AC 2011-871: ATTRACTING K-12 STUDENTS TOWARDS ENGINEERING DISCIPLINES WITH PROJECT BASED LEARNING MODULES

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Abstract

Low enrollment and high attrition rates in Science, Technology, Engineering and Math (STEM) based degree programs have created a workforce problem in industries like shipbuilding and repair which are important for national security. Part of this problem can be attributed to pedagogical issues like lack of engaging hands-on activities utilized for science and math education in middle and high schools. Lack of student interest in technical careers can also be attributed to lack of an integrated approach in teaching math, science and technical education. To engage student's interest in the technical career path, it is important that students establish a link between the theoretical knowledge and its application to solve real life problems early in their learning experience. Project based activities have a proven record as instructional tool. Effectiveness of such activities as a pedagogical tool has been supported by research in the acquisition and retention of knowledge.

Two projects funded by the National Science Foundation and National Shipbuilding Research Program have attempted to address the workforce issue for marine industry by developing project based learning kits and associated instructional modules to engage K-12 students in STEM tracks and increase awareness about shipbuilding and repair careers. Four marine kits and four instructional modules were developed under these two grants to encourage creative thinking and keep students engaged in shipbuilding and repair processes. The teacher training component of these projects has provided training in using and implementing these modules. The paper presents the motivation behind developing these project based learning (PBL) modules, issues related to implementation and results from student and teacher workshops.

Key words

Project Based Learning; Workforce Development; STEM Education; Shipbuilding Industry.

1. Introduction

Old Dominion University, Norfolk State University and Longwood University in collaboration with marine industry and local school systems are improving STEM preparation using innovative experiences for students and teachers in nation's major shipbuilding and repair areas through MaineTech and Shipbuilding Repair and Career Day Events. MarineTech project will be serving 60 students in grades eight through twelve, over a period of three years, by providing 144 hours of instruction and hands-on learning experiences in the fields of marine engineering and physical sciences with a shipbuilding focus. The program includes eight Saturdays during academic years, with an additional two-week academy during each summer. Project's progressive curriculum covers foundational skills and knowledge of basic physical science as it relates to ship building, through the application of these principles in a culminating

ship design competition. The curriculum is enriched with program activities such as field trips to shipbuilding and repair companies, marine science museums and career day events.

MarineTech project concurrently targets 60 math, science, and technology education teachers for grades eight through twelve, each of whom will receive 40 hours of summer professional development and 40 hours of follow-up training and support. Teachers will work an additional 40 hours in working with their students to build underwater robot-Sea Perch and design and build a human powered container ship for competition. Participating teachers will be fully trained in curriculum implementation and will be given materials and resources necessary to replicate MarineTech activities in their classrooms.

This project addresses the urgent need to enhance under-represented students' interest and performance in STEM courses, while fostering skills that are important prerequisites for STEM careers, particularly in marine engineering, physical science and information technology. In the near term, the project will incorporate activities designed to boost student scores on academic achievement measures like Standard of Learning (SOL). However, the project also addresses the critical shortage of qualified workers needed to sustain the defense ship building and repair industry in the USA. Support for the project from shipbuilding companies and professional organizations and government agencies is evidenced by letters of commitment to assist with the project by providing opportunities for students to see marine industries at work.

Under a previous project funded by the National Shipbuilding Research Program, four hands-on activities were developed for middle and high school students. The project team consisting of university faculty, industry personnel, school and community college teachers developed these four Marine Kits, MK-1-4 and five Instructional Modules, IM-1-5, to impart learning experience related to shipbuilding and repair. These activities and associated curriculum have been designed as an integrated experience and each one builds upon the knowledge gained during the previous activity. Figure-1 shows the MarineTech curriculum. Marine Kit-1 is related to shipyard operations which provide a big picture of how a shipyard operates. Marine Kit-2 deals with cost estimation and construction of a ship. Marine Kit-3 teaches about ship design and stability while Marine Kit-4 deals with the ship disaster investigation. First Instructional Module deals with the Terminology and history of ships. The second module deals with the structure of ships. Third Module is about the design of hull of a ship. Fourth module teaches different loading operations. Fifth module is related to environmental issues during ship building. Student comments point to a very stimulating learning experience. The paper will discuss the design and development of these activities and its subsequent implementation within the classroom.

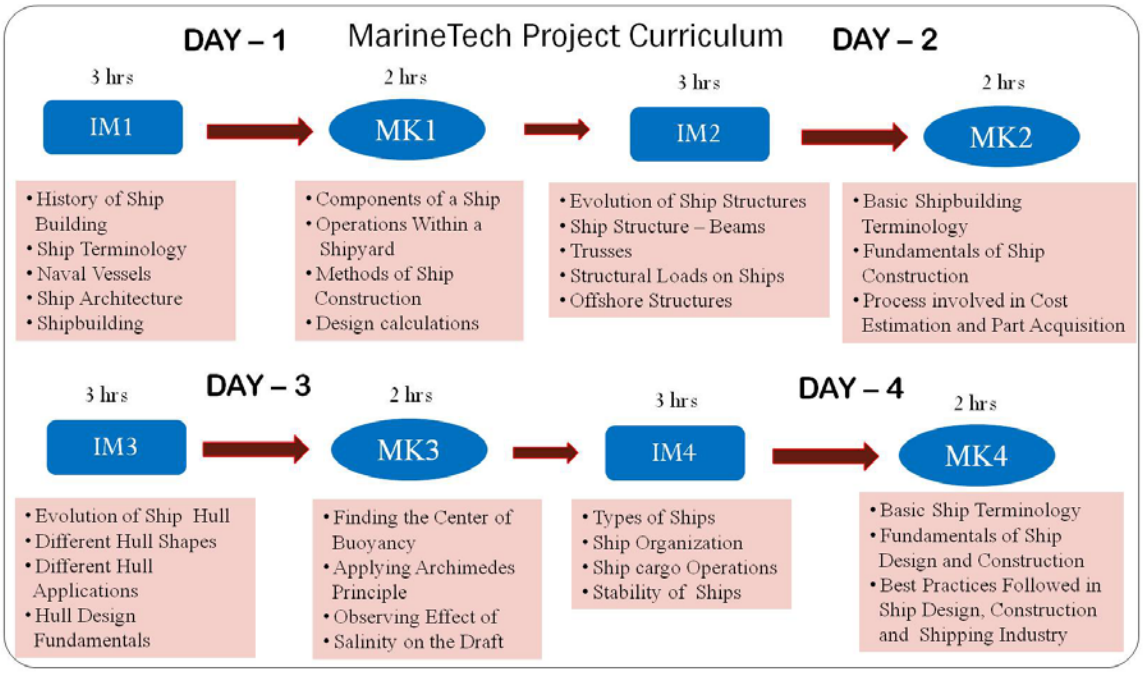

Fig. 1 MarineTech Curriculum

2. Project Based Learning as a Teaching Tool

Project Based Learning has proven record as a teaching tool. The constructivism learning theory suggests that people learn better by actively participating in the learning process. In order to involve students into the participatory learning process, the interaction among students, between students and the instructor in a classroom becomes very critical. Effectiveness of project-based learning is well recognized. Edgar Dale's cone of learning as shown in Figure-2 supports the benefits of project based learning.

Educators have been designing, using, evaluating and writing about Project Based Learning (PBL) for more than 20 years however, it has not found wide spread acceptance in classrooms. Project Based Learning is a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks[1]. Another important use of project based learning in education is to facilitate efforts at what has become known as "bridging the gap" between academics of profession and practice of that profession. PBL is ideal for connecting factual knowledge, principles, and skills to their application within a profession.

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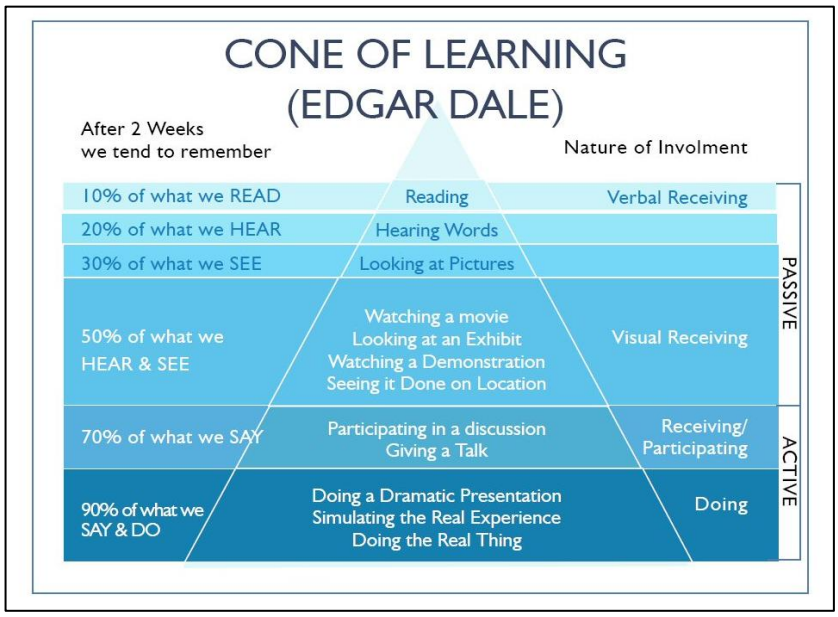

Fig.2 Cone of Learning by Edgar Dale

3. Need for Project Based Learning (PBL)

The results from Virginia's Standards of Learning (SOL) assessments reveal that there is an achievement gap between minorities and Caucasians/Asians in all grade levels in Southside Virginia. Achievement gaps may be caused by numerous complex reasons such as economic or psychological conditions, or family-school disconnects beyond a school's control. Nonetheless, many factors such as curriculum, effective instruction, and classroom management are within the control of the school environment and can be changed through organized professional development programs. This project aims to transform the pedagogical practices in the high-need schools by providing training in project based learning. In initial preparation for this project, the principal investigator interviewed many of the instructional specialists from the participating high needs schools. They stated that only a few teachers of physical sciences and chemistry use inquiry-based project-based learning strategies in their classrooms. However, research reveals that inquiry-based learning and project-based learning strategies develop communication, problem-solving, and critical thinking skills and improve student achievement[2].

MarineTech project allows teachers to integrate real world applications from a marine engineering perspective for teaching math and science concepts in middle and high schools. The project also provides professional development on marine engineering concepts to the science, mathematics, and technology teachers. As a result, it is expected that teachers will improve student achievement in math and science, bring excitement to students that results in increased enrollment in advanced math, science, and technical education courses, and enhance the workplace and college readiness of high school students.

4. Needs to Enhance Content Knowledge and Instructional Practices of Teachers

The needs reported most frequently by school division leaders include: a) concentrated assistance in math and science instruction; b) better math and science preparation for teachers; c) professional development to encourage secondary teachers to have high expectations for all students and to use a wide repertory of instructional strategies to meet student needs; d) professional development that is closely linked with curriculum; e) professional development on research-based practices and better ways to manage use of curricular materials; and f) any time, anywhere support for teachers.

In alignment with High Objective Uniform Standard of Evaluation (HOUSE) of Virginia and the research on high quality professional development[3], MarineTech will focus on improving the content knowledge of teachers as they experiment with marine kits, learn to build ships and connect the math and science concepts to real world problems. The project will enhance the pedagogical knowledge of teachers on using project-based learning in instruction, promote collaboration among students from diverse school districts that alleviates issues regarding teacher efficacy encourage active learning and other technology resources to develop 21st century skills and support teachers in developing instructional modules in the content disciplines that are aligned with the Virginia Standards of Learning in mathematics and science. By providing year-long training activities with online support, the project will help teachers collaborate while developing learning modules.

5. Future Workforce Needs in Marine Engineering and Technology

Marine engineers and naval architects are expected to experience employment growth of 11 percent in the period 2006 - 2016. Excellent employment opportunities are expected for these professions because of growth in employment, an aging workforce and limited number of students pursuing careers in these occupations. Another flourishing area in the marine field is merchant marine; phenomenal employment growth of 16 percent is expected in this field. There are good prospects in the engineering technician field that also require good STEM skills. Employment growth for environmental engineering technicians over the period of 2006 -16 is expected to be 25 percent. The occupation of an Industrial Engineering Technician is also a high growth area with the employment growth rate of 10 percent. While we are preparing our students to improve their knowledge of math and science and to develop technology skills, it is critical that we provide awareness about various types of STEM careers such as marine engineering. In this project, teachers will be able to understand about the demand for marine engineers and have an increased understanding about the way students need to enter the career.

6. Survey to Assess Student's Knowledge about Shipbuilding & Repair

A survey was designed to assess the impact of the PBL activities on the student's knowledge about shipbuilding and repair. This survey contains questions about ships components, ship design and physics principles like buoyancy. Student responses are aggregated and average score is obtained on a scale of 1-10. Students are assessed using the same instrument

after they have gone through the four simulation sessions. The difference in the score between the pre and post survey provides a measure of change in the knowledge base of the students.

7. Delivery Method

The course is instructor-led classroom training combined with in-class hands-on activities designed to invite class participation. This approach aids in the individualized instruction given to the participant. Instructional methods include facilitated discussion, hands-on activity, and on-the-job practical applications. PowerPoint presentations are used to deliver the course, supplemented by a series of videotapes from Society of Manufacturing Engineers and Productivity Inc.

8. Marine Kits - Activities Related to Shipbuilding and Repair

The four simulation activities are related to operation of a shipyard, ship construction, ship stability and best practices in the shipping operations.

a) Shipyard Operation Activity simulates operations within a shipyard. Plasma cutting, bending and welding shops are simulated. Students use card stock paper to build a container ship. This simulation demonstrates modular construction of a ship.
   Topics covered in this Marine Kit are:
   - Components of a ship
   - Operations within a shipyard
   - Methods of ship construction
   - Design calculations

b) Ship Construction Activity simulates construction of a clipper ship and a submarine. This simulation also covers calculations related to bill of material, sales tax and labor cost.
   Topics covered in this Marine Kit are:
   - Basic ship terminology
   - Fundamentals of ship construction
   - Processes involved in cost estimation and part acquisition

c) Ship Stability Activity involves the understanding of center of gravity, center of buoyancy, and Archimedes Principle. This simulation uses foam hull shape to conduct experiment to identify center of buoyancy and observe the effect of salinity on buoyancy.
   Topics covered in this Marine Kit are:
   - Finding the Center of Buoyancy
   - Applying Archimedes principle to find weight and volume of displaces water
   - Observing the effect of salinity on the draft.

d) Ship Disaster Investigation simulation involves ship disaster case studies. Students play the roles of Ship Disaster Investigation Agency (SDIA) agents analyzing the ship disaster. They identify possible causes behind the disaster. In this open ended problem based simulation students learn fundamentals of ship design, basic terminology used in the shipbuilding and

shipping industry and the correct practices followed in ship design, construction and shipping industry.

Topics covered in this Marine Kit are:

- Basic ship terminology
- Fundamentals of ship design and construction
- Best practices followed in ship design, construction and shipping industry

Figure 3 shows the contents of the four Marine Kits.

Fig. 3 Marine Kits 1-4

Students perform each activity in groups of four - five. Students are provided with handouts and manuals which include instructions to carry out hands-on activity. The kit comes with a teacher's manual and model solutions for the simulations. Among the four activities, shipyard operation and ship construction simulations are more structured while ship stability and ship disaster investigation are open ended activities where students are given clues and they are encouraged to find solutions.

9. Instructional Modules

A total of nine Instructional Modules were developed under the NSF funded MarineTech project. Each of theses modules incorporate 4-6 project based learning kits which support the concepts covered in the modules. The nine modules cover a variety of topics related to marine and maritime industry and are listed below:

1. History and Terminology of Ship Building
2. Ship and Offshore Structures
3. Hull Design
4. Ship Operations
5. Environmental Issues in Ship Operations and Ship Building
6. Force and Motion
7. Oceanography
8. Submarine and
9. Deep Sea Salvage

Figure-4 Marine Kit 1 and 2 – Activity

Each of the instructional modules were designed with the 5E learning model in mind to engage students and provide them with an opportunity to explore, elaborate and evaluate as shown in Figure 5.

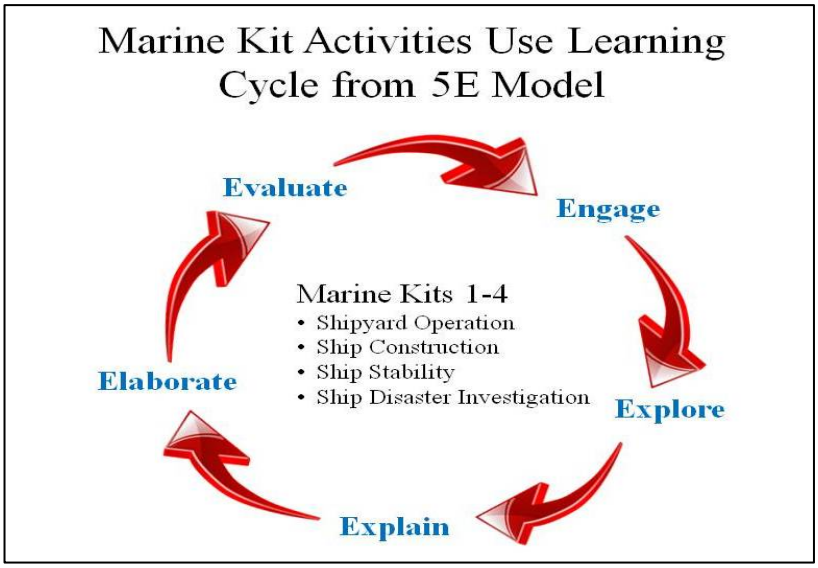

Fig. 5 5E Learning Cycle in Marine Kit Activity

Figure-6 Hands-on Activities in IM-1 and IM-2

During the hands-on activity, students are divided into groups of four to five. Figure 6 shows the hands-on activities being performed by students during History & Ship Terminology (IM-1) and Ship and Offshore Structures modules (IM-2).

10. Implementation of the Marine Kits and Associated Instructional Modules

As mentioned above, these activities are conducted in groups of four or five students and done in a session lasting for about three hours for instructional Modules and two hours for Marine Kits. The teacher explains the activity with a power point presentation and then the students are given the kits. At this point students begin the activity by going through the manuals and instruction sheets provided with the kit. Figure 7 shows students performing ship construction activity. Students use K'nex parts to construct a clipper ship. Students first count parts required to construct a given ship by examining the detailed drawings and assembly instructions provided in the manuals. This activity tests student's skills for visualization and blue-print reading, project management, cost estimation and supply chain management. After identifying the parts needed to construct the ship, students prepare a bill of material and order the parts from the teacher who serves as the supplier. Groups are penalized for not having an accurate count of parts. If the group ordered fewer parts, then they can purchase the parts during assembly at double the price. If the group ordered too many parts, then they have to pay 20% restocking fee to return the parts.

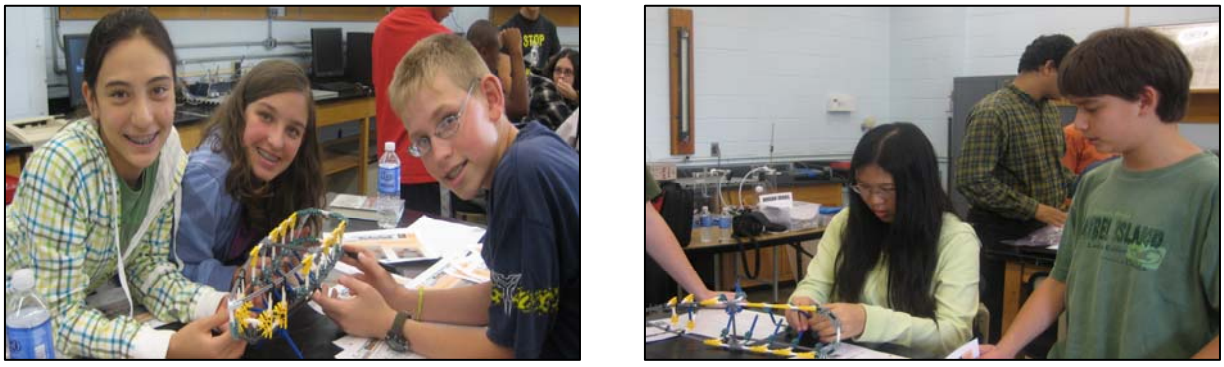

Figure-7 Marine Kit-1 Activity: Ship Construction

Each group's activity is assessed using a rubric containing performance criterions. The group that builds the ship with minimum cost, shortest amount of time, least number of defects and accurate calculations wins the competition.

11. Results

The project curriculum and associated project based learning activities have been received equally well by both students and teachers. Comments at the end of the workshop reveal that students enjoy learning about ships, ship construction, ship design and operations. Figure 8 shows the bar chart of student responses from the pre and post training evaluations. The x axis represents the questions asked during the survey before and after the workshop. The chart shows substantial increase in the strongly agree category after the students participated in the Marine Kits activity. Figure 9 shows the results from the evaluation of teacher workshop conducted during summer 2009. The chart shows that majority of teachers believed that the workshop using Marine kits was extremely beneficial to them and that they enjoyed the hands-on activities.

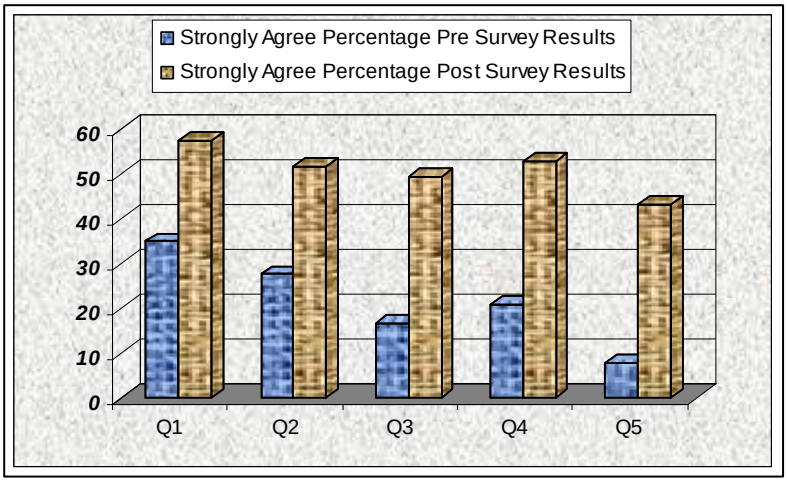

Figure-8 Plot of Student Responses

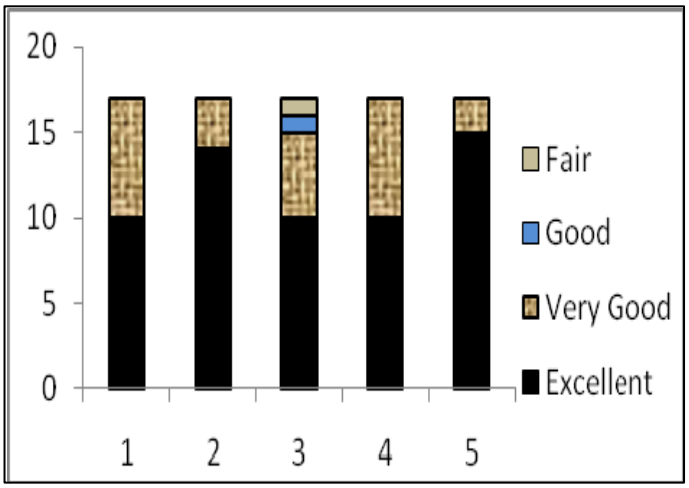

Figure-9 Teacher's Evaluation of Workshop

12. Conclusions

The project has successfully developed and integrated project based learning activities within the middle and high school curriculum. The Marine Kit activities and the Instructional Modules compliment the standards of learning for middle and high schools. The project demonstrates that, learning about ship design, construction, ship operations and ship stability concepts are made easier by incorporating project based learning activities within the curriculum. Student learning is enhanced by incorporating these activities where students work in groups to accomplish problem solving. Open ended problems provide opportunities for group discussion and creative thinking. Student's comments from curse evaluations indicate that students find these learning experiences very enjoyable. Participating teachers believed that the activities were well designed and will engage students in classroom. Widespread use of Marine Kits and associated Instructional Modules will successfully engage students and attract them towards STEM based careers in the Marine Industry.

Acknowledgements

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Biblography

1. B. F. Jones, C. Rasmusses, & M Moffit. Real life problem solving, *American Psychological Associatio,* Washington DC 1997
2. B.J.S. Barron, D. L. Schwartz, N. J. Vye, A. Petrosino, L. Zech, J. D. Bransford & The Cognition and Technology Group at Vanderbilt. Doing with understanding: Lessons from research on problem- and project-based learning, *Journal of the Learning Sciences, 7(3&4),* 1998, 271-311.
3. Newsletter, Teacher Quality and Improvement, *The Council of Chief State Offices,* 2005, vol. 10 issue 3.
4. T. Boe, The next step for educators and the technology industry: Investing in teachers. *Educational Technology,* 1989,29(3), 39-44.
5. Bureau of Labor Statistics http://www.bls.gov/oco/ocos027.htm
6. C. Czerniak, .& M. Schriver, An examination of preservice science teachers' beliefs and behaviors as related to self-efficacy. *Journal of Science Teacher Education,* 1994, Volume 5, Number 3, 77-86.
7. N. Fisher, K. Gerdes., T. Logue, L. Smith & I Zimmerman, Improving students' knowledge and attitudes of science through use of hands-on activities. *(ERIC Document Reproduction Service No. ED 436 352).*1998
8. J. Harvey, & S. Purnell, S., Technology and teacher professional development. *Report Prepared for the Office of Educational Technology, U.S. Department of Education.* Santa Monica, CA: Rand Corporation, March 1995