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The Role of Student and Teacher Creativity in Aiding Current Reform Efforts in Science and Technology Education

Stuart O. Yager
Associate Professor
Department of Educational Leadership
Western Illinois University
Macomb, IL

Ozgur Kivilcan Dogan
Research Assistant
Department of Secondary Science and Mathematics Education
Marmara University
Istanbul, Turkey

Esme Hacieminoglu
Assistant Professor
Department of Science Education
Necmettin Erbakan University
Konya, Turkey

Robert E. Yager
Professor of Science Education
University of Iowa
Iowa City, IA

Abstract

Creativity is one of the domains for science teaching and student learning for this study as recommended in the National Science Education Standards (NSES). Examples of creativity were identified by teachers and students enrolled in control classrooms and those headed by Teacher Leaders from the Iowa Chautauqua Professional Development program. Results indicate differences between the classrooms and student evaluations of teachers enrolled in Iowa Chautauqua and those from control groups from the same or nearby school districts. Over thirty features of creativity were identified by four Teacher Leaders and their students. These traits varied somewhat among five Teacher Leaders. They were then compared with student responses from other classrooms where creativity was not a domain for the curriculum and the kind of teaching advocated by the National Science Education Standards (NSTA).

Keywords: Creativity, Questioning, Nature of Science, Current Reforms, Students Perceptions

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Creativity in Science Education

Creativity is one of the more complex "domains" used to exemplify the current reforms in science education. It is related to both science and science teaching in a variety of ways. Evaluating science learning often can result in more student and teacher creativity; but, in many ways it is more difficult to establish and to define for teachers, especially for those who define science mostly in terms of curricula and disciplinary content. This problem is the major focus for this study. Carl Sagan has observed that all humans start as scientists – i.e., full of questions, enthusiasm, and interest in everything around them (NRC, 1998). These qualities are all examples of creativity. School science seems often to reverse such desired noteworthy features of science found in PreK-12 situations. Actually "doing science" is often not seen as central to science teaching or captured by curriculum frameworks or teachers.

A common definition for science is needed! Simpson has offered one which is used in this study: Science is the exploration of the material universe seeking explanations of the objects and events encountered*: but these explanations must be testable* (Simpson, 1963). Science then is a *search* for explanations of objects and events found in nature, keeping in mind the importance of looking for evidence to establish the validity of explanations offered.

In elementary schools teachers are more likely to encourage more student involvement with creativity as an outcome and a procedure than is the case in middle and high schools. Oddly, science teaching is often approached best by science teachers with the least preparation in college science classes, namely those at the PreK-4 levels. And yet these students report liking science better than do students in most middle and high schools where teachers have more experience with science courses as part of their collegiate preparation (Ali, Yager, Hacieminoglu, & Caliskan, 2011; Lee & Erdogan, 2007;Morrell, & Lederman, 1998; Penick, 1996). This is especially true when teachers do not know but are willing to help their students deal with their own interests, ideas, and interpretations of the natural world which they experience. Interestingly, student attitudes are rarely negative when creativity is used to improve teaching and learning at any level. This indicates why creativity and attitudes are often called the "enabling" domains that encourages real learning of science.

Major Efforts to Define Creativity

Torrance (1963, 1975), one of the most noted researchers studying human creativity, has argued that students in general prefer to learn in creative ways by exploring, manipulating, testing, questioning, experimenting, and testing ideas. He has argued that individuals are naturally curious and that their curiosity and creativity "can be stimulated by relevant, authentic learning tasks of optimal difficulty and novelty for *each* student" (APA, 1993, p. 7). Not being experts regarding science makes elementary teachers great – if only they have confidence that they can help students learn as they learn too!

Brandt (1986) has pointed out that creativity can be defined as a personal way of using and directing one's own abilities. Creative persons often restructure the problem rather than merely seeking solutions to the problems *presented* by textbooks and/or teachers. Questions about the problem needing solution often become "questioning" even the existence of the problem itself. Such questions give rise to ideas that would never have been considered initially.

Questioning is basic to creativity as it is to science itself. It is needed by teachers interested in improving their teaching if this teaching is to provide a means for more and better learning.

As Einstein once stated, “The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skills” (as reported by Getzels, (1975). Getzels went on to note that imagination is more important than special information that is often called “science”. It is only meaningful and successful when the mind is receptive to the unfamiliar things and when old things are perceived in new ways. Getzels (1975, p. 12) has often reported that raising new questions, new possibilities, while also focusing on old questions from new angles, both require imagination while they also encourage real advances in science itself. Creativity is something to encourage for both teachers *and* students. A creative solution is the response to a creative question. Newton and Newton (2010, p. 1990) have conducted research dealing with creativity as an active feature of people generally; they have suggested how it can be used to indicate understanding and use of science constructs and skills in science classrooms.

Creativity starts where “the ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and produce solutions to ill-defined problems” (Beghetto, 2007). In an educational context, the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) has described creativity as an “imaginative activity fashioned to produce outcomes that are both original and of value”.

Science/Technology/Society (STS) as Teaching Reform

STS teaching provides an appropriate strategy for involving students in important facets of learning including encouraging creativity and use of students in central roles. An STS teaching strategy focuses on process, not product. This is consistent with constructivist thinking: in order to construct knowledge, the learner must seek out, sort, and organize new data. This can only happen if the processes of generating those data are explicit. Otherwise, students may at most retain the “facts” given to them by the textbook or instructor, and not connect this information with any real-life situations or known phenomena. “Most persons have misconceptions about nature; further, typical schooling is ineffective in altering these misconceptions. Many of the most able students have as many misconceptions about science as the average high school student. It is also important to note that “students who score well on standardized tests are often unable to successfully integrate or connect memorized facts and formulas with the experience-based interpretations they have acquired prior to instruction” (MacLeod, 2009; Matson & Parsons, 2006; Yager, 1991). Typical schooling is ineffective but early results of studies regarding STS classrooms indicate that STS teaching is effective in involving students in actually doing science and relating it to dealing with personal, local, and current problems (SUNY, 1996; Yager & Weld, 1999).

STS programs are characterized in a Position Statement of the National Science Teachers Association (NSTA). STS teaching consists of features which include:

1. Student identification of problems with local interest and impact;
2. The use of local resources (human and material) to locate information that can be used in problem resolution;

3. The active involvement of students in seeking information that can be applied to solve real-life problems;
4. The extension of learning going beyond the class period – the classroom, the school;
5. A focus upon the impact of science and technology on individual students;
6. A view that science content is more than concepts which exist for students to master for tests;
7. An emphasis upon process skills which students can use in their own problem resolution;
8. An emphasis upon career awareness – especially careers related to science and technology;
9. Opportunities for students to experience citizenship roles as they attempt to resolve issues they have identified;
10. Identification of ways that science and technology are likely to impact the future;
11. Teachers and students have some autonomy in the learning process (as individual issues are identified and used to frame classroom discourse). (NSTA, 2007-08, p. 242)

In his book *Learning and Instinct in Animals*, Thorpe (1963) defines learning as "that process which manifests itself by adaptive changes in individual behavior as a result of experience." This definition has two points that bear emphasis. One point is the definition of learning as a process. This implies that learning is active—and so it should be; the learner should be mentally active. Passive retention of information does not result in real learning. The second point is that learning is the result of experience. This implies that the learner must have personal experiences in order to learn. If we accept Thorpe's definition, then any learning event must include opportunities for the learner to be mentally active and to have concrete experiences. Such a philosophy is basic to STS efforts.

The Iowa Chautauqua Programs

Reform efforts planned and coordinated by NSTA called Iowa Chautauqua were modeled after the Professional Development (PD) programs for college science teachers sponsored by the American Association for the Advancement of Science (AAAS, 1990). They were supported with major NSF funding for more than a decade earlier (late 1960s and through the 70s). These AAAS Chautauqua Programs for college faculty members were offered at the Iowa Science Education Center for several years. This experience and philosophy were used later with the NSTA Chautauqua efforts which focused on replacing the AAAS efforts for college teachers with similar procedures enrolling K-12 teachers in similar year-long efforts. Appendix A is included to identify the essential features of Iowa Chautauqua professional development efforts in terms of desired organization and anticipated learning outcomes. Major pre-testing for establishing success with the Iowa Chautauqua was accomplished with important pre-testing of actual activities recommended at the opening of an October short course at each site following the summer four week conference; post-testing occurred at the end of the spring short course to indicate the nature and extension of the changes in teaching and learning. These academic year assessments were considered more important than were pre- and post-measures used at the opening and closing of the summer workshops for new teachers. Nonetheless, most Professional Development (PD) projects continue to undertake assessments prior to and immediately following a particular summer workshop. Few include assessments of the changes in actual teaching that is undertaken in the schools of the teachers of those enrolled during the summer experiences. For this study the focus is on the students involved with the beginning and ending with the two short courses where use of the summer experiences were tried and evaluated. (See Appendix A)

What teaching strategies, if any, will encourage students to take responsibility for their own learning? Is there any form of teaching that can be described as dynamic rather than static? How can creativity be recognized and encouraged? How does a focus on creativity in science classrooms permit and encourage the flexibility of classroom activities necessary if students are to construct their own knowledge? Such a teaching strategy does exist. It is a strategy that places emphasis on the processes of arriving at an answer, rather than simply requiring that students merely regurgitate the "right" answer—whether or not they understand either the answer or its justification or potential use in the future. It is a strategy that allows students time to construct meaning, thus circumventing the pitfall succinctly described by Hawkins (1983): "Instruction by a teacher often fails without a matching construction by the learner."

These are all important considerations for STS learning as offered and evaluated in the Iowa Chautauqua efforts. The contrasts between STS and Non-STS teaching emphasize use of student ideas and experiences as opposed to those comprising a set curriculum or information provided by textbooks, teachers, or district frameworks. STS demands that students are important factors in defining the learning situation where their ideas and perceptions are encouraged and used. Too often teachers agree that they are not focused on teacher-centeredness as they proceed to "guide" students. However, in reality their "guiding" is perceived by students as "directed". But, original student ideas, interpretations, and opinions are important and should provide the emphasis for successful teaching. As stated by Stephanie Hirsh in *Learning Forward (Spring,2011)*, we need to strive to highlight important topics proposed by students, raise concerns, inspire debate, and motivate actions, as the results of effective and successful teaching. These traits provide information that indicates the instructional goals have been achieved. Specific contrasts include the following for teachers who experience STS via Iowa Chautauqua with those with no similar experiences.

Iowa Chautauqua	**No Chautauqua Experiences**
Class activities are student-centered	Class activities are set and controlled by the teacher
Individualized and personalized, recognizing student diversity	Group instruction geared for the average student
Directed by student questions and experiences	Directed by the textbook
Uses a variety of resources	Uses basic textbook almost exclusively

Cooperative work on problems and issues	Some group work, primarily in laboratory where procedures and directions are provided
Students are considered active contributors to instruction	Students are seen as recipients of instruction
Teachers build on student experiences assuming that students learn best from their own experiences	Teachers do not build on students' experiences, assuming that students learn more effectively by being presented with organized, easy-to-grasp information
Teachers plan their teaching around problems and current issues – often planned by students	Teachers plan their teaching from the prescribed curriculum guide and textbook
Teachers encourage students to questions and to respond to possible answers	Students are "receivers" of information; they are not expected to use what they have been taught (McShane & Yager, 1996)

The current reforms outlined in Iowa Chautauqua over the years demand changes in teachers. Teachers need to improve in terms of their confidence to teach science as well as in terms of their understanding of the basic features of both science and technology. Teachers must learn about constructivist learning and identify teaching strategies which encourage real learning. They must turn their teaching into a science where questions are raised and answers sought. They need to be creative and serve as a model for their students.

Changes in Science Teaching and Leaning: How Defined

Successes with Iowa Chautauqua have been evaluated by improvements in student learning. Appendix B is included to indicate this broader view of science while characterizing reform efforts in Iowa Chautauqua over the 1981-2011 years. The six domains comprising the model are: concept, process, creativity, attitude, application, and world view. Iowa reforms in science require changes in all the critical aspects of reform teaching, namely first establishing goals, using new forms of assessment, designing new and targeted curricula where students have been involved in creating, modifying, and changing instructional strategies as well as inventing new modes of collaboration among teachers across the whole curriculum, school administrators, and especially students. Results of most of these efforts were combined when the six domains illustrated less focus on discipline-structures and process skills. Such a two dimensional focus remain as typical features of traditional programs as indicated earlier. Creativity and attitude are the "enabling" domains – combining typical content with its actual use. Of the two domains, Creativity has the most to offer to science as real reforms in teaching by its success on student learning by providing extensive evidence of it success for outside funding (NSF, 1991-93, 1992-1993; SUNY, 1996).

Setting and Methodology for this Study

For each beginning and ending of each funded effort for a year-long Iowa Chautauqua, (See Appendix A) at least one class was selected as the experimental group taught by an Iowa Chautauqua Teacher Leader. Control teachers (a term not used or reported to teachers or their students) were selected from "similar" classrooms in the same or nearby school – but, taught by teachers with no Iowa Chautauqua experiences. The size of the control schools always matched the situation characterizing the teachers who were not involved with any particular funded project. The size of each of the experienced and control classes varied from 16 to 27 students.

The Iowa Chautauqua programs have operated since 1981 as statewide reform efforts. They have often focused on reforms for middle-school science programs, grades 5-8. At the same time PreK-4 as well as high school (grades 9-12) were frequently operating at given sites across the state. The largest interim for funding and on-going operation was the NSTA Scope, Sequence and Coordination (SS&C) project (Yager, Liu, & Varrella, 1993). This reform encouraged the creation of new frameworks for the science programs in each of the twenty participating districts. They started with grade five as the beginning of middle school as defined by the National Standards. Such frameworks match the "desired state" features advocated by the Project Synthesis reforms (Harms & Yager, 1981). What was mandated a decade later as the National Standards were conceived and published in 1996 by the National Research Council. The NSES pushed to get the ideas and major reform features throughout the 1990's through 2011. The major features of the NSES include: 1) Integrated science including the eight features of science content included, 2) Important concepts and skills used at multiple times at a given grade level and spaced across grade levels, 3) Hands-on/minds-on activities featured, 4) Problem-centered materials centered where the problems which were personally and locally relevant, 5) A focus on planned creativity of students <u>and</u> their teacher. Teacher Leaders represent the 20-30 teachers who comprised the Iowa Chautauqua staff over a 30 year period 1981-2011.Teachers Leaders from Iowa Chautauqua were teachers who recognized the importance of creativity for accomplishing exemplary science teaching. The Iowa Chautauqua included major funding from: National Science Foundation (NSF); the U.S. Department of Education, the MacArthur Foundation, and various interested business groups such as the Iowa Utilities Association.

Penick has argued that teachers need to encourage student creativity in the following ways:

1) *Asking questions that demand thoughtful answers:* No "yes/no," recall, or answers students already "know";

2) Waiting for responses: Do not rush; if a real question is asked, wait for the answer. And wait again and expect multiple responses;

3) Accepting unusual ideas, questions, or products: Make No judgments, just acknowledge and ask for more;

4) Asking students to examine causes and consequences: Structuring activities so that decisions must be made and allow students to do so;

5) Modeling creative thinking, action, and decision-making: Asking creative questions, express curiosity, make the classroom stimulating;

6) Teachers should model collaboration themselves: This should be done helping, encouraging – and not telling and deciding! (Penick, 1996, p. 90)

For this study teachers experiencing the Iowa SS&C (Yager & Weld, 1999) project were chosen to illustrate the successes of the changes in all Six Domains. They were chosen because Teacher Leaders had experienced more fully constructivist teaching and the problems with change themselves while also helping new teachers as part of Chautauqua efforts in their own and nearby schools spanning a decade. Further, all science teachers in the twenty districts were also involved with administrators and parents who were aware and supportive of the reform efforts. The Iowa SS&C effort was by far the largest continues funding over a ten year period that illustrated the reform agenda. The sequence of activities was set and involved the central staff at all of the locations in the State – consisting of five per year.

The more recent Title IIa Chautauqua efforts were basically smaller efforts involving one former SS&C center -- and occasionally a new one. But, none of the Title IIa efforts ever involved all science teachers for a district and there was no assurance of any local commitment for follow-up efforts. Use of SS&C schools, teachers, and students provided a means for continued data collection with new teachers and new grade levels added each year and use of many as the same Teacher Leaders over a period of several years. Admittedly this is not a look at a single PD effort for one particular year. It does, however, show what is possible when there is district support and continued collaboration over time. The Teacher Leaders became part of the leadership with interested citizens joining in statewide efforts to indicate their interest and support for the reforms and use of constructivist learning theory – as well as projects that involved the whole community.

Centrality of Five Teacher Leaders

The five Teacher Leaders, Marge, Harold, Gretchen, Larry, and Lonnie who were partners in the study which was carried out over a five year span. Other Teacher Leaders were involved but were not involved for the same five years and were not a part of the results reported for this study. For this study the five Teacher Leaders agreed to plan action research projects, report on changes in student learning, and explore varying teacher and student foci related to creativity. The teachers planned the year-long efforts during annual Leadership Conferences (See Appendix A). Each of the five Teacher Leaders agreed to identify a teacher colleague in the same or nearby school who had not benefited from a Chautauqua sequence. Science-Technology-Society (as previously specified) was the focus for the teaching changes with respect to creativity and its effort to encourage specific changes in students and other teachers. The research was set up for collecting student views of facets of creativity in the classrooms of the five Teacher Leaders and to compare them with the situations in classrooms with teachers having no Iowa Chautauqua-type experiences using creativity as a form of science.

Every effort was made to keep all classes (the STS focus and the non-STS) similar in terms of class size, gender, grade point averages, diversity, and concern for “good” teaching.

The difference was to be on use and development of creativity as a feature of science, science teaching, and most importantly student learning. All was focused on examples of Creativity in life as well as with experiences with STS as perceived by the Teacher Leaders involved.

The five Teacher Leaders decided on how creativity would be handled, how often, and in what contexts. In several instances past students were involved in sharing the features of creativity and the focus they had experienced. All five teachers had been involved with Chautauqua for periods of at least four to seven years. All teachers at the Leadership Conference were made aware of the study and a chance to offer advice concerning the nature of the features that could be observed and/or available in the classrooms of the five Teacher Leaders and the student teams at work in their classes and often beyond the school itself.

Many Action Research projects were undertaken by nearly all Iowa Chautauqua Teacher Leaders and their students. For the effort regarding this study where Creativity was the primary focus, all five Teacher Leaders decided to collect evidence from one or more of their classes. The students were informed about the Action Research goals; namely to demonstrate teacher leadership and student responses that indicated their views of the use, evaluation, as well as their own display of creativity activities and actions. The students helped describe creativity in terms of what their teachers did and expected them to do. In many cases the research recommended initially was shared with students enrolled in other STS efforts. This explains the student differences in terms of the questions and results obtained from multiple sites where student responses were collected and how the instruments used varied across the five sets of results – for each of the five Teacher Leaders, namely, Marge, Harold, Gretchen, Larry, and Lonnie. There were differences in terms of exact grade levels for middle schools and how the creativity facets compared with the various results obtained. None of the Non-STS teachers were named; nor were they fully aware of the purpose of the study nor the importance of the use of Creativity as content as well as a facet of teaching. This means that the results were more expected from the Teacher Leaders – more so than what was expected and or desired from the teachers and students from the Non-STS schools, class sections, and students.

Recently the NSTA has revised its Position Statement on STS broadened the focus for teaching to include all efforts that focus on "Teaching Science and Technology in the Context of Societal and Personal Issues" (NSTA, 2010). This published report was influenced by the results from the Iowa Chautauqua assessment instruments. The focus on technology and teaching where students were more central and aware of and experienced with the STS features – even though the Technology term was not used per se! It was described by the five Teacher Leaders as inclusion of the human-made world and its focus on why and how the results of science could be used in the production of devices and methods which can be used to provide "human betterment".

Results Produced from the STS and Non-STS Classrooms

The results obtained from the five teachers and sections of their middle school students (i.e., grades 5 through 10) are indicated in Figure 1 for classes taught by Marge, Figure 2 for classes taught by Harold; Figure 3 for classes taught by Gretchen; Figure 4 for classes taught by Larry; and Figure 5 for classes taught by Lonnie. The 32 factors that the five teachers and their students decided to include were used as the instrument for defining the focus on Creativity that was envisioned to be the major outcome of this study. In many respects some of the features were more important and/or more specific than what was recommended by other teachers and/or researchers. It probably should be mentioned again that similar planning was not used in professional development efforts for any of the control teachers. There was but one “control” group of teaches for each of the five Teacher Leaders who were actively involved with new groups of other middle school teachers and their students. Many of these efforts were established with involvement of principals and parents as new reforms were undertaken.

The five figures indicate the student perceptions of their teachers in one or more of the sections taught by the five teachers, namely, Marge, Harold, Gretchen, Larry and Lonnie. The control group of teachers remained nameless and without identifying precise teaching locations. They had not benefited from a four week summer workshop which focused on the importance of creativity to science and science teaching. But, they were interested in creativity as a goal and a form of content, especially as the pre and post data were analyzed. In several instances the results were used after the Action Research efforts were underway to encourage PD efforts of those teachers for the following year.

Although not specifically involved in the results, there are differences indicated in the five tables – largely as a way of indicating student input and interpretations related to student perceptions or those of their classmates and their own roles in learning. Every effort was made to use students as partners in the STS settings and not merely to be recipients of teacher expectations. At times results were collected by student counselors or other leaders with no names of actual teachers involved. All were anxious not to intimidate students – or to use the results for teacher grading purposes or as an influence for interpreting the classrooms and teaching experiences encountered.

Figure 1 indicates the percentage of students in STS and Non-STS Classes with respect to teacher focus perceived by students regarding creativity actions in the STS sections taught by Marge. The five descriptors used to collect student interpretations include what “my teacher does” related to his/her expectations regarding aspects of Creativity where student perceptions were tabulated and STS features compared to results from those in Non-STS classrooms. It appears that the students in the STS sections were much more mindful of Creativity and what their teachers viewed as important in their teaching and more importantly how “student learning” was described. The observations noted from the survey instrument were developed during earlier experiences with new teacher groups and Action Research at other times in which teachers, schools, and students had been involved earlier.

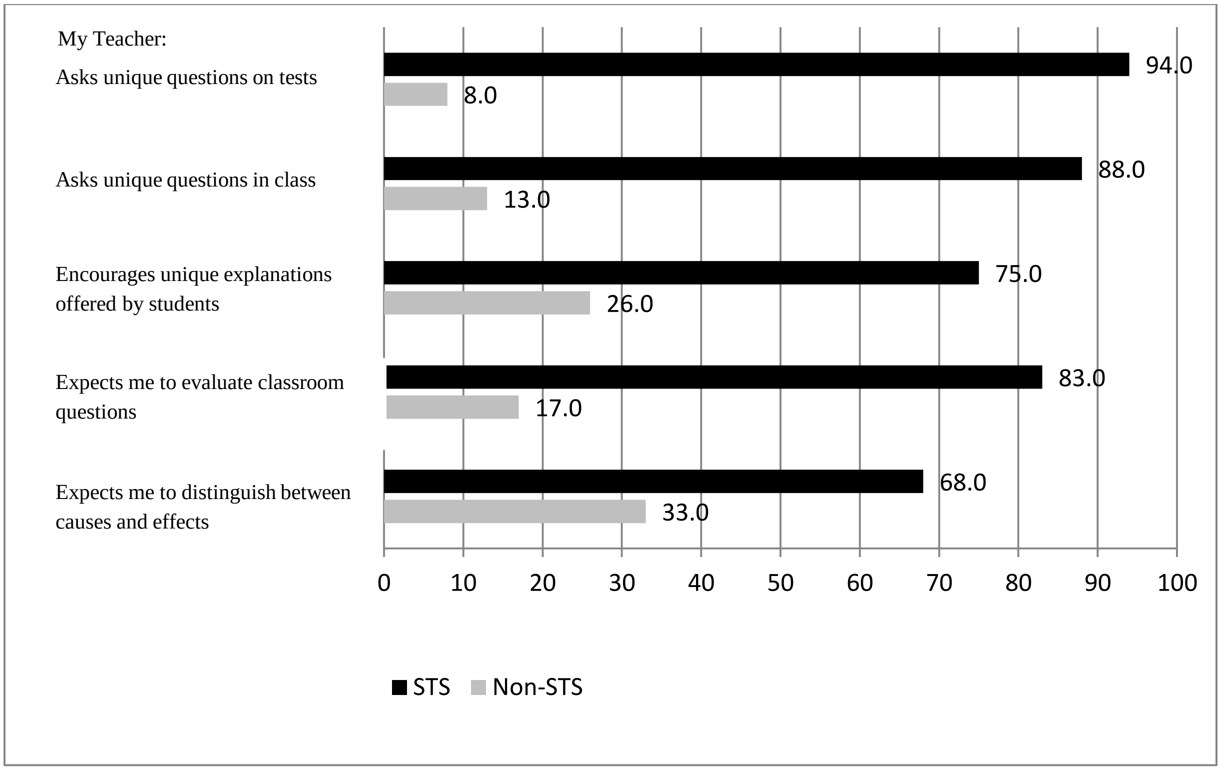

Figure 1. Percentage of students reporting on teacher expectations regarding aspects of creativity in STS and non-STS classrooms.

The observations included students reporting on teacher expectations which illustrate expressions of creativity reported by students in STS and Non-STS classrooms. Figure 2 with the STS section taught by Harold similarly indicates results from students regarding their ideas of what their science teacher expected (again, with respect to specific features of Creativity). The specific expectations were identified with six features, namely: 1) Students asking for help and directions; 2) Students illustrating ideas suggested by other students; 3) Student use of issues in the classroom and the whole community; 4) Students providing evidence for explanations offered; 5) Student explanations evaluated by others; and 6) Students asking intriguing questions of other students. Again, the students in the STS sections were clearly focused on precise creativity features and the role they should and could play in science classrooms. No such foci were present in the Non-STS classrooms.

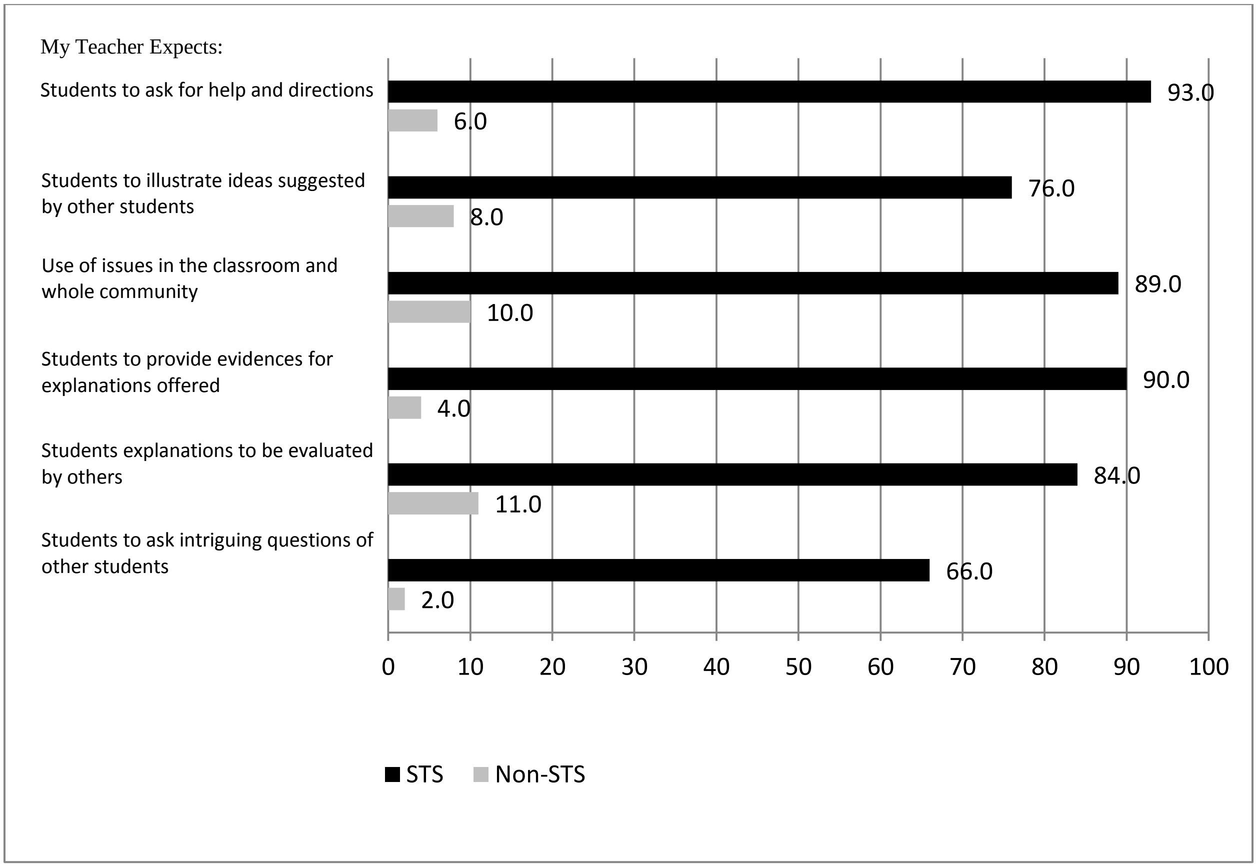

Figure 2. Percentage of students reporting on teacher expectations which illustrate creativity in STS and non-STS classrooms.

Figure 3 as taught by Gretchen indicates student reactions concerning the importance of student evaluation of their own projects as well as those of other students with their projects. Again, the points were designed to be an indication of evidence reported by students in an STS section compared with students in the Non-STS class. The students experiencing STS were clearly aware of and supportive of the focus on the Creativity features identified. Other students in sections assisted with the elaboration of creativity features. The students were clear in reporting teacher encouragement in learning regarding the use of student inputs used and their use for evaluating real success in science classes. Additionally, students suggested ways to involve other students in their efforts. They also identified and used questions related to personal problems. They found and used answers that had personal value. These included student use of science in their daily lives. Students related science to current personal/societal issues. They helped assess the value and actual use of project results in other settings and situations. There were major difference tween student sin STS and Non-STS sections.

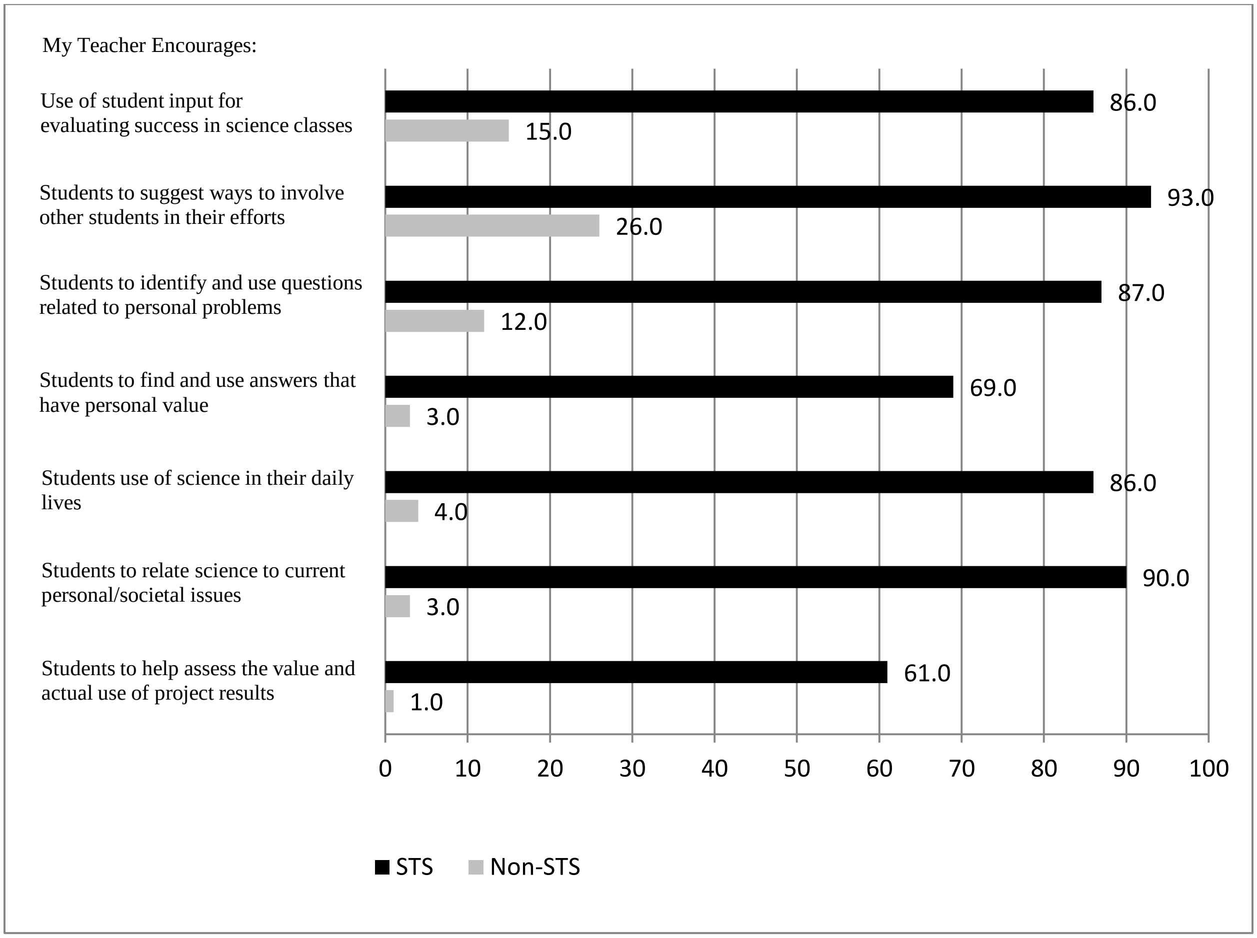

Figure 3. Percentage of students who evaluated their own science projects as well as those offered by other students in STS and non-STS classrooms.

Figure 4 as taught by Larry indicates student responses to classroom efforts to determine what students felt their teachers expected. Again, there were vast differences between student perceptions of what their teachers expected between students in the STS classes and those in Non-STS classes. The eight facets asked included information regarding the help and involvement of other students; the use of varied sources for needed information; new ideas and explanations offered and tried; how multiple evidences were used to support ideas offered; participation of students in groups and work in teams; encouragement of arguments and debate among students; encouraging students to gather information outside of school; and encouraging use of information from members in the community. The students in Larry's classes indicated clearly their views regarding certain aspects of creativity. How they compared with the situations where students had no experience with STS teaching or learning provided vast differences.

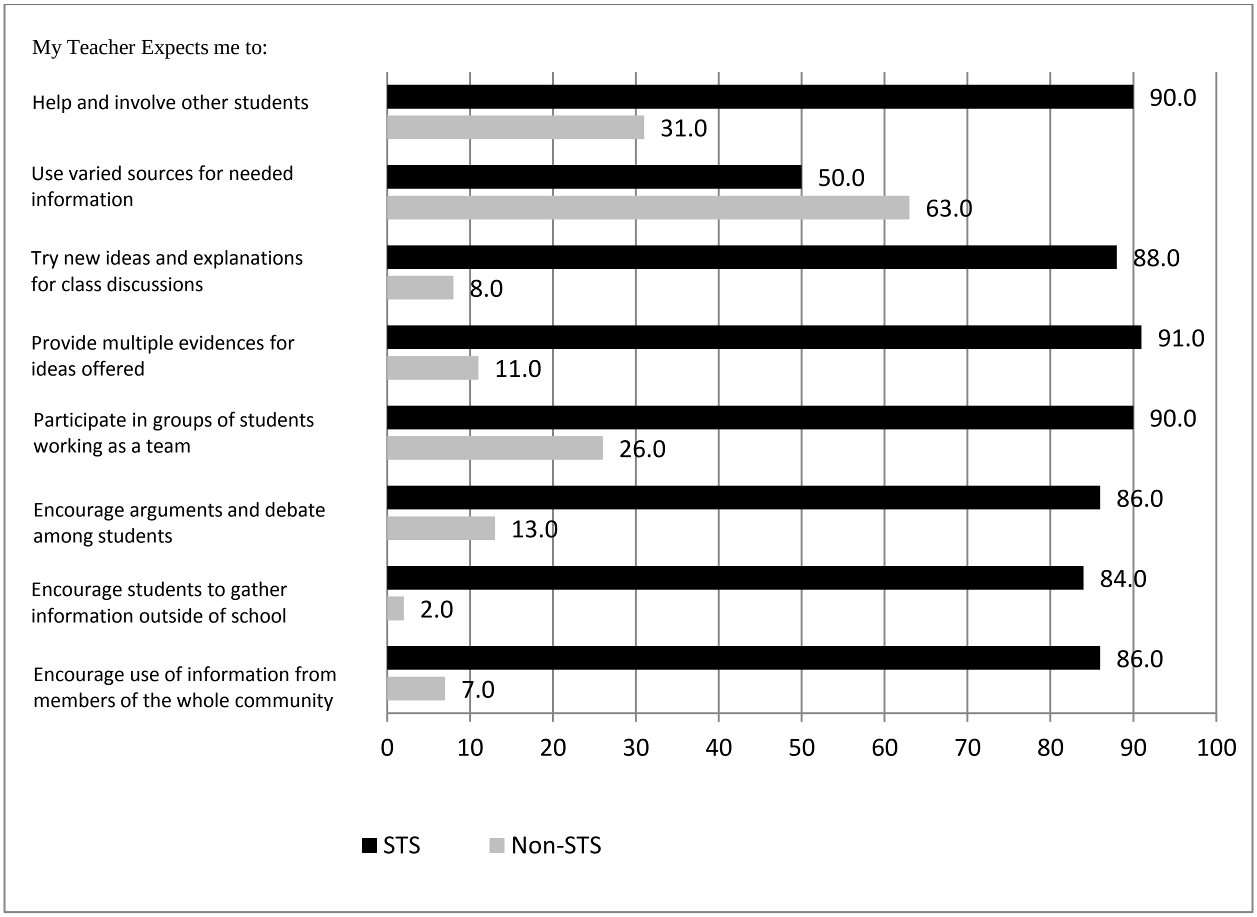

Figure 4. Percentage of students responding to teacher expectations resulting from student-student interactions in STS and non-STS classrooms.

Figure 5 as taught by Lonnie as a Teacher Leader focuses on creativity with respect to how students were encouraged to learn, especially in creative and in non-directed ways. "Lonnie" was seen as encouraging students to suggest multiple examples to support their own ideas; saw their teacher as liking students who investigated their own ideas; saw their teacher as aiming to use class discussions to share more ideas and interpretations among students. Lonnie was seen as being willing to change directions and actions regarding class activities; students saw Lonnie as liking to support collaboration and many varying interpretations among students he was willing to judge student successes and actions while encouraging whole class discussions.

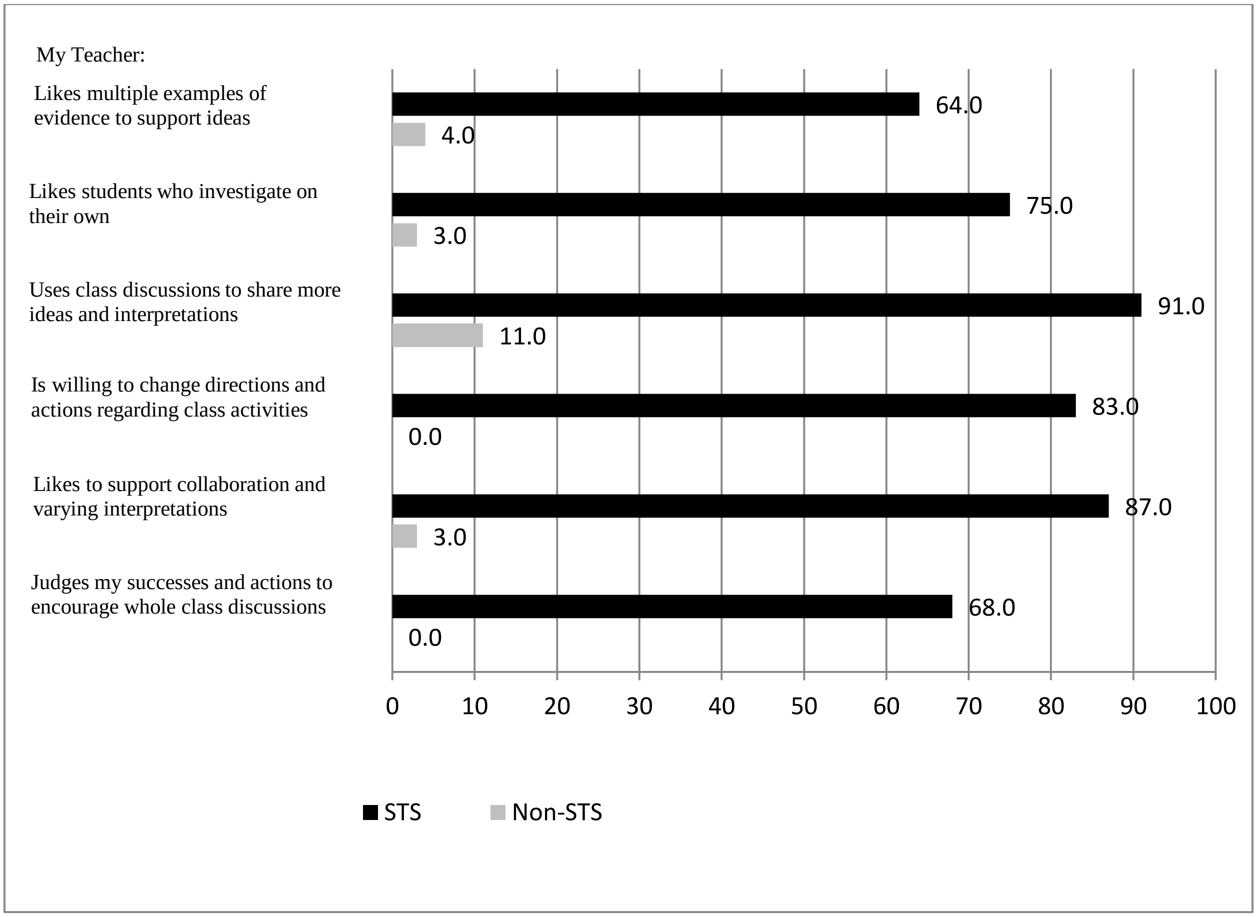

Figure 5. Percentage of students reporting on their views of science learning in STS and non-STS classrooms.

In all five situations the differences in student percentages were vastly different between students in STS and those in Non-STS classes! Further, the focus was mostly student-centered in the STS sections. But at times the students experienced exercises and use of "teacher behavior with information which was shared concerning what the textbook expected students to remember". But, the use of such structures was always associated with "why" is this important? How can it be used? The differences included in the tables all define what STS and the National Standards advocate for students "doing" real science. It also indicates the value and importance of creativity as an important teaching and learning domain for science. Similar observations were seldom found in the Non-STS classrooms.

All students in STS sections were involved with SS&C Teacher Leaders with varied results reported by students for the five Teachers Leaders (and their control group counter-parts). The five figures include data reported from multiple workshops involving more than 1,000 teachers K-12. As indicated earlier each Chautauqua generally included 30 teachers (10 elementary, 10 middle school; and 10 high school) even while SS&C was in progress. Again, for this study with SS&C focus included only teachers, students, and classes for grades 5 through 10. The student numbers for class size for each STS and Non-STS were nearly the same. It should be noted that the numbers of new teachers added for the two Short Courses (October and April) included a few collaborating teachers who were not enrolled in the four week summer workshop.

Review of Results and Their Implications

The five figures generally provide the results of this study – without specific comparative analysis among the five Teachers Leaders. It is clear, however, that creativity changed little -- and its use is positive for all teachers from an STS perspective. Convincing evidence is offered for the success of sections taught by the STS teachers as opposed to those enrolled in control groups. The total of Non-STS teachers and students represent only 14 percent of the teachers and the students that comprised the non-STS groups.

All information available indicates that SS&C Teacher Leaders were successful in helping students learn and experience creativity and its being seen as an "enabler" for learning and "doing" real science. The results reported for the five Teacher Leaders are similar and show impressive increases in student and teacher creativity. The results show stark differences from the students in Non-STS classes. Of interest is the fact that SS&C as such began with middle schools and proceeded only through grade ten before other support was terminated. This is too bad since the high school curriculum is mostly structured around disciplinary 9th and 10th grade biology, 11th grade chemistry, and 12th grade physics as typical in most schools. The New Standards to be released in 2011 may provide interesting new directions for curriculum as well as the place for further STS reforms. The results noted in the figures are reported without comparative analysis. It is clear, however, as to how creativity changed and provided evidence for the practice of STS teachers as opposed to those reported in each of the control groups.

Conclusions

Creativity can be argued as the most important facet of *content* for school science. The earlier reports regarding the centrality and actions indicating creativity was used as a basis for this study. Creativity is a content that provides an entry for study of science defined as the explanations of the objects and events encountered in life where students become involved with actually "doing" science. It provides evidence that the first goal of the National Science Education Standards (NSES) can be reached. Exploring objects and events experienced in the natural world is something that all humans do! Why do positive perceptions typically worsen the longer science is encountered in most schools? The results of this study show clearly that creativity is enhanced by STS efforts and that it improves each year with STS teaching. Although not reported in this study, student attitudes do improve instead of declining when creativity is encouraged and used (Ali, Yager, Haciemenoglu, & Caliskan, 2011; SUNY, 1996; Yager, Liu, Varrella, 1993). Similarly, results of Lee and Erdogan (2007) indicated that students' attitudes toward science between classes taught with traditional methods and those with STs approaches significantly different. Positive attitudes of students toward science increased in STS oriented classrooms, whereas the positive attitude decreased in classrooms with traditional methods. Involved students become even more knowledgeable of science and see it as explorations and not merely information provided and agreed upon in terms of its validity by practicing scientists. Creativity is a vital feature of doing science which is featured by questioning, providing answers, and offering evidence for the validity of explanations of teachers and learners.

Several specific conclusions can be identified from the five figures included as the primary results of this study as reported by the STS students comprising the STS classrooms that were taught by Marge, Harold, Gretchen, Larry, and Lonnie who were successful SS&C Teacher Leaders. Their views were compared to those from the five control group teachers from the same or nearby schools. These general conclusions include:

- Teacher Leaders were seen by their students as frequently asking and questioning other students and using varied assessment efforts (like those required of science itself).
- The Teacher Leaders expected students to question.
- Teacher Leaders expected students to differentiate between causes and efforts.
- Students in STS sections expected students to request help and involvement from other students as well as their teacher.
- In STS classes, students were expected to identify current issues and use them to initiate "doing" science and using creativity.
- In STS classes, students are expected to offer explanations for happenings and to provide evidence of their validation.
- Students in STS sections expect involvement and evaluation from fellow students.
- Students report that STS teachers use student efforts and ideas for determining success.
- Students welcome the involvement and help of other students as partners in collaborative teams.
- Students experience science as STS from Teacher Leaders who use students in posing questions and evaluating successes in science classes.
- Students in STS classes are expected to ask thought promoting questions as a starting point for all science.
- Students in STS classes see science as important in dealing with personal problems.
- Students in STS classes see science as important in dealing with societal problems.

- Students see science as a subject that affects and improves their daily lives.
- Students in STS classes see science as tied to current events.
- Students in STS classes see science occurring in local schools and the communities.
- Science, when approached by STS teachers, requires student involvement in assessing learning and use of it in homes, schools, and community.
- Science helps students to use a variety of sources of information for studying across the curriculum.
- Arguments and debates are basic to "doing" science.
- Science from an STS standpoint is not seen as something confined to science classrooms.

What the Specific Results Indicate

All the general conclusions pertain only to what the five figures illustrate by comparing student responses in the STS and control sections. In one sense the results generalized from the students in the STS sections are complete reversals of the results from students in the Non-STS sections.

A look at specific differences between the results of the five tables follows. Figure 1 presents (Marge) expectations regarding aspects of creativity in STS and Non-STS classrooms. Percentages of the positive reports by students varied from 68% to 94% in STS classrooms and from 8% to 33% in Non-STS classrooms. One of the most striking findings was the large differences between percentages of the teachers' test questions which were found to be unique by students. Ninety-four percent of the participants in STS classrooms agreed that their teacher asked unique questions on tests. This percentage reported in Non-STS classrooms was 8%. It is clear that STS oriented teachers are more successful than others in how to get student attentions for tests for evaluation purposes. On the other hand, the least difference occurred between percentages of teacher expectations on the subject of what their student understandings were regarding cause-effect relationships (STS=68%, Non-STS=33%). These findings show that teachers who use the STS approach consider their students to be capable of using their creativity in their classrooms. Students are central!

Figure 2 presents students' responses about their teacher (Harold) and his expectations with regard to features of creativity as also indicated in Figure 1. For instance, a huge proportion (90%) of students in STS classrooms believed that their teacher expected explanations from them which are justified as evidence. Conversely, 96% of students in Non-STS classrooms reported that their teachers did not expect them to use evidence to support their explanations. Parallel to the results reported in Figure 1, Harold's students thought that their teacher expected them to ask intriguing questions for their fellow classmates (66%). Oppositely, this percentage was only 2% for the students in Non-STS classrooms.

The findings in Figure 3 clearly revealed that STS oriented teachers encourage their students to integrate science in their daily decision-making efforts related to personal/societal issues that are important to them. According to these results, it can be said that students in STS classrooms have greater appreciation of the value of other student ideas. Additionally, Gretchen's students believed that using project results (which were undertaken by them in actual life) is an important component and generally important for life. Positive student reports of their teachers in STS classrooms ranged from 61% to 93% and from 1% to 26% in Non-STS classrooms.

Congruently, results indicate that student-student interactions are expected and essential as a teacher expectation in Larry's STS classroom (Figure 4). Generally all percentages about student-student interactions varied from 86% to 90% in STS classrooms but only from 8% to 31% in Non-STS classrooms. Apparently, Larry supports his students in generating arguments and discussing their validity with explanations in his classrooms. Similarly, Larry encourages his students to provide multiple pieces of evidence for ideas (91%), and to gather information outside of school (84%). Maybe the most interesting finding in this study is the following: The percentage of students in Non-STS classes who thought their teachers use multiple sources for needed information (63%) was more than the one in STS classes (50%).

Figure 5 shows student views of learning regarding their teachers' actions in the classroom. Consistent with the most of the previous results, Lonnie's students had more positive beliefs about learning in comparison with students in Non-STS classrooms. One hundred percent of the students in Non-STS classrooms thought that their teachers did not like using specific directions for student actions regarding class activities and did not support student successes while encouraging whole class discussions.

The Design Focus

Students who have experienced Iowa Chautauqua excel in illustrating and improving their creativity skills and actions. They are more motivated and illustrate the features demanded of real learners. They report that "science" affects their daily living and their participation generally in society. They see their teachers as active learners and enjoy the actual "doing" of science. There is emerging evidence that students who experience the reform elements characteristic of Iowa Chautauqua ideas and focus on involvement with the processes of science itself excel in college to a greater degree than do students without such experiences.

Generally, students who have experienced Iowa Chautauqua excel in illustrating and improving their creativity skills and actions. They are more motivated and illustrate the features demanded of real learners of science. And, such leaners do so by actually "doing" science rather than studying about science and the evidence accomplished from and among practicing scientists. Students with STS experiences report that "science" affects their daily living and their participation generally in society. They see their teachers as active learners and enjoying the acts of "doing science" themselves. There is emerging evidence that students who experience the reform elements resulting from Iowa Chautauqua for one full year (and up to three years) illustrate the needed Professional Development with evidence of its effects as an important a means for accomplishing change. The involvement with acts of creativity are better preparation for science in college to a far greater degree than do students without such experiences. More importantly, though, is seeing science as important for all as ways of using science in all aspects for future thinking and personal endeavors!

Students in STS sections see the importance of students first needing to know before they are able to learn from teachers, textbooks, or curriculum. Students seemingly need to want to learn in order to learn! How can so many science classes in K-12 settings continue to be devoid of examples of students experiencing science itself? Too many K-12 science courses should be labeled focusing on "what scientists have found over the years which explain the natural world and how their questions have been central to finding answers. It is also important for all to see how the explanations have changed over time (sometimes drastically). The emergence of new technologies in recent years is a vivid example. Too often students do not have positive attitudes about science study nor are they provided with any opportunities to become creative in defining problems and working with their solutions. This situation may explain why student attitudes about science are often so negative and why they worsen the longer students are enrolled in traditional science courses (K-12) (Ali, Yager, Haciemenoglu, & Caliskan, 2011; George, 2006; Jarvie, & Pell, 2002; Reiss, 2004; Simpson & Oliver, 1985, 1990).

"Reforms" in classrooms result in situations where science is seen and experienced as creative interpretations, taking personal actions, and proposing solutions of real problems. These do not come from books or other materials. Student attitudes improve and creativity grows when students help in determining the activities, identifying the problems, developing interest in solving them, and providing ways that evidence is gathered to support their own ideas. Many see such classrooms and teaching as enhancing learning while also changing the teaching focus in science classrooms.

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Appendix A

The IOWA CHAUTAUQUA MODEL: A Professional Development Model Approved by the National Diffusion Network

LEADERSHIP CONFERENCE

A Two Week Long Conference Designed To Prepare Teacher Leaders to:

1. Organize staff teams for conducting a workshop series each for 30 new teachers. The staff team consists of:
   a) One lead teacher per ten new teachers
   b) Scientists from a variety of disciplines
   c) Scientists from industry
   d) School administrators
   e) Science Coordinators as chair of staff teams
2. Organize and schedule each workshop planned for a given summer
3. Prepare materials for publicity and recruitment
4. Work on examples of specific assessment strategies, including:
   a) Six domains for teaching and assessment foci
   b) Use of reports and other written materials from past years
   c) New Action Research plans for Teacher Leaders
   d) Focus on how students use science concepts and process skills in new contexts
   e) Use of videotapes of classroom to study teachers and students

FOUR WEEK SUMMER WORKSHOP

Experiences that Characterize the Iowa Chautauqua Professional Development Model include:

1. Special activities and field experiences that relate specific content within the disciplines of biology, chemistry, earth science, and physics.
2. Make connections between science, technology, society within the context of real world issues.
3. Examine societal issues such as air quality, water quality, land use/management that can be used as the context for concept mastery and process skill development
4. Use of personal problems for individual projects (related to health, natural hazards, population growth)
5. Every staff member and every teacher participant selects at least one issue/problem and completes at least one Action Research Project regarding it.
6. Plans for continuing Action Research in the classrooms over the next academic year.
7. Completion of several videotapes of teaching experiences with both self and group analyses.
8. Organize 3 grade level groups, e.g., K-5, 6-8, & 9-12 (with up to 10 in each group) for continuing collaboration during the next academic year.

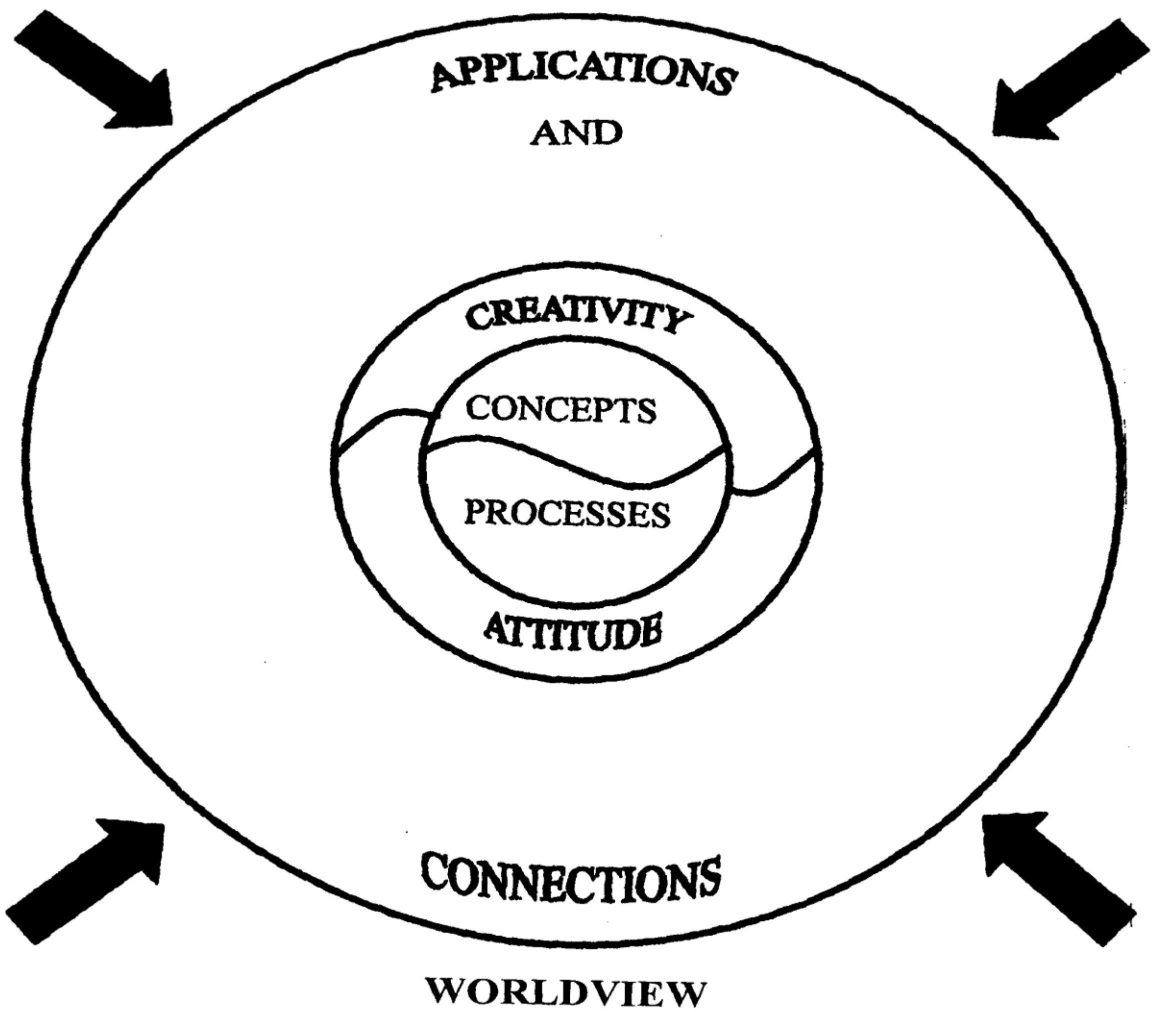
ACADEMIC YEAR SHORT COURSE SERIES

(3 days) Fall Short Course		Three Month Interim Projects		(3 days) Spring Short Course
20 hr Instructional Block (Thursday pm. Friday, & Saturday)		**Plan for 3-5 Week Module**		**20 hr Instructional Block** (Thursday pm. Friday, & Saturday)
Activities Include: 1. Review problems with traditional views of science and science teaching 2. Outline specific features of the More Emphasis features from the NSES in a science context in terms as grade levels, curriculum frameworks, and the school community 3. Define techniques for developing 3-4 week modules and assessing their effectiveness in teaching 4. Select tentative module topics 5. Practice with specific assessment tools in each of the six Domains. 6. Use “Lesson Study” designs 7. Analyze one videotape involving a teacher volunteer with each grade level group to be shared		Activities Include: 1. Developing instructional plans for minimum of twenty days 2. Administer pretests in six domains 3. Develop a module to illustrate the reforms featured in the NSES 4. Collect posttest information 5. Communicate with regional staff, other Lead Teachers, and central Chautauqua staff 6. Complete and analyze one class videotape with colleagues from a particular site 7. Plan at least one Action Research Project for all in each of the grade level group(s)		Activities Include: 1. Report on experiences 2. Report on assessment efforts 3. Interact on new information concerning group and individual projects and new teaching strategies 4. Show one videotape of teaching in one class for each group level 5. Analyze changes from summer, fall, and spring 6. Plan for involvement in professional meetings over the summer and following fall 7. Plan for next-step initiatives, including complete reorganizing of the existing course

Note: (Kimble, Yager, & Yager, 2006, p. 314)

Appendix B

The Six Domains for Science Teaching and Assessing Science Learning



Concept Domain
Provess Domain
The typical focus for traditional teaching

Creativity Domain
Attitude Domain
The two enabling domains

Application Domain → Using concepts and processes in new contexts

Worldview Domain → Examining the philosophy, history, and sociology of the whole science enterprise (Yager & Weld, 1999, p. 173)