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Comparing Science Instruction Methods in the High School Classroom Setting: A Case Study in Inquiry-Based Methods.

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Comparing Science Instruction Methods in the High School Classroom Setting:

A Case Study in Inquiry-Based Methods

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by

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ABSTRACT

Comparing Science Instruction Methods in the High School Classroom Setting:

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The science education system currently in place in the United States does not adequately prepare students to compete well with international students. The development of new teaching methods is essential to ensure improvement of the system and provide its students with better scholastic achievements and employment opportunities. Various methods have been studied, with one implemented in a high school classroom to compare the results of the new method with the traditional method of instruction. Rather than the traditional lecture-based approach, Honors Chemistry students learned the theory of the gas laws using inquiry-based methods and hands-on activities. The students were then evaluated using the same assessment as in previous years where instruction was more direct. Preliminary results indicate a 3% increase in the final assessment score using the inquiry method rather than the straight lecture approach.

DEDICATION

I wish to dedicate this project to my family. Without the help and encouragement of my entire family, I would have been unable to complete this process. Most especially, I wish to dedicate this project to my husband Josh whose patience and encouragement have inspired me. Also, I wish to dedicate this to my son Jacob whose existence inspires me to do greater things.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

America's high schools are obsolete. By obsolete, I don't just mean that our high schools are broken, flawed, and under-funded—though a case could be made for every one of those points. By obsolete, I mean that our high schools—even when they're working exactly as designed—cannot teach our kids what they need to know today…This isn't an accident or a flaw in the system; it is the system. Bill Gates

Background: What is the Problem?

In 1983 the U.S. Department of Education's National Commission on Excellence in Education published the report, *A Nation At Risk*.[1] This document reportedly indicated that students in the United States would be the world's best in mathematics and science by the year 2000. The American education system had become riddled with mediocrity, and it had reached the point that it was essential to reevaluate the system itself. Despite the recommendations presented in this report, America continues to fall further and further behind. In fact, American students were ranked 14th of 19 economies in these fields in assessments in the year 1999.[1]

There is also evidence to suggest that there is a marked decline in the awarding of degrees to students in the United States in the fields of engineering and natural science relative to other countries. [1] The number of baccalaureate degrees in natural science and engineering awarded dropped from 3rd to 14th from 1975 to 1999 among 19 economies measured at both times. This alarming decline suggests that other nations are surpassing America in the rate of development of the natural science and engineering workforce. [1]

The American education system is inadequate in the fields of mathematics and science. [2] Though the most recent Programme for International Student Assessment results have indicated a slight improvement in mathematics, performance on science assessments has actually declined between 1996 and 2000 among seniors in high school, with no changes in the performance of students in 4th and 8th grades on the Trends in International Mathematics and Science Survey .[2] In fact, on the 2003 Programme for International Student Assessment (PISA) tests, 15 year-old students in the United States performed below the international average, ranking at or near the bottom of the 29 nations tested. These tests measure the student's ability to apply mathematical and scientific concepts. Students who take the PISA test are those in industrialized nations only. [1] Results from the most recent assessment of this type were tabulated and published by the National Science Foundation in Table 1.

The United States government has attempted to provide standards for schools and teachers in the form of the No Child Left Behind Act. This legislation discussed more than 50 educational initiatives in over 1000 pages of information. It established goals of high standards and accountability that theoretically are supported by all school personnel.[3] However, many teachers are crying foul as it seems to have had little impact on performance assessments in the last few years. [4]

Table 1: Average performance of 4th graders, 8th graders, and 15-year-olds on International Science Assessments as compared to the United States in 2003

Country	TIMSS 4th grade	TIMSS 8th grade	PISA 15-year-olds
Australia	↓	•	↑
Austria	n/a	n/a	•
Belgium	↓	↓	↑
Canada	n/a	n/a	↑
Czech Republic	n/a	n/a	↑
Denmark	n/a	n/a	↓
England	↑	n/a	n/a
Finland	n/a	n/a	↑
France	n/a	n/a	↑
Germany	n/a	n/a	↑
Greece	n/a	n/a	↓
Hungary	↑	↑	↑
Iceland	n/a	n/a	•
Italy	↓	↓	•
Japan	↑	↑	↑
Luxembourg	n/a	n/a	↓
Mexico	n/a	n/a	↓
Netherlands	↓	•	↑
New Zealand	↓	•	↑
Norway	↓	↓	•
Poland	n/a	n/a	•
Portugal	n/a	n/a	↓
Russian Federation	•	↓	•
Scotland	↓	↓	n/a
Slovak Republic	n/a	↓	•
South Korea	n/a	↑	↑
Spain	n/a	n/a	•
Sweden	n/a	•	↑
Switzerland	n/a	n/a	↑
Turkey	n/a	n/a	↓

Up arrows indicate a higher performance than American Students, while down arrows indicate a higher performance by American Students. A dot indicates similar performance. [2]

Comparison to Finnish System

Results of Assessment Test

In contrast to the American education system, many systems in other worldwide nations have a much different focus. A recent study involving the testing of 15-year old students worldwide indicated that Finnish students were the highest performers in Science and second in Math and Reading of 57 nations tested.[5] These tests, sponsored by the Organization for Economic Cooperation and Development, involved about 400,000 students worldwide. The multiple choice Science and Math tests were designed to measure critical thinking and the application of knowledge. The average score on each of the assessments was 500 out of 1000. Finnish students scored 563 in Science, with Hong Kong second at 542 and American students scoring a 489. In Math, Taiwan was first with 549, with Finland a close second at 548. Again, American students scored below average at 474. Due to a glitch in the reading test, there were no data available for the United States students.

Because of these results, much study has been done regarding the Finnish school system in order to compare it with that found in America. In fact, educators from more than 50 countries have travelled to Finland to observe its teachers and their teaching practices. Most teachers have adopted a relaxed, "back to basics" method of instruction. These observations indicated qualified teachers and responsible students. Though simple, this exemplary combination is not easy to achieve.[5]

Differences Between Finnish and U.S. Education Systems

General Information. There are many differences between the systems found in the United States and Finland. Finnish students have only about half an hour of homework per day. Their schools have no honor societies or valedictorians, and the school systems do not differentiate those considered gifted from the average students. There is very little standardized testing, and students do not begin school until age 7. Many schools do not even have sports teams, prom, or marching bands.

Another major difference between the United States system and that in Finland has to do with the integration of technology into the educational system. In November 2007, officials from the United States Department of Education, the National Education Association and the American Association of School Librarians visited Finnish schools. At this time, these officials observed teachers using chalkboards instead of white boards and transparencies in lieu of power point. [5]

Differences in Teaching Requirements. The differences do not end there. Teachers must hold master's degrees, and the teaching profession is very competitive. On average, more than 40 people apply for any teaching opening. Salaries for teachers in Finland are similar to their U.S. counterparts but the teachers in Finland have more freedom in instructional methods. This translates to customized lesson plans based on national standards. [5]

Educational Funding Differences. Another major difference is, of course, financial. However, the results are somewhat surprising. Each year, the United States spends $8,700 per student for his or her education, while the Finnish government spends only $7,500. However, because Finnish citizens pay a higher tax rate than Americans, funding is very even among all schools. In contrast, richer school districts in America provide many more educational opportunities than the poorer ones. However, in Finland, the achievement gap between the best and worst schools on the assessment test was smallest of any nation tested, suggesting the importance of an equal playing field.[5]

Postsecondary Education Differences. Another difference is in postsecondary education. There is little stress placed on teenage students regarding college because college is free to all students. While there is a degree of competition to get into more prestigious schools, there is no school or group of schools similar to the Ivy League in America. With the removal of this pressure, Finnish students are able to have a more relaxed childhood.[5]

Student Independence**.** With this low pressure childhood and the later start to school, Finnish students are much more independent that their American counterparts. Even first graders in Finland walk to school alone and have much less reliance on their teachers at lunch time and such than American first graders. Finnish students are required to take care of themselves at a very young age both at home and at school, thus encouraging a sense of responsibility among younger students.[5]

Reasons for Finnish Success

Educational Priorities**.** Studies show that one reason Finland has found so much success in educating its children is its effort to instill the love of reading in its students. Part of this stems from a government sponsored program that provides every newborn with a picture book. In Finland, libraries are attached to shopping malls and there is a Bookmobile that travels to remote areas. Despite the fact that there is no other country on earth that shares the same language with Finland, many popular books are translated to Finnish to enable its residents to enjoy the book and benefit from the great literature of other nations.

Observations of all these factors impacted in some way the officials from the Department of Education. More importantly, however, the United States contingent from the Department of Education observed excellent teaching practices that sparked the desire to reform teaching in American schools. These good teaching practices are evident in many ways. In fact, a Finnish high school senior named Elina Lamponen was part of an exchange program where she spent a year in a Michigan high school. The Michigan school had far stricter rules regarding student behavior and required much more homework but lacked more rigorous assignments and dedicated students. In fact, the less rigorous lessons and testing provided by the Michigan school prompted her Finnish high school to require her to repeat the year upon her return. [5]

Problems with Replicating Finnish System in U.S.

The primary problem with replicating the Finnish system in the United States has to do with the homogeneity of the students. [5] In Finland, there are very few students who do not speak Finnish, while in America nearly 10% of students are currently learning English. Additionally, there are fewer differences in socioeconomic status and less disparity in educational background among the students in Finland. In fact, Finland separates its students based on grades during the last three years of high school, with only 53% of the students attending high school and the rest attending vocational programs. It must be noted, however, that all 15 year olds took the assessment test. Additionally, the dropout rate among high schoolers is only about 4% versus the 25% average in the United States. [5]

The differences between the two systems are tremendous. These differences have sparked reform in many American schools. However, some of the differences are simply insurmountable in American schools in our current setup. To model our schools after those of the Finns would require a major overhaul and a change in the focus of the education system in a way that many would find objectionable.[5]

Reasons for Decline of the American System

There are many reasons that contribute to the poor performance American students exhibit on international assessments. These reasons are varied and are still being studied so that improvements can be made. The first of the identified reasons has to do with Teacher Requirements.

Teachers: General Requirements

It is believed that quality teachers are deficient in the current education system. There are simply not enough teachers entering math and science fields. Furthermore, many that do enter the teaching profession do not possess many of the academic skills necessary to do their jobs adequately. In fact, on average, college graduates who become teachers have fewer academic skills than their nonteaching counterparts. Additionally, many current teachers have been found to take fewer rigorous academic courses in high school They also scored lower on standardized tests than their non-teaching classmates. This culminated in the entrance of these students into less prestigious colleges and universities to become teachers, thus exacerbating the issue.[1]

Teachers: Certification Issues

Another issue plaguing United States teachers is the trend in placing teachers in academic areas in which they are not properly trained to teach. This phenomenon is especially prevalent in mathematics and science. In fact, "between 17% and 28% of public high school mathematics and science teachers lacked full certification in their teaching field in the academic year 2002 (the school year that began in fall 2002)."[1] The percentage for middle school levels is even higher. In academic year 1999, between 23% and 29% of public middle school mathematics and science teachers did not have a college major or minor in their teaching field.[1]

With this handicap, it is nearly impossible to provide students with the best possible education. The basic truth is that there are not enough qualified teachers in mathematics and science. In fact, the rate that college students received certification in math and science education declined from 1990 to 2002. [1]

<u>Teacher Retention</u>

Another problem to be considered regarding this situation relates to the hiring and retention of quality teachers. One situation that must be discussed is the salary associated with the profession. There has been a very small increase in public school teacher salaries from 1972 to 2002. In 2002, the average salary of public school teachers was $44,367, which is only $2,598 above the salary in 1972 after adjusting for inflation.[6]

Another reason that teachers are in short supply has to do with teacher dissatisfaction with working conditions. This is a very serious issue and is considered the primary reason for math and science teachers to leave the profession for another field. Those teachers who left the education profession reportedly did so primarily to get a better salary or benefits or to retire. These professionals also reported more job satisfaction in nonteaching fields. Another issue involves teacher retention. Some 20% of new public school teachers leave the profession by the end of the first year, and almost half leave within 5 years.[6]

Proposed Improvements

Professional Development Improvement

In response to the problems associated with teacher qualifications, many states have implemented programs to increase teacher development and improve teacher quality. In the late 1990s, professional development in most school systems consisted of a one-time workshop with little to no follow-up. Teachers generally attend professional development conferences for a few hours each year, far less than the 60-80 hours recommended to make any sort of meaningful impact.[7] By the year 2002, all but 2 states required some level of professional development for teacher license renewal. Additionally, 24 states had modified the professional development requirements to align more closely with state standards of learning. By 2004, 37 states had provided financial assistance to fund professional development programs. Additionally, 35 states had already developed and implemented a professional development program for their teachers. Funding for professional development programs was also provided to all districts by 27 state governments. Furthermore, 16 states required and provided financial means to develop mentoring programs for new teachers and 13 states required its districts to provide time for professional development. [7]

Requirements for Teachers

In response to these challenges, states are implementing more stringent teacher standards. Each state has its own standards; for example, Virginia requires its teachers to have completed various education, reading, and psychology courses in addition to the courses in the content area. There are also technology requirements each candidate must meet and minimum scores on the PRAXIS Series tests, which measure knowledge and problem solving skills. Virginia has the highest standards in the nation regarding the scores of these tests; however, the required scores are still just over 75% of the total points possible.[8]

Many states have implemented programs to provide high quality teachers in every classroom. Since July 1, 1995, the Commonwealth of Virginia has increased efforts to improve student achievement through initiatives such as the Standards of Learning.[8] There is also a system in place that demands accountability of both students and schools by measuring how well schools are meeting the standards. This initiative has also compelled education officials to examine the quality of teaching in every classroom. Education officials believe that the quality of teaching is the most important school related factor that improves student performance.[8]

Challenges to Improving Teacher Quality

In order to address teacher quality, three challenges must be overcome. First of all, the number of teachers must be increased. However, increasing the quantity is not the only concern. The state of Virginia must also increase the quality of the teachers it employs. Finally, providing equitable teachers to all school districts, regardless of financial matters or location, must be a priority. In order to accomplish this, a report from the Committee to Enhance the K-12 Teaching Profession entitled *Stepping Up to the Plate…Virginia's Commitment to a Highly Qualified Teacher in Every Classroom* was published . This report attempts to provide comprehensive guidelines to develop and retain high quality teachers. [9]

<u>Report from Committee to Enhance the K-12 Teaching Profession</u>

<u>Recommendation One</u>. The committee made five recommendations along with strategies to implement each recommendation. The first recommendation was to develop a comprehensive database that contained pertinent data on all Virginia teachers. Contained in this database would be data regarding the qualifications of Virginia educators. It also provided information that enabled the division to "better understand how to affect teacher retention and effectiveness." The database also contained information regarding the teachers available for any discipline and to allow educational institutions to predict shortages in different fields before they happen. [9]

<u>Recommendation Two.</u> The next recommendation called for the expansion of teacher recruitment to enlarge the pool for better teacher candidates. This initiative included the development of a statewide marketing plan to attract prospective teaching candidates. It also recommended the implementation of a statewide Job Bank that allowed teachers worldwide to post credentials to match available positions. It also recommended the development of "Teach for Tomorrow" programs for middle and high school students to encourage young people to enter the educational field. It also

provided incentives for teachers who wished to serve in critical shortage areas, male teachers in elementary and middle schools, and for teachers of color statewide. It also recommended an increase in funding to provide adequate compensation to attract and retain high quality teachers. [9]

Recommendation Three. The third recommendation was to expand teacher development programs. It addressed the need for qualified teachers in shortage areas by expanding teacher preparation programs that were higher in quality than the present ones. To accomplish this, teacher preparatory programs needed to be better aligned with licensure standards. This recommendation also indicated the need for an incentive-based funding system that would reward successful teacher preparation programs. [9]

Recommendation Four. The committee also recommended that efforts be expanded to develop and retain good teachers. In order to accomplish this, mentoring programs should be designed and implemented to train high quality teachers. These programs require training and guidelines for mentor teachers along with plans to evaluate mentoring programs effectively. This particular recommendation also indicates the need to provide a more focused professional development requiring each teacher to maintain an individualized growth plan. It also made the provision to ensure that the salary and benefit packages offered to teachers both attract new professionals and retain the current ones. It also recommended that licensure be a multistep process that indicated the level of professional development achieved and also encouraged continuing growth and development of teachers. Finally, this recommendation addressed the need for schools to be positive work environment led by effective administrative professionals. [9]

Recommendation Five. The final recommendation of this committee focused on the type of research necessary to evaluate and train quality teachers. This recommendation defined the most "pressing data needs" of government and education officials, along with teachers and administrators. It also recommended the establishment of a statewide research plan to develop and share data that addressed the fields labeled high priority. This recommendation also dealt with the collaboration of school divisions with colleges and universities, professional association, and state and regional officials to improve research methods. As part of the research program, a Center for Research on the Teaching Profession was proposed. Additionally, it was recommended that state efforts be aligned with regional and national standards. Finally, it recommended the necessity to seek additional funding from both government and private sources to support these initiatives.[9]

National Science Education Standards

Professional Development. The challenges to improving teacher quality are also addressed by the National Science Education Standards, which recommend a changing emphasis in Professional Development. [10] Rather than attending in-service activities designed to impart knowledge, teachers should be used as resources for each other. The National Science Foundation has published National Science Standards related to Professional development that required the teacher to assume the primary responsibility in his or her own staff development. One component of this ownership involves teachers learning how to do science rather than relying on content only. In order to accomplish this, professional development activities should involve teachers as active participants, address significant issues, provide teachers with an introduction to scientific literature or media resources that improves scientific knowledge, and encourage collaboration among teachers.[10]

For professional development to be meaningful, it must also be applicable to the knowledge the teacher already possesses. These activities should serve to integrate all aspects of instruction. Additionally, it is recommended that these activities occur in an environment that allows teachers to observe real-life situations in learning to expand knowledge. Additionally, it is recommended that teachers truly become students and become immersed in an environment of inquiry and process-oriented lessons.[10]

Another issue with professional development as it stands today is its transient nature. The National Science Education Standards seek to remedy this by creating professional development opportunities that are part of a network of lifelong learning. In order for this to occur, the National Science Education Standards stipulate that professional development must provide opportunities to observe and improve instructional practices at regular intervals. Additionally, they must also allow teachers to receive feedback, including peer coaching and journals, regarding their instructional practice that is used to improve methods. Professional development should also employ the use of mentor teachers and advisers to allow novice teachers to improve skills by working closely with experienced teachers. Finally, professional development should give teachers research opportunities to develop new knowledge about science and its teaching. [10]

The final aspect of professional development addressed by the National Science Education Standards requires that the activities and programs themselves are of high quality. In order to accomplish this, the program itself must be based on clear goals shared with all the people involved. These programs must also coordinate different aspects of development over time rather than just at a one-time meeting. This requires a differentiation of professional development for teachers of different levels of expertise. The program must promote collaboration among all people involved in the educational process and recognize the history of the school program itself. Finally,the developmental program must also provide continuous assessment, uses many strategies, and is directly related to the improvement of the program itself. [10]

The National Science Education Standards seek to change attitudes about professional development. According to these standards, professional development should not be something to endure once or twice a year. It should provide teachers opportunities to actually implement changes in teaching practice and attitudes. Ultimately, staff development should improve teaching practices and provide students with a better education. The teamwork mentality employed in effective professional development is essential for the success of the school system .[10]

Student Motivation

Student focus has shifted tremendously in recent years. With the advent of the technological age in which we live, students have been inundated with the newest, coolest technology at the expense of true learning. Many students are now more interested in *how* the information is presented rather than the information itself. Therefore, there are obvious problems with the quality of material actually retained.

Additionally, student focus has also become split in some ways. Rather than focusing on the courses needed to succeed in college, the majority of high school students participate in many extra curricular activities, including clubs and sports, some of which are in season year-round. Students also feel competitive pressures from their classmates and students worldwide to obtain admission into prestigious universities, so they attempt to take many high level courses, some of which may provide insurmountable challenges. This obviously is problematic for that student but is also difficult for the other, more capable, students because class time is spent going over the same concept with higher frequency rather than covering new material.

Future Problems

In order for the United States to remain an economic powerhouse globally, it must better prepare its current students to be future workers. The modern age requires its workforce to possess more sophisticated process skills in math, science, and technology. It is expected that scientific and engineering occupations will grow more rapidly that other occupations, increasing by a projected 26% by 2012 versus the 15% increase expected overall.[1] This translates to 1.25 million additional science and engineering jobs that American students under the current system will be incapable of filling. This trend has been around since 1980 and is expected to continue. Therefore, America's students must be better prepared to fulfill these requirements so as to retain quality employment.[1]

CHAPTER 2

REVIEW OF EDUCATION PEDAGOGY

Educational Theories

Though it is widely accepted that understanding is central in science education, the means by which students obtain this understanding are still debated. Theories related to the procurement of understanding focus on the basic premise that learning is an active process regardless of the level of the learner. [11] Various theorists have suggested a myriad of processes. Piaget began this investigation by stating that learning process begins with "the acquisition of organized knowledge structures and the gradual acquisition of strategies for remembering understanding and solving problems ".[9] Other theories, such as the one developed by educational theorist Lev Vygotsky focus on social interaction as the basis of learning. Furthermore, Ausubel studied the necessity of relating information, regardless of the means by which it is obtained, to "existing cognitive structures so that the learning process is complete.[11]

Teaching Methods

These educational theories dramatically impact the methods a teacher employs as part of his or her instructional practice. Because students have preconceived notions about learning and the world that surrounds them, teachers are faced with the additional challenge of identifying these notions and using them to aid instruction. The ideal situation, quite obviously, is one that can provide the integration of the information already stored in a student's brain with new information, the combination of which results in a more meaningful understanding of content. Deciphering these situations is especially challenging and presents, at times, overwhelming challenges .[11]

Effective Education Indicators

Contextualization of Information

In order for science instruction to be effective, students must have the ability to contextualize information. Obviously, factual information is important but its usefulness is dramatically decreased without a broader scope. Because they are teaching for understanding, educators face demands that exceed the demands of either direct instruction or open inquiry .[11]

There are certain requirements for this to occur. First, teachers must have adequate knowledge in their fields of study. Furthermore, teachers must be able to employ a variety of instructional methods and provide various activities to represent this knowledge. Finally, it is essential that the environment enables student learning, meaning that the teacher must be an effective classroom manager. [11]

Educational Improvement Studies

The Case Study in Science Education

The premise that the most effective instruction occurs when teachers are able to provide students with the ability to contextualize information is not a new concept; however, studies in recent years were the first to study the extent to which effective science instruction is actually occurring. The first of these, entitled *The Case Study in Science Education* began in 1978. [11] This study involved the evaluation of 11 school districts in the United States. The study presented the needs and conditions of the educational processes for Science, Math, and Social Sciences. A variety of evaluations and results ensued that rated both instructional methods and content taught. Some observers reported classes that stressed concepts and provided an engaging learning environment. However, the vast majority of these classes observed provided an overemphasis of facts that were irrelevant to students .[11]

Inside the Classroom

General Information. In response to the dismal results of the *Case Study in Science Education*, a more in-depth study followed. The *Inside the Classroom* study provided new information about teaching for understanding and its place in the nation's schools. This study provided information about nearly 200 science lessons nationwide that were considered representative of national curriculum standards. The members of the study also interviewed the instructors of the lessons. Additionally, the lessons were also analyzed in many ways, including the quality of content provided and the extent to which the environment was conducive to learning. Their assessments were based on the likelihood that the lessons would increase understanding and enhance the students' abilities to "do" science .[11]

Evaluation Criteria. The *Inside the* Classroom study evaluated lessons based on several criteria, such as the quality of teacher questioning. Once all observations were made, the lessons were rated using the following system:

Level 1—Ineffective Education

A—Passive Learning

B—Assignment of an activity for activity's sake

Level 2—Elements of Effective Instruction

Level 3—Beginning stages of effective instruction

A—Low

B—Solid

C—High

Level 4—Accomplished Instruction

Level 5—Exemplary Instruction

The lessons rated as 3 or more were observed to engage students and enhance understanding that science was based on process rather than memorization of facts. The study reported that 62% of the 200 lessons were low in quality, receiving ratings of 1 or 2, while only 13% were considered high in quality, receiving ratings of 3-C or higher. This study indicated that in most situations, there was an absence of teaching for understanding. It is also important to note that a portion of the 13% rated as high in quality were traditional in nature, with the majority being inquiry based. The one unifying characteristic, however, was the level of student engagement during the learning process. While most lessons that were part of the study contained important content, they were nonetheless ranked as poor. The implication of this is substantial, indicating the tremendous problems in science education today .[11]

Educational Improvement

Definition of Inquiry

There are mixed feelings in the education community as to which method of instruction is better. There are also significant questions regarding the definition of inquiry itself. Some believe that inquiry should assume an instructor-driven guided approach, while others believe that students should devise their own models and questions.

Some educators define inquiry as the employment of hands-on activities, but others argue that these activities do not engage an active thought process. Still others argue that computer simulations and experiments are inquiry activities. Despite the disagreement about the strategies themselves, there is a general agreement that science education should focus on understanding both content and the importance of scientific process. The balance between these two is the primary focus of inquiry .[11]

Problems with Inquiry Methods. A primary concern related to inquiry deals with the ever-increasing time constraints placed on teachers. With such a limited amount of time, some educators are concerned that the more student driven the inquiry, the fewer actual concepts the student has time to learn. With the advent of end-of-course testing, many educators and education systems have changed focus. Most education systems focus on the quantity of material covered. Many states have adopted their own standards that vary from very general to extremely specific topics. In response to the pressures applied by the passage of the No Child Left Behind Act in

2001 , school districts have developed pacing guides that dictate the amount of time allotted for each topic. The entire school year is planned and there is little, if any, room for modifications. Furthermore, in many school districts, it is demanded that all classes in the school district cover the exact same concept at the exact same time. Table 2 illustrates the pacing guide for Chemistry in Washington County, Virginia.

With the pressures found in this pacing guide, most public school teachers have succumbed to the traditional method of instruction. In Washington County Virginia, for example, the 5-point teaching model includes the following steps:

1—Review of Previous lesson

2—Introduction of Topic/ Provision of step-by-step instruction

3—Guided practice

4—Independent Practice

5—Review of Lesson

If the steps of this method is followed, it is very difficult to change the method of instruction because inquiry methods are more time consuming.

Table 2: Washington County Public Schools Pacing Guide for Chemistry content taught each day of the 180 instructional days school is in session

		Standards of Learning	Lessons/ Assignments
Day 1-3	First Teaching Day	CH.1 a-c	Chapter 1
Day 4- 8		CH.1 a-c CH. 1 d-h	Chapters 1 and 2
Day 9-13		CH. 1 d-h	Chapter 2
	Labor Day, Schools Closed		
Day 14 -17		CH. 1 d-h CH. 2h	Chapter 2 Chapter 3
Day 18 – 22	9/15 - School Day at Fair (Students Dis 2 hrs early)	CH. 2h	Chapter 3
Day 23 – 27		CH. 2h CH.1 i CH.2 a-c, i	Chapter 3 Chapter 4
Day 28 – 31	Wednesday, Sept 27 - End of First six weeks	CH.1 I CH.2 a-c, i	Chapter 4
	Teacher Workday, schools closed	CH.1 I CH.2 a-c, i	Chapter 4
Day 32 – 36		CH.1 I CH.2 a-c, i	Chapter 4
Day 37 – 41	SACS Audit Oct. 8 – 11	CH. 2g	Chapter 5
Day 42 – 46	*Benchmark testing window Oct 16 - Oct 20*	CH. 2g	Chapter 5
Day 47 – 51		CH.2 d-f, h	Chapter 6 Chapter 7
Day 52 – 56		CH.3 a, c, d	Chapter 8
Day 57 – 60	Friday, Nov. 10 - End of 2nd Six weeks	CH.3 a, c, d	Chapter 8
	Election Day, Schools closed		
Day 61 – 65		CH.3 a, c, d	Chapter 8
Day 66 – 67		CH.3 a, c, d	Chapter 9
	Thanksgiving Holiday, schools closed Nov 22 - Nov 24		
Day 68 – 72		CH.3 a, c, d	Chapter 9
Day 73 – 77		CH.3 a, c, d	Chapter 9
Day 78 – 82		CH.3 a, c, d	Chapter 9 Exam Review
	Winter Break, Schools Closed Dec 16 - Jan 1		

Table 2 (continued)

Day 83 – 86	Schools re-open	CH.3 b, e	Chapter 10
Day 87 – 91	Thursday, Jan. 11 - End of 3rd six weeks, 1st Semester	CH.3 b, e	Chapter 10
Day 92 – 95		CH.3 b, e	Chapter 10
Day 96 – 100	*Benchmark testing window Jan 22 - Jan 26*	CH.4 a CH.3 c	Chapter 11
Day 101 – 105		CH.4 a,b	Chapter 12
Day 106 – 110		CH.4 a,b	Chapter 12
Day 111 – 115		CH.4 a,b	Chapter 12
Day 116 – 120	Friday, Feb. 23 - End of 4th six weeks	CH.5 a-c	Chapter 13
Day 121 – 125	Tuesday, Feb. 27-Teacher Collaboration (stud. dis 2 hrs early)	CH. 4 c,d	Chapter 14
Day 126 – 130		CH. 4 c,d	Chapter 14
Day 131 – 135		CH. 4 e CH.5 f	Chapter 15
Day 136 – 140		CH.4 g	Chapter 19
Day 141 – 145		CH. 5 d, e	Chapter 16
Day 146 – 149		CH. 5 d, e	Chapter 16
	Spring Holidays - Schools Closed Apr 6-10		
Day 150 – 152	Wednesday, Apr 11 - End of 5th six weeks	CH. 3 f	Chapter 17
Day 153 – 157		CH. 3 f	Chapter 17
Day 158 – 162	SOL Window: April 23 - May 16	CH. 3 f	Chapter 17
Day 163 – 167		CH. 4 f	Chapter 18
Day 168 – 172	AP Testing: May 7 - May 16	CH. 4 f	Chapter 18
Day 173 – 177		CH. 4 f	Chapter 18
Day 178 – 180	Wednesday May 23 - Last Day of school (if no snow days)	CH.3 a., c	Chapter 22 Chapter 23

Possible Solutions

General Information

It has been said that modern schools *"model 1950s architecture, use 1990s technology, and deliver 1960s curriculum."* [12] With these limitations it may seem hopeless that America can once again return to powerhouse status in the field of education. However, many in the field of education feel that all is not lost. A suggestion that has been made to correct this problem is beautiful in its simplicity…school life should more closely mirror real life. This could occur with better technology and with a more project-oriented learning process rather than independent assignments. [12]

National Science Foundation Recommendations: State Systemic Initiatives

In response to the problems attributed to the education system, the National Science Foundation has begun making recommendations for improvement. Since 1991, the National Science Foundation has set up cooperative agreements with 26 states to reform education programs in science, math, and technology. These agreements, known as State Systemic Initiatives, or SSIs, are based on the premise that all parameters of learning must be aligned to achieve success. These parameters include school level initiates, increased personnel, and increased funding for professional development. For the SSI to be effective, two assumptions must be made:

1— Students will meet higher standards if asked to do so in an appropriate environment.

2— State and Local Policies may be implemented to determine the standards to which its students are held.[7]

National Science Foundation: National Science Education Standards

General Information. In response to the increasingly flawed system of education in America, a series of National Science Standards has been implemented. These standards attempt to reduce the inequity students encountered as a result of cultural experiences and educational backgrounds. [13] The purpose of these standards is to develop nationwide scientific literacy. Every person in the nation has a stake in the development of scientific literacy. In addition to the development of scientific principles, scientific literacy strengthens many skills that people use every day, including analytical thinking and cooperative learning, and the implementation of technology.[14]

The National Science Education Standards seek to help students achieve scientific literacy. Despite the simplicity of this goal, there are many challenges in implementing these standards so that the goals are reached. The National Research Council defines scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" .[8] This definition should not be confused with that of science literacy which focuses on content knowledge. The issue is in the application of this scientific knowledge to situations enabling students to achieve "social good."

Teaching Standards. The National Science Standards Teaching Standard A provides teachers with the tools to develop a new curriculum that promotes inquiry. In the design of this curriculum, teachers should develop a schedule of year-long and short-term goals for students. The standards should also contain science content that meets both the interests and abilities of the students. Teachers should also select teaching and assessment strategies that develop a quality learning environment, and, finally, this standard requires cross-curriculum collaboration among teachers in all disciplines and grade levels .[10]

Teaching Standard B indicates the shift of the instructor from the role of lecturer to facilitator. To accomplish this, teachers should encourage and support both inquiry and discussion of scientific ideas when working with students. Teachers and school systems must also require students to accept ownership of their own learning process. Student diversity is also both recognized and used to enhance participation. Finally, teachers should encourage skills such as curiosity, open-mindedness, and healthy skepticism associated with science .[10]

According to the National Science Education Standards, teachers must also alter their methods of assessment. Rather than using a traditional multiple choice assessment exclusively, a variety of assessment tools should be used. In fact, assessment should be an ongoing process using multiple methods of data collection regarding student understanding and ability. These data should be analyzed to guide instructional methods. Furthermore, student data and observations should be used to improve teaching practices and to report student achievement .[10]

Learning Environment. The next natinal science teaching standard deals with the management of the learning environment. Supporting true inquiry in science goes far beyond the classroom itself. A major issue with our current system that must be reformed involves time. Most students are unable to use the time available to them well enough to support extended investigations. It is up to the teacher to both schedule the time available and create flexible scheduling arrangements. Teachers must also provide a safe working environment with all necessary tools, materials, and media. Obviously, this presents many problems for the already overextended school systems. Teachers should also encourage students to design their own working environment and identify and use resources other than those provided by the school .[10]

Science Program Development. The final teaching standard included in the National Science Standards involves the active participation of teachers in ongoing planning and development of the school's science program. It provides that teachers have an active voice in the allocation of time and other resources needed to teach science. It also allows for teachers to improve professional development plans for themselves and their colleagues .[10]

Assessment. Science assessment has also been a focus of the National Science Standards. Assessment for the sake of assessment has become all too commonplace in science education. In fact, many members of the education field received this same type of assessment while in school themselves. They are accustomed to standardized tests filled with multiple choice questions designed to assess knowledge rather than process. The standards recommend that assessment should focus on highly valuable information, the assessment of which is more complicated and time consuming,, rather than the easily measured assessments found in multiple choice tests. They also suggest that assessments should focus on scientific understanding and reasoning rather than the assessment of the factual knowledge solely. Furthermore, students should be party to ongoing assessments that are designed by their teachers rather than an end of course assessment designed by education officials .[10]

These standards focus on formative rather than summative assessment. The goal of formative assessment is to improve both teaching and learning. Its focus is on a daily progression and emphasizes the need for assessment to be part of the actual learning process. Conversely, the primary assessment method in most classrooms involves summative assessment, which includes items such as chapter and unit .[10]

There are several guidelines recommended for teachers when designing assessments. To begin, they must be deliberately designed with clearly stated purposes. The relationship between "decisions and the data" should be clear, and the assessment practices themselves must be consistent. Assessments should be guided by their purpose and should have multiple methods of data collection that provide information to both student and teacher .[10]

Assessments should also be geared toward more than analyzing simple content knowledge, such as facts, laws, and theories. In addition to content knowledge, assessments should also test process and application skills. The process skills tested are those identified by the American Association for the Advancement of Science and include observation, prediction, spatial relationships, inferring, data collection and interpretation, and experimental design. Application assessment is used primarily to encourage students to engage in critical thinking processes that define links between science, technology and society.[10]

Based on the recommendation of the National Science Standards, attitudes about science should also be assessed. Studying student attitudes about science is more subjective than the others because it involves understanding of personal values held by each student and the students' abilities to express their feelings constructively. The goal of these assessments is to improve attitudes about science as well as developing effective interpersonal skills .[10]

There are other aspects of assessment included in the National Science Standards. Rather than purely objective assessments, the new assessment procedures also include the assessment of student creativity. These processes provide feedback on student ability to develop alternate conclusions, consider viewpoints other than their own, design experiments, and communicate results in a variety of ways. The student's viewpoint about the nature of science should also be assessed. This viewpoint allows students to develop useful questions, develop and implement experiments useful in research, and work as part of a research team.[10]

The National Science Foundation states that the primary goal of science education is to engage students in an environment of learning by inquiry in its National Science Education Standards. Assessment of the inquiry process includes many facets because both achievement and the learning opportunity itself must be assessed. In order to accomplish this, assessment should focus on the most important aspect of science content for that particular topic. The prioritizing of material to be learned is ambiguous at best but includes *how* students perform science and *how* students think in scientific ways and apply that to reason out answers. Additionally, the assessment of learning opportunities should focus on the most powerful indicators, which include teacher content, student understanding, and the school's curriculum. Finally, equal measure must be given to both student achievement and learning opportunities. With the time constraints placed on most education systems with the advent of standardized testing, assessment of learning opportunity is even more important .[10]

A very important part of assessment is the concept of validity. This simply means that it must actually measure the subject matter it claims to measure. In order for this to happen, assessment tasks must be authentic. Additionally, there must be similarity in performance by one student on two or more tasks that seek to evaluate the same concept. Students should also have ample opportunity to demonstrate their knowledge and achievements. Finally, the methods of assessment used must provide data that lead to the same results if used at different times .[10]

Another important aspect of assessment is the fairness of the method used. This means that an assessment needs to measure what students know about science without regard to environment, socioeconomic status, or race/ethnicity. The assessments cannot make assumptions about the life experiences of the students involved. Additionally, assessments must be made so that language barriers must be avoided. Furthermore, assessments must take place in a variety of contexts and be engaging to students of varied backgrounds without assuming any stereotypical experience .[10]

The final assessment standard deals with the correlation between instructional goals and assessment. Obviously, educational objectives are important to teachers. These objectives help to set goals and plan the lessons themselves. These goals can be for a specific unit or be derived from state or local standards. Useful learning objectives include the following criteria: 1) They must be aligned with the material studied 2) They should be "meaningfully aligned" with assessment method 3) The objective and assessment are developed together, and 4) Objective defines proficiency level the teacher expects. At times, students do not achieve the level of assessment a teacher hopes to see. This can be the result of several different conditions. First of all, it must be considered that the assessment may be too difficult or was poorly designed. A more likely problem is the lack of preparation by the student. A third indication is a possible inconsistency with teaching and learning practice, and, finally, cultural biases could prevent students from communication knowledge .[10]

Assessment practices seem to be increasingly challenged. Obviously, all teachers agree that assessments should be fair and be based on the material taught. However, the classroom teacher is required to perform multiple assessments simultaneously, ranging from student effort and behavior all the way to content knowledge and process skills. The United States Department of Labor has defined instructional goals for students as the ability to perform the following skills:

Decision making

Problem Solving

Communication

Mathematical applications

Learning how to learn

Cooperative teamwork

Leadership

Self-management

Based on these criteria, it is obvious that the education system is moving toward a more abstract assessment. Rather than traditional assessments that measure only content knowledge, most assessment now is based on process skills and problem-solving skills in addition to the knowledge necessary to be successful.

These performance-based assessments also require more preparation by the teacher. In order to have successful assessments, there are several hurdles that must be crossed. First of all, the teacher must have current knowledge of his or her content and its relationship to the process oriented assessment. There are also issues in the development of these assessments and the role that assessment takes in schools. Many teachers must also learn to use assessment as a means to improve instruction and must provide accommodations for students whose native language is not English.

These issues are not easily overcome. However, the most reasonable practice to enable proper assessment seems to be the movement toward a model of teaching where instruction and assessment are not as rigidly defined. Multiple education practices must be used in order to achieve this. Additionally, teachers can find assistance in the study of various instructional models. Finally, assessment must be efficient in our difficult economic times. With schools receiving a minuscule amount of funding for each student per year, the assessment practice must not be cost prohibitive.[10]

<u>Content.</u> The next aspect of the National Science Education Standards deals with the actual content taught. The changes recommended in the content standards really do not change the actual information the student is expected to master. Rather, the changes related to how the student obtains this knowledge are studied. The general recommendation of these standards is simply the reduction of learning facts or basic scientific information and the increase in process-oriented learning with the integration of content with process to achieve an atmosphere of inquiry.

The general emphasis of science content has shifted in these standards. Rather than a basic knowledge of scientific facts and information, the new standards emphasize understanding of scientific concepts and developing proficiency in inquiry processes. Traditional content focuses on studying different disciplines for the sake of the discipline itself. The new standards, instead, focus on the attainment of knowledge in any particular subject matter in the context of inquiry, technology, and the nature of the subject itself. Traditional content additionally separates science into knowledge and process, whereas the new standards recommend the integration of these aspects together into one. Another difference has to do with the scope of material taught. Traditional content focuses on many concepts, whereas the new methods focus on fewer fundamental concepts. Finally, inquiry was once considered to be a set of processes in the classroom but is now implemented as a combination of instructional strategies, abilities, and concepts.

The final difference in content led to a new set of emphasis changes. Traditional instruction focuses on activities that verify content itself rather than the analysis of scientific questions. Another difference is the time frame involved. Traditional science content has discussions or investigations confined to one class period, whereas the newer method of instruction focuses on content that allows investigations to occur over an extended period of time. The new content standards also require that process skills are part of the context of the class itself and use multiple process skills, rather than the development of these skills by students individually. Focus has also shifted from getting the answer to using inquiry as part of developing an explanation of events. Science was once considered to be exploration and experimentation but most science curricula focus on argument rather than experimentation. Another recommendation is the movement of group analysis without defending a conclusion to a group that analyzes data after conclusions are defended. Other changes recommended include the public communication of student ideas rather than private communication of these ideas, and the development of arguments and explanations as a result of experiments rather than the conclusion of inquiry with the end of an experiment.[10]

Authentic Learning

General Information. A method of instruction currently employed by some teachers is that of Authentic Learning. [15] Because learning by doing is generally considered the most effective way to learn, the concept of authentic learning is very useful. The premise of authentic learning is the application of knowledge and problem solving skills to real-world problems. Studies suggest that students are motivated by the opportunity to solve real-world problems rather than simply listening to a lecture.

This method of learning typically focuses on complex situations and the development of solutions to these situations. In order to develop these solutions, role-playing exercises, problem-based activities, and case studies are often employed. The learning environments are integrated and cocurricular, meaning that one specific discipline or subject isn't the focus of the problem. Authentic learning goes beyond content, allowing for the collaboration of multiple disciplines, multiple perspectives, and communities.

Important Skill Development. Many important skills are developed using the authentic learning method. Examples of these skills include the ability to distinguish reliable data from the unreliable. Authentic learning also helps to cultivate patience to follow longer discussions and the ability to recognize patterns in unfamiliar situations. Authentic learning also provides students with the opportunity to develop flexibility in working with groups of students in different disciplines and of different cultural backgrounds to develop solutions to problems in learning.[15]

Criteria. The authentic learning experience is composed of 10 main elements that can be used to create an authentic learning environment in any situation. The first is real-world relevance. The concept that an authentic learning experience seeks to teach should mirror a situation that a professional in the specific field of study is faced with already . The problem must also be one that requires innovation to solve. It cannot be a problem easily solvable by current means. Authentic learning also requires sustained investigations that occur over a period of time in which the students are able to develop socially and intellectually. Authentic learning environments also require the employment of multiple resources from which the students have to determine what information is reliable and what is unreliable. Another requirement of authentic learning is collaboration. Quite obviously, the real-world requires team work to solve any given problem; authentic learning simulates this in the educational setting. Similarly, authentic learning is not confined to one subject. The activities have consequences that far outreach any one discipline. Authentic learners must also be metacognitive, meaning that they force learners to make decisions based on their learning practices. Another important characteristic of authentic learning is that of integrated assessment. Just as in the real-world, assessment practices in authentic learning are formative rather than summative. Another important part of authentic learning is the end result. Rather than preparatory exercises, authentic learning serves to create a new product whose value far exceeds the project itself. Finally, authentic learning provides for diverse interpretation of results rather than one "correct" answer.

<u>Advantages of Authentic Learning</u>**.** Research has shown that students involved in projects that are authentic learning based seem to maintain their motivation despite difficulties. This occurs because it allows them to see a social implication of the subject studied. It also encourages students to consider career and educational choices beyond their comfort zone .[15]

<u>Case Study</u>**.** As part of a more ambitious goal to encourage students to study and understand science, the Advanced Placement Chemistry students at Abingdon High School have been involved in an authentic learning project for the last 2 school years. The project is centered around a partnership with students from various levels at the four high schools in Washington County, Virginia, along with students from a local community college and a local 4-year institution. Part of the project also requires the addition of a business partner's input to mimic a real-world experience. Our project received assistance in this form from the United States Forest Service and the Mount Rogers National Recreation Area. The project, which has received funding from the National Science Foundation, focuses on the impact of global warming on society by studying the destruction of salamander habitat. The project received the Virginia

Community College System National Science Foundation Grant which funds training and travel for the study.

Students involved are introduced to the problem, namely the decline in the salamander population worldwide. The students then must perform a variety of tasks ranging from independent research to interviews with Forest Service officials to explain this phenomenon. The teachers involved received multidimensional training both in implementation of the method and technology use. The instructors created a video that introduced the problem but offers no solutions. The students then research and brainstorm regarding this topic. After research is complete, students travel to Whitetop Mountain in Whitetop, Virginia to look for specific species of salamanders. The salamanders are tested for fungus and cataloged then released. The final aspect of the project involves a presentation by the students to the business partner and National Science Foundation officials about their findings.

The students love this project for many reasons. Aside from the fact that global warming is a controversial issue in the news almost daily, it applies to their lives. This application forces students to focus on the possibility that science is more than what one learns from a book. This method also allows them to control the pace and direction of their learning process, which is invaluable. Finally, it allows them practice in compiling and analyzing data that they are responsible for explaining to a group of scientists. In short, it is the best of all worlds.

Examples of Authentic Learning Methods found in Universities. There are several major universities that use similar methods of instruction. One such example is the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project implemented at North Carolina State University at Raleigh..[16] It is believed that projects such as SCALE-UP can radically change the system of education currently used. It is believed that the main factor that enables projects such as this to be successful is the social interaction among students and facilitators. This method is used primarily in large classes. Its format enables a large class to transform into a small one by grouping a few students together into an independent entity. It can even be used in internet and ITV courses. Class time is consumed by studying "tangibles". This means that hands-on activities or hypothesis-driven labs are used rather than traditional lecture methods. The classroom setup used in this project is similar to that in the more widely accepted Process-Oriented Guided Inquiry Learning method, POGIL.[16]

An important benefit of programs like SCALE-UP and POGIL is that many students who are deemed "at risk" are able to find success. For many of these students, school is a miserable experience, and using programs like this enables them to find success, in many cases for the first time. This success provided confidence building, which extends to many other areas of education and further to life.[16]

Another well-known program with a similar setup was researched at San Diego State University. It is geared toward high school physics education in the area. Much of physics education is accomplished through the Constructing Physics Understanding project. This project is aimed at developing computer-based physics labs and projects that allows students to take primary responsibility for their educations. There are currently seven modules implemented in the schools involved. This project has recently been extended to other areas of science including physical science. [17] There are many additional resources available in various disciplines. These resources vary from curriculum materials to professional development. [18]

Complications with Authentic Learning Methods. There are problems with authentic learning methods, however, that prohibit their use in high school classrooms. Some experiments are considered too dangerous, difficult, or expensive to implement at this level. Others are considered even impossible due to the nature of the problems themselves. With the emergence of new forms of technology, some of these problems have abated. However, others still exist. For example, most high school curricula require a measurable assessment. Also, many authentic learning investigations span the course of months or even years which may not be feasible in a year-long course .[15]

Process Oriented Guided Inquiry Learning

Basic Facts. POGIL, Process-Oriented Guided Inquiry Learning, is a method of instruction based on various learning theories. It is based on a simple learning cycle, beginning with exploration, followed by inductive reasoning. Through this process, concept invention occurs, which is then followed by deductive reasoning. Finally, applications are processed. This method parallels the scientific method, which is obviously important in science instruction .[19]

Criteria. Similar to the authentic learning program without some of its major pitfalls, the POGIL method of instruction is growing in popularity among high school and college professors. It is a student-centered learning method that helps to develop both critical reading and analytical thinking skills. This method of instruction focuses on the group concept. The class is broken into groups of 3 or 4 and each person in the group is assigned a role. These roles include a manager, a recorder, a technician, and a presenter. The group is a self-contained unit that receives no assistance from any other group or from the facilitator. Rather than asking the teacher questions as in the traditional classroom, the group works together to find answers to their questions. Only the manager is permitted to address the facilitator, who can provide guidance without providing answers.

The roles are specifically defined and are very important to the process. The manager assigns the group tasks, keeps students on task, and communicates information from the facilitator. This person learns time management, interpersonal skills, and communication skills. The recorder must take all the information given by all members of the group and decide what is important to the task at hand, which requires tremendous analytical skill. The presenter obviously must develop communication skills necessary to all careers. Each student plays a vital role without which the group would not be successful. Though this seems frustrating for students, studies show that it enables longer retention and less stress. This combination helps to ensure that students will continue their education in the field of science. Additionally, each time a module is used, the students in any POGIL group are assigned different roles so that each student is able to experience the different roles.[9]

Modules. The POGIL method centers around the module concept. A module is an informative packet that also requires students to analyze data and make predictions. In order for a module to be considered acceptable, there are certain criteria that must be met. First of all, there is a lot of flexibility in the type of activity included. The only requirement is that the module must begin with a problem to be solved. Examples include equations, diagrams, graphs, etc. The module must present one to three key concepts clearly. The students must then be able to make observations and collect data to develop a theory. A successful module must also contain guided questions to assist students in their endeavors. The specific format is important because it allows clarity, which is essential in learning. Modules should also contain prerequisites and the specific standards contained within the module .[19]

Research Objectives

Most Americans will agree that education is one of the most important issues plaguing our nation today. The provision of an adequate education system is paramount in order for our students to be successful, both in school and in life. Improving the current system is a burden that must be carried by every citizen, not just those involved in the education system.

The focus of this research project is to study instructional methods so that better student outcomes are obtained. The proposed objectives are outlined and described below.

1. To identify the shortcomings of the current American education system by an extensive review of available educational literature.
2. Critically compare the more successful educational systems to discern the differences that exist between those successful systems and the American system and to find ways to emulate what is possible in my classroom.
3. Design and implement a nontraditional teaching method which is an inquiry base methodology like POGIL to study the learning outcomes.
4. Compare the learning outcomes of traditional and the proposed implemented nontraditional method using appropriate assessment protocols**..**

CHAPTER 3

EXPERIMENTAL SETUP

Basic Information

Due to the success Process-Oriented Guided Inquiry Learning has achieved, it is the primary focus of this research project. I taught three Honors Chemistry classes during the 2007-08 school years. The division of Chemistry classes at Abingdon High School is as follows:

1. First year students are grouped into Chemistry I or Honors Chemistry. Chemistry I students are those who are on track for a General Studies Diploma and have no intention of majoring in a science field in college. Conversely, Honors Chemistry students are in the process of fulfilling the requirements of an Advanced Studied Diploma , and a portion of the students plan to major in a scientific field upon entrance to college.
2. Advanced Placement Students. These students are those who have completed Honors Chemistry already with an A average and plan to enter a science or engineering major in college.

I chose to use the Honors Chemistry students as part of the research for several reasons. Because most of them are highly functioning, many are classified as gifted. Therefore, they should have excellent reasoning skills already. Also, because they are involved in many difficult classes, many focus on memorization rather than true learning. This method is designed to allow students to use logic and reasoning to make more meaningful connections regarding the material they are taught. Table 3 provides demographic information about the Honors Chemistry students at Abingdon High School in Abingdon, Virginia.

Statistical Data

Nearly all of the 64 students involved in my research were on track to receive an Advanced Studies diploma. The math and science requirements for this diploma option include 4 years of math including Algebra I and II, Geometry and higher math(s) and 4 years of science including Earth Science, Biology, Chemistry and higher science(s). The 64 students also included 29 males and 35 females. Additionally, 63 of the 64 are classified as Caucasian with one Asian/Pacific Islander. The average GPA of these students is 3.621 and half of them are classified as gifted or talented.

Table 3: Summary of Demographic Information for Honors Chemistry students at Abingdon High School in Abingdon, Virginia who were involved in research study.

Average Grade Point Average	3.621
Percentage in Pursuit of Advanced Studies Diploma	98.44
Percentage Classified as Gifted	50.00
Gender	
Percentage Male	45.31
Percentage Female	54.69
Ethnicity	
Caucasian	98.44
Asian/Pacific Islander	1.56

<u>The Experiment</u>

The experiment began early in the school year when I provided the occasional POGIL activity for the students to complete. Most of these were simple in nature and were designed to allow the students to grow accustomed to the format of this instructional method. The primary portion of the research project, however, began January 11, 2008, with the study of Gas Laws. Initially, the students were advised of the departure from "normal" instructional methods. The project was implemented for a duration of 11 school days, in which there were eleven 50-minute class periods. During this time, the students completed six POGIL modules and a lab. The first day consisted of the students completing a pretest that consisted of conceptual questions of varied difficulty. Each student ranked each given question question based on the confidence level he or she attributed to that particular question. The ranking system was as follows:

1—Fairly confident

2—Partially uncertain

3—Completely uncertain

The pretests were scored and data were compiled. The pretest scores and rankings were tabulated as shown in Table 4.

Table 4 : Summary of Gas Law Pretest Data with Confidence Ranking of 1-3

Pretest Data	
Highest Score	61.9
Lowest Score	9.52
Average Score	28.72
Average Confdence Ranking	2.56

For the pretest, the mean ranking of certainty the students felt about the answers given was 2.56. This ranking indicated a lack of confidence in the understanding of the material initially. The next day, students began working on various modules to complete in their groups.

These modules began with the study of Boyle's Law. Initially, the students answered five short questions regarding this topic and then proceeded to begin a group exercise. It is important to note that each module required the assigned roles to differ so that each student was able to experience all facets of the group concept. In this particular exercise, students were provided marshmallow hearts, shaving cream, and water. The students then placed these items in the vacuum to observe the changes. After that, the students worked within their groups to answer a few questions and further develop a mathematical relationship of Pressure and Volume that was used to answer computational questions. At the conclusion of the exercise, the students were then asked the same five questions they had been asked prior to the start of the activity to see if the answers to the same questions had changed. Then the class discussed the answers.

This procedure was repeated for Charles' Law, Ideal Gas Law, Graham's Law of Effusion, and the Kinetic Molecular Theory of Gases. The modules varied with the subject taught but the process remained the same. Students also participated in a lab exercise based on the Ideal Gas Law in which the students derived the ideal gas constant. While some of the modules took very little class time, others took a few days. Overall, however, the time seemed to be well-spent, as the students both enjoyed the exercises and seemed to grasp the concepts.

Upon completion of all the modules and lab, the students were then given a final evaluation. The evaluation used was the exact same test that had been used for the last 5 years in this particular class. The evaluation consisted of the same 21 questions as the pretest along with some application questions, primarily in the form of mathematical computation. Results are as tabulated in Table 5.

While these data may seem unremarkable, they are very revealing. The mean score on this test after POGIL instruction was 80.5, which is 3 points higher than the average on the exact same test in the exact same level of chemistry over the last 5 years. More importantly, there was tremendous improvement in student scores as illustrated in Figure 1. Two-thirds of the students involved improved scores by 50% or more, illustrating the success of the teaching method used.

Table 5: Gas Law Posttest scores by Student

Student	Posttest Raw Score	Student	Posttest Raw Score
1	96	33	96
2	95	34	81
3	93	35	60
4	82	36	60
5	77	37	80
6	94	38	70
7	87	39	96
8	85	40	63
9	65	41	91
10	84	42	82
11	95	43	60
12	90	44	56
13	74	45	92
14	96	46	81
15	89	47	66
16	78	48	70
17	66	49	91
18	96	50	75
19	74	51	91
20	86	52	89
21	95	53	63
22	58	54	80
23	89	55	64
24	81	56	66
25	98	57	94
26	73	58	94
27	83	59	80
28	97	60	82
29	93	61	57
30	81	62	92
31	63	63	71
32	91	64	73
		Mean	80.5

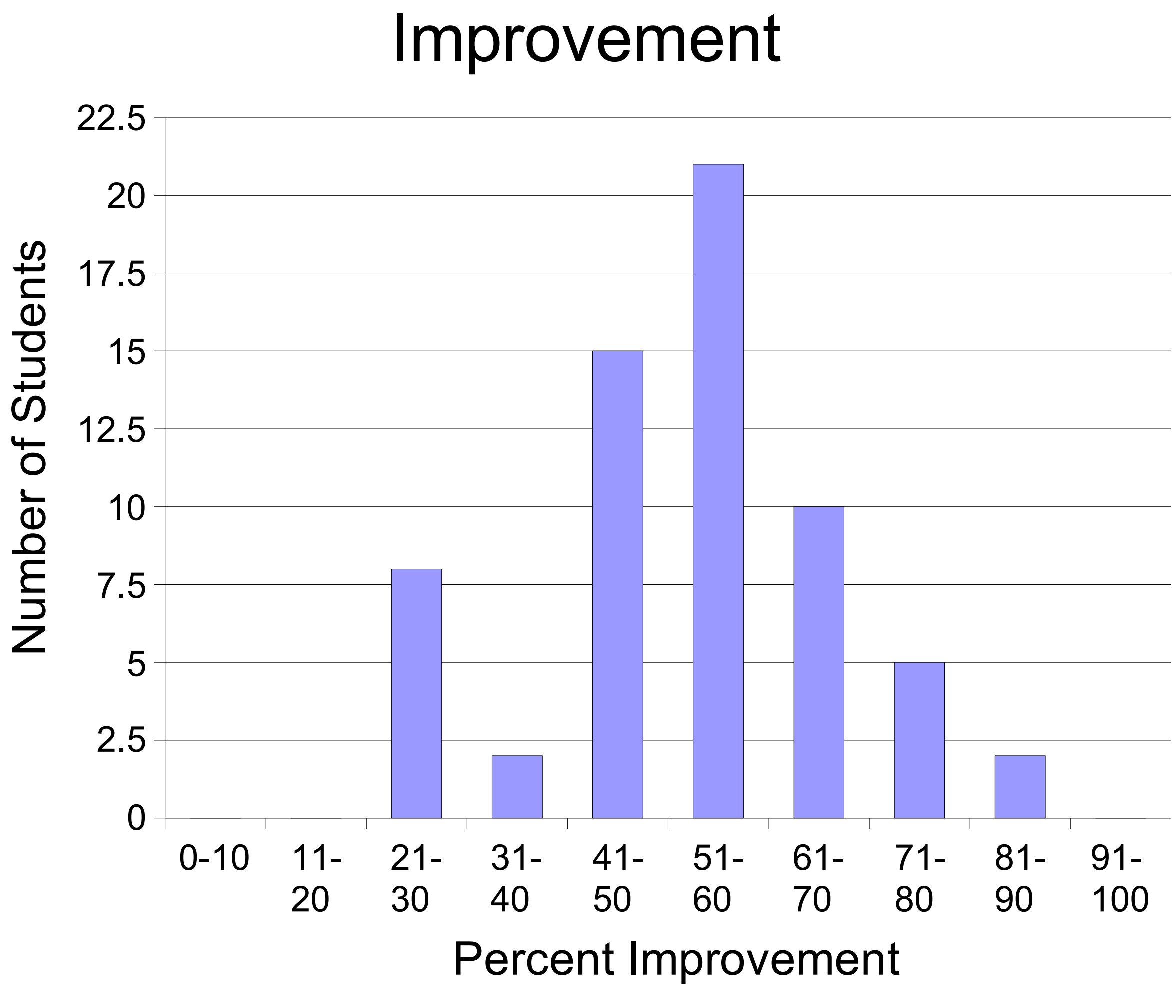

Figure 1: Percent improvement from Gas Law Pretest to Posttest by number of Honors Chemistry students involved in research study at Abingdon High School

CHAPTER 4

RESULTS AND DISCUSSION

Data

Standards of Learning

In Virginia, the final evaluation of courses in high school core areas is the Standards of Learning test. The Standards of Learning End-of-Course test is a 50-question multiple choice test designed to measure minimum proficiency. Each End-Of-Course test requires a different level of mastery, but they are all scored out of 600 points. A minimum score of 400 indicates proficiency in the subject, while a score of 500 or more indicates an advanced proficiency in that subject. On average, between 95.0% and 98.0% of students enrolled in my classes in the last 5 years have passed the end of course evaluation. During the 2007-08 school year, 98.4% of the students involved in this project passed. For students to achieve a score of 500 on the Chemistry Standard of Learning Test, fewer than five questions can be missed.

The scores are broken down by subject area. I have also included the information by student regarding the Gas Law strand. Each particular strand has a maximum score of 50, and the average on the Gas Law strand this year was 42.66. This is an important consdieration because this material was covered by POGIL exercises in January but the Standards of Learning test was administered May 12. The success students found on this strand in particular suggests a high level of knowledge retention, which is essential to success. This information is provided in Table 6.

The scoring range achieved by number of students can be useful to examine. Figure 2 provides a visual representation of this information. During the 2007-08 school year, the majority of the students scored between 426 and 475 on the Standards of Learning test, indicating that between 8 and 14 questions were missed. However, the mean score of 42.66 out of 50 on the Gas Law Strand indicates a much lower percentage of those particular questions was missed.

Table 6 : Chemistry Standards of Learning Scores including Gas Law Strand Scores for tithe students involved in the research project conducted at Abingdon High School in Abingdon High School in Abingdon, Virginia during the 2007-08 school year

Student Number	SOL Score	Gas Law Strand Score	Student Number	SOL Score	Gas Law Strand Score
1	513	50	33	491	50
2	547	50	34	440	40
3	579	50	35	430	45
4	450	45	36	407	27
5	456	34	37	421	37
6	501	45	38	450	40
7	462	37	39	547	50
8	450	34	40	483	45
9	445	37	41	513	45
10	456	40	42	491	50
11	468	45	43	425	37
12	513	50	44	430	40
13	475	37	45	513	50
14	491	45	46	468	50
15	513	50	47	440	40
16	456	40	48	450	50
17	421	32	49	456	40
18	547	50	50	440	40
19	416	34	51	513	50
20	462	37	52	462	40
21	527	50	53	513	50
22	527	45	54	475	45
23	440	45	55	421	40
24	462	34	56	468	40
25	501	45	57	421	32
26	450	37	58	501	50
27	513	50	59	579	50
28	501	45	60	483	45
29	440	34	61	513	50
30	462	45	62	412	34
31	395	24	63	579	50
32	468	37	64	462	45

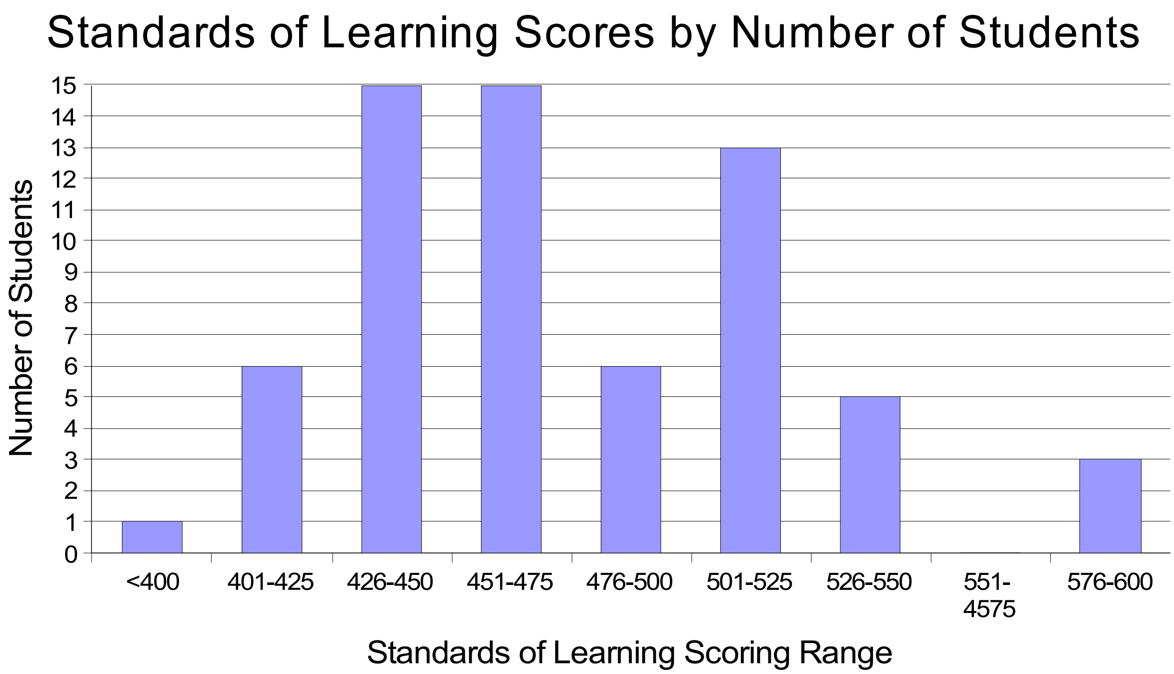

Figure 2: End of Course Chemistry Standards of Learning Scoring Ranges by Number of Students in Honors Chemistry Classes at Abingdon High School for the 2007-08 School Year

Discussion

These experimental data have many implications. Though still in the very early stages of investigation in the high school setting, the results obtained seem to indicate a substantial improvement in assessment. While it will take much more study and data analysis to ascertain the impact of these results, the preliminary data are promising.

The modules I wrote were designed to be a combined method of instruction, with partial inquiry and partial traditional educational methods. I chose this to enable my students to use a variety of methods. The other modules used were purely POGIL and were obtained from POGIL sources. I have included examples of the ones I wrote and a link to one of the modules released by POGIL in Appendices 2-4 for comparison.

Some students truly enjoyed the inquiry method, while some were still reliant on lecture-based instruction. I must admit that I met tremendous resistance to the new method in some areas. While most students ended up being at least as successful as they normally were, a very small portion of them indicated that they actually felt as though they learned more using the POGIL method.

Similar Research Projects

There have been many other studies regarding inquiry learning. One such study conducted at the University of South Florida , published in the Journal of Chemical Education in January 2005, seems to have very promising results. This experiment focused on two sections of General Chemistry at the university. One was taught in the traditional method and served as a control group. The other section used guided inquiry methods. Each section was assessed using the same evaluative tools, and the guided inquiry section consistently performed at a higher level. [20] More importantly, however, the study at the University of South Florida indicated a positive attitude from the students involved. In fact, 74% of the students in the guided inquiry group had a positive response to the method, and 85% indicated that they would choose to enroll in another course that employed this method of teaching. [20]

Another successful study was conducted at Bismarck State College, which received a 2-year grant from the National Science Foundation to combine guided inquiry methods and computer based labs to study chemistry. This exciting project allowed for the development of new curricula not only at the college but also at rural high schools in the region. The impact of this study is still being determined but seems to be widespread in that it has opened up the world of science to many who would otherwise not be part of it. [21]

There have also been other research projects published that seek to teach gas laws by inquiry methods. Though all a bit different in methodology, all seemed to have similar results. One such study was conducted in an undergraduate general chemistry course at Evergreen State College in Olympia, Washington. This particular study was completely laboratory based, teaching concepts and formulation through experiment. Students involved used laboratory data obtained through the use of Vernier software to derive gas law formulas. The experiments involved related pressure and volume, pressure and temperature, volume and temperature, and pressure and moles to determine the ideal gas constant. Data were graphed and analyzed to provide a mathematical relationship of the variables involved. Aside from the fact that students seemed to understand and retain the information throughout the semester, the method also provided excellent opportunities for collaboration among the students, resulting in an overall more positive experience. [22]

Another research project with similar goals was conducted at Hunter College in New York, New York. This particular project combined tradition lecture with open-inquiry instruction in a 7-day module designed to teach the gas laws at an undergraduate level. Preliminary results of this module are very promising as well. Students in the classes taught by the integrated method aforementioned scored consistently higher than those students involved in traditional lecture only. In fact, in Spring 1997 courses, the average score of the students in the integrated class was 74% versus the average of 51% in the traditional classroom. The following year found similar results, with the students in the integrated class scoring an average 71% while the students in the traditional class scored average of 66%. [23] It is important to note that the classes are composed of students of similar educational backgrounds, so the difference in performance cannot be attributed to different student ability levels. A survey at the end of the project also found that 71% of the students involved enjoyed the inquiry methods more and felt that they learned more despite the fact that 90% of them felt that the inquiry method required more work on their part. Along with the test scores themselves, the seemingly positive attitude shift is also important to the continuation of science education. [23]

Other studies have been conducted that also suggest positive results using inquiry methods. At Franklin and Marshall College, a 9-year study using the same three instructors was conducted to determine how POGIL methods affect final grade distribution. After the 9-year project was completed, the W, D, and F rate dropped from 22% to 9.6%. Additionally, students in the lower half of the class showed marked improvement and the absence rate declined. Another important statistic was found at a small liberal arts college. The 1993 American Chemical Society exam for General Chemistry was administered for a 10 year period, with an average score of 55.5%. In the first year a POGIL class was offered, however, the average improved to 68.5%. [24]

The outcome of this research project is similar to those discussed above. The research was very beneficial to the students involved. It allowed them to control their learning environment more closely and to develop essential analytical skills. Just as the studies above suggest, the students involved in the study at Abingdon High School consistently performed at a higher level than previous years. Though it will require more study to cement these results, they are very promising.

Future Plans

Because of the promising preliminary results obtained in this research project, I plan to continue to implement inquiry methods in all levels of chemistry I teach. The research I have conducted has illuminated many facets of education, ranging from instruction methods to creative ideas that can be used to encourage interest in chemistry itself. To begin, I plan to do similar studies in the Honors Chemistry classes during the 2008-09 school year for other topics, including acid/base chemistry and Chemical Kinetics. I also plan to implement the Gas Law module in the Chemistry I level at Abingdon High School.

Additionally, I plan to continue the authentic learning project my Advanced Placement students are currently pursuing and expand it further to the class I am scheduled to teach at a local community college this fall. This project has served as a guide in many ways. The first year of its inception produced similar results to those found in the inquiry study conducted. The second year produced even better results, both in attitudes and skill development. Therefore, I am very hopeful that each year of the inquiry study will produce better and better results.

CHAPTER 5

CONCLUSION

Quite obviously, the American education system is flawed. As a teacher, this is a very troublesome statement. I am constantly striving to improve the education I can provide my students but so far, it seems to be a constant challenge. Traditional methods of instruction have been used for many years with mixed results. Some students thrive while others struggle. Determining what causes these differences is very important in correcting the flaws in our system.

Many students find traditional methods of instruction boring and quickly lose interest. Many educators argue that this is the result of immature students who have been coddled by society. Many feel that the responsibilities of the teachers have increased tremendously, with teachers now serving as parental figures, counselors, and referees along with the primary goal of providing knowledge for his or her students.

Additionally, many good teachers grow frustrated with the school system itself and leave teaching. There are many pressures placed upon the public high school educator in the current system. Many teachers simply feel that the pressures placed on teachers are too great and the rewards too small. Unlike many other more successful systems, teaching is not as respected a profession as it once was. This lack of respect has resulted in a lack of respect for the teachers themselves.

However, I feel that it is not a lost cause. There are many opportunities for improvement in the education system, and many strides have been made to create a more modern system in America. Aside from more stringent standards for teachers and their preparation programs, there is a system of accountability that has been put in place to require teachers, schools, and students to share the responsibility.

My research objectives were fulfilled through the implementation of this project. I read countless journal articles regarding worldwide education systems. These articles ranged from those written from a purely educational standpoint to those that focused on the economic impact of such allegations. Despite the different scope, all were enlightening and helped to illuminate the situations our system faces. I was also able to see many differences between the American system and other more successful ones. While some differences would require a complete reorganization of the system itself, some differences are minor and inspire changes that are actually possible.

These somewhat minor changes focus on the improvement of teacher education programs as well as the implementation of newer instructional methods that create a better learning environment. For this reason, I chose to integrate inquiry-based units into the traditional curriculum and actually observed some positive outcomes. When the inquiry methods were compared with traditional ones used in the past, I found a slight increase in student performance on final assessments. This intriguing comparison has inspired me to continue the current changes and increase the scope of the changes themselves.

The fact of the matter is that most students are not going to become chemists. Many of them feel that chemistry is too difficult or boring for them to continue its study. While the minds of some will not be changed by changing the method of instruction, there are some who flourish with the inquiry methods.

In order to fully understand the situation, much more extensive study must be done. I plan to incorporate these methods into my classes in future years. By working through the issues I encountered during this research project, I feel that I am better able to determine what problems may arise so as to avoid them. I also feel that varying instructional methods helps to make me a better teacher and forces my students to subscribe to a level of accountability higher than they are used to.

To be honest, I do not care which method is used to provide information to my students. My only concern is their hearing AND retaining the information in question. While long-term studies need to be performed to ascertain the extent to which inquiry affects learning, there is evidence to suggest that we are on the right track. It is definitely a good time to be in the education system and we all can find hope for its future.

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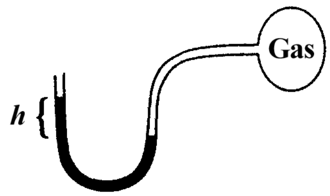
APPENDICES

Appendix A: Gas Law Pretest

1. You and a friend have gas samples in open manometers as shown:



You have Hg(l) in your manometer and your friend has water. The height *h* is the same in both manometers. Which of the following statements is true?

[A] Both samples of gas have the same pressure.
[B] Your friend's sample of gas has the higher pressure.
[C] There is not enough information to answer the question.
[D] Your sample of gas has the higher pressure.
[E] None of these is correct.

2. Three 1.00-L flasks at 25°C and 725 torr contain the gases CH_4 (flask A), CO_2 (flask B), and C_2H_6 (flask C).
In which single flask do the molecules have the greatest mass, the greatest average velocity, *and* the highest kinetic energy?

[A] flask A
[B] flask C
[C] flask B
[D] all
[E] none

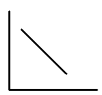
3. You are holding two balloons, an orange balloon and a blue balloon. The orange balloon is filled with neon (Ne) gas and the blue balloon is filled with argon (Ar) gas. The orange balloon has twice the volume of the blue balloon. Which of the following best represents the mass ratio of Ne:Ar in the balloons?

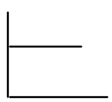
[A] 1 : 2
[B] 1 : 1
[C] 3 : 1
[D] 1 : 3
[E] 2 : 1

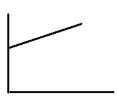
4. Hydrogen and chlorine gases react to form HCl. You and a friend are on opposite sides of a long hallway, you with H_2 and your friend with Cl_2. You both want to form HCl in the middle of the room. Which of the following is true?

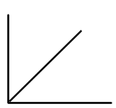
[A] You need to know the temperature to answer this question.
[B] Your friend should release the Cl_2 first.
[C] You should release the H_2 first.
[D] You both should release the gases at the same time.
[E] You need to know the length of the room to answer this question.

5. Which of the following is the best qualitative graph of *P* versus molar mass of a 1-g sample of different gases at constant volume and temperature?

[A] 

[B] 

[C] 

[D] 

[E] None of these

Four identical 1.0-L flasks contain the gases He, Cl_2, CH_4, and NH_3, each at 0°C and 1 atm pressure.

6. Which gas has the highest density?

[A] CH_4
[B] Cl_2
[C] all gases the same
[D] He
[E] NH_3

Four identical 1.0-L flasks contain the gases He, Cl_2, CH_4, and NH_3 each at 0°C and 1 atm pressure.

7. For which gas do the molecules have the highest average velocity?

[A] He
[B] CH_4
[C] all gases the same
[D] NH_3
[E] Cl_2

8. Which gas sample has the greatest number of molecules?

[A] He
[B] CH_4
[C] NH_3
[D] Cl_2
[E] all gases the same

9. For which gas are the collisions elastic?

[A] He
[B] all gases the same
[C] NH_3
[D] Cl_2
[E] CH_4

10. For which gas do the molecules have the smallest average kinetic energy?

[A] NH_3
[B] Cl_2
[C] CH_4
[D] He
[E] all gases the same

11. Zinc metal is added to hydrochloric acid to generate hydrogen gas and is collected over a liquid whose vapor pressure is the same as pure water at 20.0°C (18 torr). The volume of the mixture is 1.7 L and its total pressure is 0.810 atm. What would happen to the average kinetic energy of the molecules of a gas sample if the temperature of the sample increased from 20°C to 40°C?

[A] It would double.
[B] It would increase.
[C] It would become half its value.
[D] It would decrease.
[E] Two of these.

12. Which of the following is *not* a postulate of the kinetic molecular theory?

[A] The average kinetic energy of the particles is directly proportional to the absolute temperature.
[B] Gas particles have most of their mass concentrated in the nucleus of the atom.
[C] The moving particles undergo perfectly elastic collisions with the walls of the container.
[D] The forces of attraction and repulsion between the particles are insignificant.
[E] All of these are postulates of the kinetic molecular theory.

13. Consider the following gas samples:

Sample A	**Sample B**
$S_2(g)$	$O_2(g)$
n = 1 mol	n = 2 mol
T = 800 K	T = 400 K
P = 0.20 atm	P = 0.40 atm

Which one of the following statements is *false*?

[A] Assuming identical intermolecular forces in the two samples, sample A should be more nearly ideal than sample B.
[B] The volume of sample A is twice the volume of sample B.
[C] The fraction of molecules in sample A having a kinetic energy greater than some high fixed value is larger than the fraction of molecules in sample B having kinetic energies greater than that same high fixed value.
[D] The mean square velocity of molecules in sample A is twice as large as the mean square velocity of molecules in sample B.
[E] The average kinetic energy of the molecules in sample A is twice the average kinetic energy of the molecules in sample B.

14. Use the kinetic molecular theory of gases to predict what would happen to a closed sample of a gas whose temperature increased while its volume decreased.

[A] The number of moles of the gas would decrease.
[B] Its pressure would decrease.
[C] Its pressure would increase.
[D] The average kinetic energy of the molecules of the gas would decrease.
[E] Its pressure would hold constant.

15. Which of the following would have a higher rate of effusion than C_2H_2?

[A] CO_2
[B] CH_4
[C] N_2
[D] Cl_2
[E] O_2

16. Which of the following statements is true concerning ideal gases?

[A] A gas exerts pressure as a result of the collisions of the gas molecules with the walls of the container.
[B] The gas particles in a sample exert attraction for one another.
[C] The temperature of the gas sample is directly related to the average velocity of the gas particles.
[D] At STP, 1.0 L of Ar(g) contains about twice the number of atoms as 1.0 L of Ne(g) since the molar mass of Ar is about twice that of Ne.
[E] All of these are false.

17. Which of the following effects will make PV/nRT less than 1 for a real gas?

[A] A large number of molecules have speeds greater than the average speed.
[B] The gas molecules attract one another.
[C] The gas molecules are large enough to occupy a substantial amount of space.
[D] The gas molecules have a very low molar mass.
[E] none of these

Consider three 1-L flasks at STP. Flask A contains NH_3 gas, flask B contains NO_2gas, and flask C contains N_2 gas.

18. Which contains the largest number of molecules?

[A] flask B
[B] flask C
[C] flask A
[D] all are the same
[E] none

19. In which flask are the molecules least polar and therefore most ideal in behavior?

[A] flask B
[B] flask A
[C] flask C
[D] all are the same
[E] none

20. In which flask do the molecules have the highest average velocity?

[A] flask C
[B] flask B
[C] flask A
[D] all are the same
[E] none

21. You have two samples of the same gas in the same size container, with the same pressure. The gas in the first container has a kelvin temperature four times that of the gas in the other container. The ratio of the number of moles of gas in the first container compared to that in the second is

[A] 1 : 4
[B] 4 : 1
[C] 1 : 1
[D] 2 : 1
[E] 1 : 2

Appendix B: Boyle's Law

Boyle's Law: Relationship between Pressure and Volume:

Pre-test questions:

1. In a vacuum, the volume of a gas:
   a. Increases
   b. Decreases
   c. Is unchanged

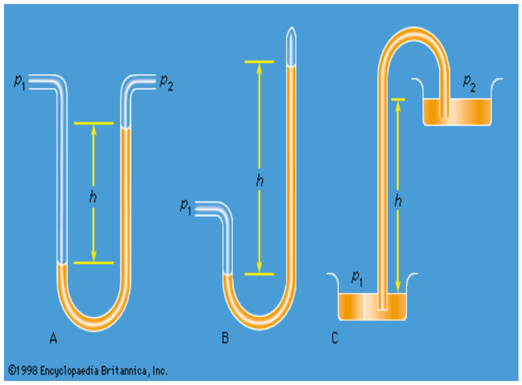
2. This occurs because:
   a. The pressure surrounding the gas decreases
   b. The pressure surrounding the gas increases
   c. The pressure remains unchanged

3. Therefore, pressure and volume are:
   a. Directly proportional
   b. Inversely proportional
   c. Unrelated
   d. Related in an unpredictable manner

Background Information:

Pressure of air is measured with a BAROMETER (developed by

Torricelli in 1643) Hg rises in tube until force of Hg (down) balances the force of the atmosphere (pushing up). Pressure of Mercury pushing down is related to the column height.



The first scientist to study quantitatively the relationship between pressure and volume was Robert Boyle in the mid sixteen hundreds. His experiments can be applied to many modern situations, including a bicycle pump. As the volume of the air trapped in the pump is reduced, its pressure goes up, and air is forced into the tire.

Demonstration:

Place the Marshmallow Heart into the vacuum. Seal the chamber and close the air valve. Once the pump starts, notice the changes in the marshmallow heart.

Repeat the above demonstration using shaving cream.

Exercises:

5. Based on your observations of the marshmallow heart, what is the relationship between pressure and volume?

2. Derive a mathematical formula to express this phenomenon.

3. Given 6.0 liters of a gas at STP, what happens to the volume if the pressure is increased to 1432 mm Hg without changing the temperature?

4. The highest pressure ever produced in a laboratory setting was about 2.0×10^6 atm. If we have a 1.0×10^{-5} liter sample of a gas at that pressure, then releaese the pressure until it is equal to 0.275 atm, what would the new volume of that gas be?

5. Atmospheric pressure on the peak of Mt. Everest can be as low as 150 mm Hg, which is why climbers need to bring oxygen tanks for the last part of the climb.

If the climbers carry 10.0 liter tanks with an internal gas pressure of 3.04×10^4 mm Hg, what will be the volume of the gas when it is released from the tanks?

When the above questions are complete, move to the computer station and complete the activity found at the following address:
http://www.chm.davidson.edu/chemistryapplets/gaslaws/BoylesLaw.html

Appendix C: Charles' Law

Charles' Law: Relationship between Temperature and Volume:

Pretest questions:

1. If the temperature of a gas increases but pressure remains constant, the volume of a gas:
    a. Increases
    b. Decreases
    c. Is unchanged

2. This occurs because:
    a. The gas particles collide more frequently
    b. The gas molecules collide less frequently
    c. The gas molecules do not collide
    d. The gas molecules collide with equal frequency as they did before the ` temperature change

3. Therefore, temperature and volume are:
    a. Directly proportional
    b. Inversely proportional
    c. Unrelated
    d. Related in an unpredictable manner

Background Info:

Primary study of the relations between temperature and volume is credited to Jacque Charles, a French balloonist, Because of his occupation, he was well versed in this topic. Much study has been done to further develop Charles' theories, and there are many modern applications.

Demonstration:

Put a few drops of water in an otherwise empty aluminum can. Heat the can for 3 minutes and then place the can upside down into a beaker of cool water (using tongs).

Exercises:

1. Based on your observations of the can, what is the relationship between temperature and volume?

2. Derive a mathematical formula to express this phenomenon.

3. What unit must temperature be measured in? Why?

4. On hot days, you may have noticed that potato chip bags seem to "inflate", even though they have not been opened. If I have a 250. mL bag at a temperature of 19.0 ^{0}C, and I leave it in my car which has a temperature of 60.0^{0} C, what will the new volume of the bag be?

5. A soda bottle is flexible enough that the volume of the bottle can change even without opening it. If you have an empty soda bottle (volume of 2 L) at room temperature (25 ^{0}C), what will the new volume be if you put it in your freezer (-4 ^{0}C)?

6. When a balloon is placed in liquid nitrogen, what happens? (for hints, visit http://www.chem.uiuc.edu/clcwebsite/demos/gases/gases.htm)

Upon Completion of the above questions, visit the following website and complete the assignment:
http://www.chm.davidson.edu/ChemistryApplets/GasLaws/CharlesLaw.html

Appendix D: Kinetic Molecular Theory

Kinetic Molecular Theory

Please refer to the following link:

http://pogil.org/downloads/HS/8_Kinetic_Molecular_Theory_v2.pdf

Appendix E: Demographic Information

Demographic Information for Honors Chemistry students at Abingdon High School in Abingdon, Virginia who were involved in research study

ID #	GPA	Diploma	Gifted	Gender	Race	ID #	GPA	Diploma	Gifted	Gender	Race
1	3.912	Advanced		M	C	33	3.969	Advanced		F	C
2	4.000	Advanced	X	M	C	34	3.586	Advanced		M	C
3	3.938	Advanced	X	F	C	35	3.471	Advanced		F	C
4	3.735	Advanced		M	C	36	3.125	Advanced		M	C
5	3.438	Advanced		F	C	37	2.912	Advanced		M	C
6	4.000	Advanced	X	M	C	38	3.824	Advanced	X	F	C
7	3.412	Advanced		F	C	39	4.000	Advanced	X	F	C
8	3.625	Advanced		F	C	40	3.000	Advanced		M	C
9	2.833	Advanced		F	C	41	3.912	Advanced		F	C
10	3.882	Advanced		F	C	42	3.500	Advanced		M	C
11	3.794	Advanced	X	M	A	43	3.375	Advanced		F	C
12	3.882	Advanced	X	F	C	44	3.324	Advanced		F	C
13	3.182	Advanced	X	F	C	45	3.912	Advanced	X	F	C
14	3.905	Advanced		F	C	46	3.935	Advanced		F	C
15	3.941	Advanced	X	M	C	47	3.235	Advanced		F	C
16	3.625	Advanced		F	C	48	3.765	Advanced	X	F	C
17	3.500	Advanced		F	C	49	4.000	Advanced	X	M	C
18	3.971	Advanced	X	F	C	50	3.563	Advanced		M	C
19	3.029	Advanced	X	M	C	51	3.943	Advanced	X	F	C
20	3.735	Advanced	X	F	C	52	3.412	Advanced	X	F	C
21	4.000	Advanced	X	M	C	53	4.000	Advanced	X	M	C
22	3.882	Advanced	X	M	C	54	3.968	Advanced		M	C
23	3.176	Advanced		M	C	55	3.676	Advanced	X	F	C
24	2.882	Advanced		M	C	56	3.563	Advanced		F	C
25	3.971	Advanced	X	M	C	57	3.265	Advanced		M	C
26	3.563	Advanced		M	C	58	3.912	Advanced	X	F	C
27	3.765	Advanced	X	F	C	59	3.971	Advanced	X	F	C
28	3.735	Advanced	X	F	C	60	3.882	Advanced	X	M	C
29	4.000	Advanced	X	M	C	61	3.824	Advanced	X	F	C
30	3.324	Advanced	X	M	C	62	2.833	Advanced		F	C
31	2.647	Advanced		F	C	63	2.844	Advanced	X	M	C
32	3.912	Advanced	X	M	C	64	3.478	Standard		M	C

Appendix F: Gas Law Pretest Data

Gas Law Pre-Test Data with Confidence Ranking of 1-3, where 1 indicates confidence, 2 indicates partial uncertainty and 3 indicates complete uncertainty by Question number 1-21.

		Question Number																			
Student	Raw Score	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21
1	23.81	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	61.90	2	2	1	2	2	3	2	1	3	1	2	1	2	3	2	1	3	3	3	3
3	38.10	2	2	1	1	2	1	3	2	3	3	3	3	2	2	3	1	3	1	3	2
4	28.57	3	3	3	2	2	2	3	3	3	3	3	3	2	2	3	2	3	2	2	3
5	23.81	3	2	3	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3
6	42.86	2	2	1	2	1	1	3	2	2	1	2	1	2	2	3	1	3	3	2	2
7	33.33	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
8	23.81	2	2	2	2	2	2	2	2	2	3	2	2	2	2	3	2	3	2	3	2
9	23.81	3	3	3	1	3	1	3	3	3	3	3	3	2	3	3	2	3	2	3	2
10	38.10	2	2	3	2	1	2	2	2	2	2	1	2	2	3	2	2	2	1	2	2
11	28.57	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
12	28.57	2	2	3	2	1	2	3	3	2	1	2	3	2	2	3	2	3	2	3	2
13	19.05	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
14	38.10	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
15	42.86	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	3	2	3	2
16	19.05	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
17	9.52	1	1	2	1	2	1	2	3	3	3	3	3	2	3	3	3	3	3	3	2
18	42.86	2	2	2	2	2	2	2	2	2	1	2	2	2	3	2	1	2	3	2	2
19	28.57	2	3	2	1	3	1	3	3	3	2	3	3	2	3	3	3	2	3	3	3
20	19.05	3	3	2	1	3	1	3	3	3	3	2	2	1	3	2	3	2	3	2	3
21	42.86	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
22	33.33	3	3	2	2	3	1	3	2	2	2	2	3	3	3	3	1	3	2	3	2
23	42.86	3	3	3	2	3	2	3	3	3	3	3	3	3	3	3	1	3	3	3	2
24	19.05	2	3	1	1	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	2
25	42.86	2	2	1	2	1	2	3	3	2	1	2	2	2	3	1	2	2	2	2	3
26	28.57	2	1	1	2	3	1	2	2	2	3	2	3	1	2	1	1	3	2	2	3
27	42.86	2	2	1	3	3	2	3	2	2	3	3	3	2	3	2	2	2	3	3	3
28	47.61	3	3	1	3	3	3	2	3	2	3	3	2	2	2	3	2	2	3	3	3
29	23.81	2	1	2	2	2	3	2	1	1	2	2	1	2	2	1	2	2	2	1	2
30	38.10	3	3	3	1	2	1	2	3	3	2	3	3	3	3	2	1	3	3	2	1
31	33.33	2	3	2	2	3	2	1	3	3	3	2	3	2	3	3	1	2	2	3	2
32	14.29	2	2	2	3	3	2	2	2	2	2	3	3	2	2	3	2	2	2	2	2
33	47.61	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
34	19.05	1	3	1	1	2	1	3	3	3	3	3	3	3	3	3	2	3	2	3	2
35	38.10	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
36	23.81	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
37	23.81	2	3	2	3	3	1	3	2	3	2	3	3	3	3	3	3	3	3	3	2
38	19.05	2	2	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2	2	3
39	38.10	2	2	3	3	3	3	3	2	2	3	3	2	3	3	2	3	2	2	2	3
40	9.52	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2

		Question Number																		
Student	Raw Score	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21
41	28.57	1	3	2	1	3	1	3	3	3	1	3	3	3	3	3	2	3	3	3	3
42	23.81	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3	2	3	3	3	2
43	33.33	3	3	3	3	3	2	3	3	3	1	3	3	3	3	3	2	3	3	3	3
44	33.33	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
45	19.05	2	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	2	3	2
46	28.57	3	3	3	3	3	3	3	2	2	1	2	3	3	3	3	3	3	3	3	2
47	19.05	3	3	2	2	3	2	3	3	3	3	3	3	3	3	3	2	3	2	3	2
48	23.81	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
49	23.81	3	3	3	3	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3
50	19.05	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
51	14.29	3	3	2	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3
52	28.51	3	2	2	2	3	2	2	2	3	2	3	3	2	3	3	2	1	3	2	3
53	38.10	2	2	3	2	3	2	3	3	3	1	3	3	3	3	3	3	3	3	3	2
54	9.52	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
55	19.05	3	2	1	2	3	1	1	3	3	3	3	2	3	2	3	3	3	3	3	2
56	19.05	2	3	2	1	3	3	3	3	3	2	2	3	2	3	1	2	3	3	3	3
57	9.52	3	2	2	1	3	2	1	3	3	3	3	3	3	3	3	3	3	3	3	3
58	9.52	2	3	3	2	3	2	2	3	3	2	3	3	3	3	3	3	3	3	3	2
59	57.14	3	3	3	2	2	2	3	3	3	1	3	3	2	3	3	3	3	2	3	3
60	28.57	3	3	2	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3
61	33.33	1	2	3	2	3	1	3	3	3	2	3	3	3	3	3	3	3	2	3	3
62	28.57	2	2	2	2	2	2	3	2	3	1	3	3	3	3	3	1	3	2	3	3
63	19.05	3	3	3	2	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	2
Avg	28.72																				

VITA

SARAH HOLBROOK SAWYERS

Personal Data:	Date of Birth: October 10, 1977 Place of Birth: Bristol, Tennessee Marital Status: Married
Education:	Castlewood High School, Castlewood, Virginia Virginia Intermont College, Bristol, Virginia Bachelor of Science 1999 East Tennesee State University, Johnson City, Tennessee Chemistry, Master of Science, 2008
Professional Experience:	Teacher, Abingdon High School, Abingdon, Virginia August 1999-present Adjunct Professor, Virginia Highlands Community Colllege, Abingdon, Virginia, Summer 2005-present
Honors and Awards:	Who's Who Among American High School Teachers