reviewing problems with traditional view of science and science teaching
- Outlining the essence of constructivist teaching and learning
- Defining techniques for developing teaching modules and assessing their effectiveness
- Selecting a tentative topic from the target curricula
- Practicing specific assessment tools in multiple domains
- Analyzing current practices in relation to constructivist practices

Interim Project

4-7 week Interim Project

Activities include:

- Developing constructivist modules for use with grade level students
- Administering pretests in multiple domains
- Teaching the new modules
- Reflecting on constructivist practices
- Developing a variety of authentic assessment strategies
- Communicating with regional staff, lead teachers, and central Chautauqua staff

Spring Short Course

20 hour Instructional Block

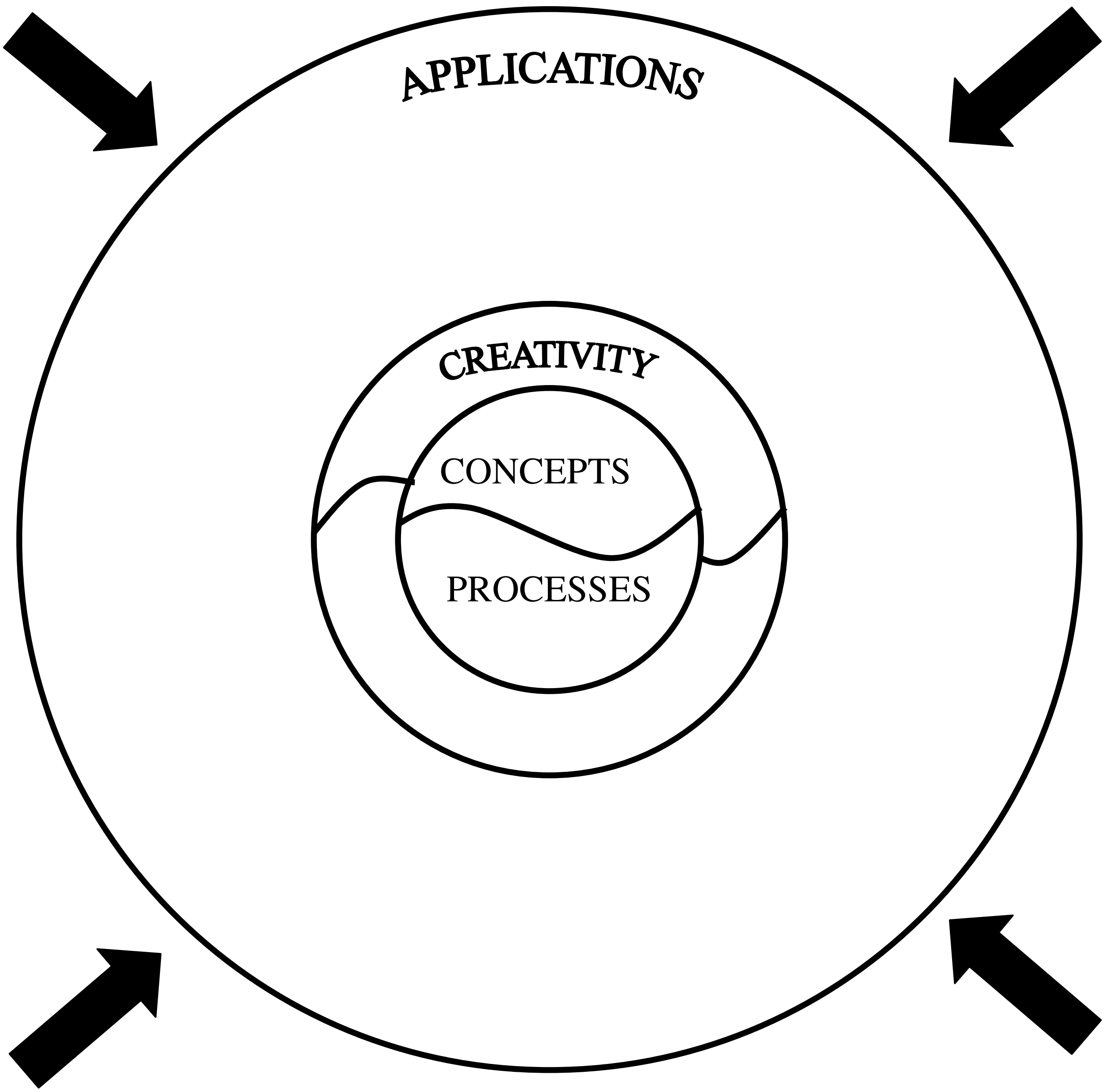
Activities include:

- Analyzing constructivist experiences in grade level groups
- Discussing assessment results
- Reflecting and analyzing teaching changes related to constructivist practices
- Considering new information concerning constructivist practices
- Planning next steps for expanding practice
- Planning for involvement in professional meetings and local school transformations
- Organizing a Chautauqua Sequence for other teachers in the building/district of the new leadership groups.

Figure 2

DOMAINS FOR TEACHING AND ASSESSING SCIENCE LEARNING

THE WHOLE OF SOCIETY



Chautauqua Assessment Domains
1. Concept Domain. Science aims to categorize the observable universe into manageable units for study and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. Part of any science instruction always involves learning by students of some of the information developed through science. The concept domain includes: facts, concepts, laws (principles), and existing hypotheses and theories being used by scientists. This vast amount of information is usually classified into such manageable topics as: matter, energy, motion, animal behavior, and plant development.
2. Process Domain. Scientists use certain processes (skills). Being familiar with these processes concerning how scientists think and work is an important part of learning science. Some processes of science are: observing and describing, classifying and organizing, measuring and charting, communicating and understanding communications of others, predicting and inferring, hypothesizing, hypothesis testing, identifying and controlling variables, interpreting data, and constructing instruments, simple devices, and physical models.
3. Creativity Domain. Most science programs view a science program as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to development of students' imagination and creative thinking. Little has been done to encourage curiosity, questioning, explaining, and testing – all the basic ingredients of science. Some of the specific human abilities important in this domain are: visualizing; i.e., producing mental images; combining objects and ideas in new ways; producing alternative or unusual uses for objects; solving problems and puzzles; designing devices and machines, and producing unusual ideas. Much research and development has been done on developing students' abilities in this creative domain, but little of what has been learned about creativity has been purposely incorporated into science programs.
4. Attitudinal Domain. In these times of increasingly complex social and political institutions, environmental and energy problems, and general worry about the future, scientific content, processes, and even attention to imagination are not sufficient parameters for science programs. Human feelings, values, and decision-making skills need to be addressed. This domain includes: developing positive attitudes toward science in general, science in school, and science teachers; developing positive attitudes toward oneself (an "I can do it" attitude); exploring human emotions; developing sensitivity to, and respect for, the feelings of other people; expressing personal feelings in a constructive way; making decisions about personal values, and making decisions about social and environmental issues.
5. Applications and Connections Domain. It seems pointless to have any science program if the program does not include some substantial amount of information, skills, and attitudes that can be transferred and used in students' everyday lives. Also, it seems inappropriate to divorce "pure" or "academic" science from technology. Students need to become sensitized to those experiences they encounter which reflect ideas they have learned in school science. Some dimensions of this domains are: seeing instances of scientific concepts in everyday life experiences; applying learned science concepts and skills to everyday technological problems; understanding scientific and technological principles involved in household technological devices; using scientific processes in solving problems that occur in everyday life; understanding and evaluating mass media reports of scientific developments; making decisions related to personal health, nutrition, and life-style based on knowledge of scientific concepts rather than on "hear-say" or emotions, and integrating science with other subjects. For many, the applications of science can provide the entry to the knowledge and process domains. For others (probably a definite minority), applications represent moves to the use of science known and developed. Many in education are looking to technology (the application of science concepts) or the applications domain as a starting point.
6. World View Domain. Science should portray the nature of the discipline – not just a study of the current views that characterize the various disciplines. Often scientists themselves are poor students of what they do, how they do it, and how their discipline changes (and has changed). Many, however, feel a primary justification for science in the general education of all students, kindergarten through college, is to portray the nature of science as a major intellectual pursuit of all humankind. This domain is concerned with: ways in which scientific knowledge is created; the nature of research processes; the meaning of basic concepts of scientific research (e.g., hypothesis, assumption, control, replication); the history of scientific ideas; the ways scientists work and their organization; and the interactions between science, economy, politics, history, sociology, and philosophy.

Figure 3

Comparison of Student Growth in the Six Assessment Areas For Those Enrolled in Traditional (Textbook-dominated) and Reform-based (STS) Sections