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Abstract – This paper presents our outreach efforts in the Department of Ocean Engineering at Florida Atlantic University. The main theme of the outreach effort is "project-oriented, team-based" learning philosophy, which goes beyond the typical "cookie-cutter hands-on" ideas in that there is an overall goal for learning to take place. This is drastically different the traditional "tool-based" learning where the students have to learn all the tools first before they can solve a particular problem. By promoting project-oriented, team-based education, students can appreciate better why they are learning what they are learning, how they can work together as a team, and apply their skills to solving interesting and relevant problems. Over the past four pasts, we have hosted a Model Submarine Design Workshop for high-school students in 2004, and a teacher training workshop in 2007. In addition, we have been offering a yearly dual-enrollment summer class for high school students since 2005. The main goals of these outreach effort are to stimulate high school students' interests in pursuing science and engineering as their fields of study and careers, and to enhance the research experiences for the in-service high school teachers in science and technology areas so they can bring the knowledge and experiences back into their classrooms.

Keywords: Project-based learning, K-16, Education Methods, Innovative Classroom Practice.

1. MOTIVATION

Our outreach effort addresses the inadequacy of high school students in math and science literacy in the United States. According to [3], U.S. high school seniors ranked below their counterparts in 17 other countries in math and science literacy. In physics, U.S. high school seniors scored last among 16 countries tested. Based on [1], [2], our high schoolers remained outperformed in math and science when compared to their international counterparts. Another alarming finding is that while more students are enrolling in colleges and receiving degrees, there are fewer degrees awarded (5% decline) in engineering and engineering technologies (between 1989-90 and 2003-04).

The literacy problem is further exacerbated with a severe shortage of qualified science teachers. According to [4], the enrollment in public high schools is expected to increase by 4% (between 2000 and 2008), more than 25% of teachers are at least 50 years old and the median age is 44, and a stronger push for class-size reduction. 37% of high school math teachers and 31% of science teachers lack qualifications in their fields. The situation is succinctly described by Judith Ramaley, who is the NSF Assistant Director for Education and Human Resources: "There is too little funding, too many under performing students to reach, too little interest in science and too few teachers able to develop their professional skills, to name a few".

2. OUTREACH ACTIVITIES

Over the past four years, we have organized a number of outreach efforts specifically for high school students. This section provides a summary of each of the individual activities.

2.1 1st Model Submarine Design & Testing Workshop (2004)

This was our first attempt made in addressing students' math and science literacy. The principal investigator conducted the 1st Model Submarine Design & Testing Workshop during May 5-9 of 2004 at the SeaTech Campus in the Department of Ocean Engineering at Florida Atlantic University. In the 2004 workshop, students learned how to design, build and test model mechanical submarines. A total of 23 competitive high

school students (GPA at least 3.0) with interest in engineering, math, and science were selected to participate in this workshop: 20 of them were in Grade 9 from South Broward High, one from North Miami Beach High, one from Boynton Beach High, and one from Lemon Bay High from Inglewood, Florida. The last three students were all in Grade 11. All the students were divided into 5 groups. There were two high school teachers who attended the workshop: one from South Broward High, and one from Robinson High from Tampa, Florida.

In the workshop, we considered only the mechanical aspect of submarine design, and introduced the concept of balance of forces: weight, buoyancy, drag, thruster, and control surface. We built five sets of kits, one for each student group. Each kit contained mainly 4 different nose sections (blunt, cone, Gertler, and multi-faceted), 2 tail sections (Gertler, and cone), one cylindrical mid-section, one power core, rubber bands (for propulsion energy), and 2 styrene sheets for the control surfaces. The design categories given to the students consisted of speed, stability, and accuracy. From these materials, the students had to determine the right combination of nose and tail sections, rubber band configuration, weight and foam balance, and the shapes and sizes of the control surfaces. One important focus in this workshop was about engineering design. We facilitated discussions about how a number of design ideas can be turned into a final product using standard matrix evaluation, and whether the final product meets the original design requirements. Each team learned how to consolidate the design ideas from its members, and had to determine by testing and evaluation the "right" balance. There was no automatic or human control involved in this project, and this means the students had to produce a statically stable and fast submarine that could stay the course as much as possible. A competition was held at the end of the workshop to determine which team had the fastest and stable submarine. The competition turned out to be very effective because it pushed each group to design a better system.

Student Evaluation Results

Overall, we received very positive responses from the students and parents about the technical design and planning for the workshop. The exit survey (see Appendix I) shows that the workshop has had an overall positive impact on the students in their interests in ocean engineering. They considered staffing support and competition close to *excellent*, whereas they considered time to construct, test and modify only *average*. One important observation from this survey is that 15 out of 18 students who filled out the survey are now considering Ocean Engineering to be their college choice, two of them are not considering, and one of them remains undecided.

2.2 Introduction to Ocean Engineering and Underwater Vehicles (2005)

The principal investigator has built upon the 2004 Model Submarine Design Workshop effort, and conducted a summer class, which is called Introduction to Ocean Engineering and Underwater Vehicles, in 2005 for 24 high school students (Grade 11 and 12) on the Boca campus in the Department of Ocean Engineering at Florida Atlantic University. This class was one of the Engineering Scholarship Program (ESP) classes funded by the Governor's Summer Program in State of Florida. The enrollment requirements for the ESP class are that the students are required to have at least 3.0 GPA (out of 4.0), and have taken either SAT, ACT or CPT test (with pre-defined minimum scores). The students came from schools in Palm Beach and Broward Counties (Suncoast High, Dillard High, Spanish River High, Atlantic Community High, West Boca High, and JP Taravella). In the class the students worked in groups to finish three big projects. They were 1) model submarine, 2) remotely operated vehicle (ROV), and 3) autonomous surface vehicle (ASV). The model submarine project was the same as the one chosen for the 2004 workshop. In the ROV project, students learned how to put together a simple electric circuit, solder wires and switches in a control box, waterproof DC motors, built the vehicle frame using PVC pipes and joints. Besides that the ROV had to move in six degrees of freedom without getting tangled with its tether, the students had to figure out how to improvise some kind of capture mechanism that could pick up various objects sitting on the pool bottom. The ROV project is based on an existing national outreach program called SeaPerch [6] funded by the Office of Naval Research (ONR), and the tool kit was generously donated by the ONR.

By building upon the previous mechanical and electrical components, the principal investigator introduced in the ASV project the basic elements of mission design, software programming and feedback control. The students were provided with foam materials, batteries, two DC motors, two model propellers, and a black box that houses all the electronic amplifiers and control circuitry, and a digital compass sensor. Each team had to build a platform made of foam materials. This task reinforces their understanding about the balance of weight and buoyancy forces. In addition, each team had to determine how to integrate the black box onto their autonomous surface ship, and learned how to program a desired heading using a text file based on the current and next waypoints. Students were encouraged to do research and find out design ideas from existing Navy and commercial surface vehicles. The vehicle design categories consisted of speed, stability, maneuverability, innovation, and steering accuracy, and the design variables include the vehicle size, geometry, weight and balancing, and propellers position. In all three projects, the students went through the same engineering design process mentioned previously, starting from individual ideas to a final product (see the students' survey listed in Appendix II). This summer class has been repeatedly offered from 2006 through 2008 with slight variation in program components.

Student Evaluation Results

Overall, the students found the hands-on, project-oriented approach a very valuable learning experience. There were very positive responses in how the projects improved their understanding of how math/science relate to the world and enhanced their capabilities for creative thinking and problem solving skills. Interestingly, some students found the classes only moderately challenging. This could be explained by the fact that these students had already achieved good academic skills at school before they could enroll in the ESP class, and they might have been expecting to learn more complex math and science concepts in the class. One important observation from these responses is that while the students might have learned an adequate level of math and science at school they have not yet gathered enough insights and intuition into how they can apply their knowledge to solving real-world problems. This suggests that teaching the students very complex math and science concepts alone in an isolated framework does not appear to adequately promote their interests in math and science. Rather, it is the application of science in terms of interesting, problem-solving projects that captures the students' interests in math and science. We believe that once we have captured their interests, the effect is perpetuating. In terms of teaching, the effectiveness of the instructor in communicating ideas, showing respect and concern, and facilitating learning appeared to have played an important role in their learning experiences. Last but not least, the students indicated that they would strongly recommend this class to their peers so that they can share the same experiences.

2.3 Teacher Workshop (2007)

While the ESP class and workshop appear to be a success in promoting the students' interests in math and science, there can be only twenty plus students who can participate in each of these classes. We would like to expand our effort in order to reach out to many more students of diverse academic levels and socio-economical backgrounds. One effective way to achieve this is to get their schools and teachers involved. With this in mind, we organized a five-day professional development workshop at Florida Atlantic University during June 25-29 of 2007 during which 15 local, in-service high school teachers were invited to participate in the workshop (2 South Broward High, 1 Dillard High, 1 Blanche Ely High, 2 Santaluces High, 1 Palm Beach Lakes High, 1 Palm Beach Gardens High, 2 Boca Raton High, 2 West Boca High, 1 Jupiter High, 1 Boynton Beach High, 1 Olympic Heights High). Each of the teachers was reimbursed with a stipend of $500 for taking time to participate in the workshop. The main objective of the workshop was to immerse the teachers in the project-oriented, team-based environment in which the students experienced in the ESP class. In particular, we explored how "Ocean Engineering" can be used as an application domain for enhancing math and science teaching.

At the beginning of the workshop, all the teachers were given a pre-workshop survey [5] that consists of the following nine questions:

1. What subject(s) have you taught?

2. What are the key concepts or ideas that the students should learn in these subjects?
3. What methods or techniques work well for you in explaining these key concepts?
4. What are the obstacles or challenges in teaching these key concepts?
5. How would you define "Project-based" learning? Please explain as much as you can.
6. Do you provide any project-based or hands-on experience for your students? If so, what kind?
7. Are you involved in any extra-curriculum activities at school that might enhance math and science education? If so, what kind?
8. Have you collaborated with any university for teaching enhancement? If so, what kind?
9. What do you want to get out of the workshop?

The main theme of the workshop is focused on "project-oriented, team-based learning" and "learning-by-doing" principles. The teachers were specifically tasked to work on the "Remotely Operated Vehicle (ROV) engineering project, which is similar to that in the ESP class except that the mechanical structure of the vehicle involved is not fixed. This means the teachers not only had to brainstorm their designs but also perform basic calculations and analysis. This is an example of how we can fine-tune the project challenges according to the skill levels of the students involved. During the workshop, the teachers went through two hands-on exercises (thruster assembly and control box assembly), brainstormed the ROV designs and material selection, and finally built and tested their ROVs. This project was chosen because we believe it could be accomplished in the time frame of the workshop, and the materials required were inexpensive and readily accessible. After the teachers finished the ROV project, they could then share their learning experiences with their students at their schools. Each teacher was reimbursed with $100 worth of materials and supplies needed for building an ROV. On the final workshop day, the class was held at Seatech Campus, Dania Beach, Florida. In the morning, the teachers participated in the ROV competition with their vehicles. There were three categories in the competition: speed, target recovery, and waypoint transect. The design criteria consisted of speed, maneuverability, innovativeness, stability, and accuracy. After the competition, the teachers were provided with a tour at the SeaTech Campus facilities.

At the end of the workshop, all the teachers participated in the closing discussion about the workshop, and its effectiveness. They were given a post-workshop survey, which consisted of the following questions:

1. How would you integrate the Project-based Learning method in your class? How would you teach differetnly? Please explain as much as you can.
2. Will you consider summer internship programs for your students, and how that might be organized?
3. Do you think collaborating with FAU for teaching/curriculum enhancement is an important goal for you or your school? Elaborate on what collaboration should be.
4. What impact has this workshop had on you? Did you get what you wanted to achieve from this workshop?
5. Do you think this workshop should be repeated for other teachers? And what suggestions or ideas do you have that can improve the workshop?

The post-workshop survey results can also be found in [5]. Based on the discussion and the survey results, we found the teachers' challenges at their schools consist mainly of the following: 1) lack of interesting and relevant applications that can be provided to their students, 2) students' short attention span, 3) lack of interests in students, and 4) lack of resources at school. Overall, all the teachers found the workshop a very positive professional experience, and viewed "project-based" learning style as a very effective teaching method for high school teachers. The majority of them believe that the project-oriented, team-based learning style can be readily incorporated in their classrooms, thereby greatly enhancing the interests of high school students. All the teachers strongly suggested that this workshop should be repeated so that other high school teachers can have the opportunity to experience the "project-based" learning philosophy. In addition, the results show the teachers view the collaboration with universities and summer internship for students highly important.

3. CONCLUSION

This paper has summarized the high-school outreach activities that have taken place at Florida Atlantic University. In these activities, students were exposed to a number of relevant engineering problems, and taught how to derive a solution to each of these problems by means of an engineering design process.

Overall, students expressed interest in learning how to apply learned knowledge to solve a "relevant and interesting" problem in a "project-oriented" and "team-based" environment. However, most students preferred trial-and-error when designing and building a system, rather than relying on basic math and calculations. For an example, most students know how to recite Newton's laws, but a number of them failed to understand how to determine whether an object of known density and volume will float in water. This might be due to the fact that they mostly learn how to plug numbers into a known physical law (forward thinking), but do not master an adequate skill about how the law can be applied and manipulated (reverse thinking). The author surmised that reverse thinking is much more important because true learning actually occurs.

In these outreach activities, the author emphasized more on concept building from observational experiences. In other words, what happens if the load is off the centerline, or the propellers have small separation? The author surmised that by building up a solid engineering intuition are students able to judge or estimate whether the results of some mathematical calculations (often abstract) are realistic or feasible.

The author surmised that the lack of students' interests in mathematics and science might be correlated with the fact that the learning materials taught at school lack "relevancy", and the subjects tend to be "disconnected". It is hoped that the "project-oriented" approach taken in the workshop/ESP classes can help address this important issue.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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Name of the First Author

Dr Edgar An received his B.S.E.E. degree from the University of Mississippi in 1985, M.S.E.E. and PhD degrees from the University of New Hampshire in 1988 and 1991 respectively. From 1991 to 1994, he was a post-doc fellow in the Department of Aeronautics and Astronautics at the University of Southampton, UK, working on the European Prometheus project. In the Fall of 1995, he became an assistant professor, became an associate Professor in 1999, and became a full professor in 2005, all in the Department of Ocean Engineering at Florida Atlantic University. His areas of interest are autonomous underwater vehicles, navigation, control, robotics and automation, modeling and simulation, system architecture, and neuro-fuzzy systems. He is currently the director of the Advanced Marine Systems Laboratory, and is in charge of advanced marine vehicle research and development.

APPENDIX I (2004 MODEL SUBMARINE DESIGN WORKSHOP SURVEY)

Categories	Poor	Fair	Ave	Good	Excellent	Overall
Previous interest in Ocean Engineering	0	3	3	8	4	3.72
Interest in Ocean Engineering after workshop	0	0	2	7	9	4.39
Instructors/Mentors/Staff	0	0	0	2	16	4.89
Design Process Presentation	0	0	5	8	5	4.00
Scientific Concepts Activities	0	0	3	10	5	4.11
Machining Principles Presentation	0	1	3	10	4	3.94
Kit Contents	0	0	2	10	6	4.22
Brainstorming & Alternate Solutions time	0	2	3	9	4	3.83
Construction Time	1	2	5	7	3	3.50
Testing Time	1	0	4	9	4	3.83
Modification Time	1	1	4	11	1	3.56
Competition	0	1	0	6	11	4.50
Presentations/Sharing/Awards Session	0	0	2	10	6	4.22

APPENDIX II (2005 ESP SUMMER CLASS SURVEY)

Florida Atlantic University
College of Engineering
ENGINEERING SCHOLARS PROGRAM - 2005
Evaluation Form

Course Name: Intro to Ocean Engineering Instructor: Dr. Edgar An

Item	1	2	3	4	5	
	SD	D	N	A	SA	averages
1. valuable learning experience for me.	0	0	1	7	14	4.59
2. appropriate for my ed. Background	0	2	1	11	8	4.14
3. Course requirements were clearly stated.	0	0	4	10	8	4.18
4. Able to complete assignments w/info given by professor	0	2	1	7	12	4.32
5. text and/or handouts helpful meeting course requirements	0	1	3	8	8	*4.15
6. assignments/projects helpful in undertanding concepts presented	0	0	2	4	16	4.64
7. Lab equip and/or comp hardware/software helpful for concepts	0	1	2	4	14	*4.48
8. The instructor was effective in communicating ideas and info	0	1	2	9	10	4.27
9. The instructor stimulated my interest in the course.	0	0	2	11	9	4.32
10. The instructor facilitated my learning in the course.	0	0	2	10	10	4.36
11. The instructor showed respect and concern for me.	0	0	1	6	15	4.64
12. instructor inspired me to put forth my best effort in course	0	0	1	10	11	4.45
13. The course mentor was helpful to me.	0	0	1	7	14	4.59
14. This course was challenging for me.	0	3	5	8	6	3.77
15. improved proficiency in using lab equip/computers	0	0	2	7	13	4.50
16. improved understanding & comprehension math/science	0	2	6	4	10	4.00
17. improved understanding of how math/science relate to world	0	1	1	5	15	4.55
18. enhanced my capabilities for creative thinking, problem solving	0	0	3	11	8	4.23
19. This course enhanced my ability to work effectively in teams	1	2	2	8	9	4.00
20. increased my understanding of eng/comp sci as career choices	0	1	1	6	14	4.50
21. gave me a better understanding of university level work	1	1	3	7	10	4.09
22. course increased confidence to handle univ. level studies	0	1	3	11	7	4.09
23. This course was worth my time and effort.	0	0	2	10	10	4.36
24. I would recommend this course to others.	0	0	0	6	16	4.73
25. course left me with a favorable impression of FAU/Engineering	0	0	1	10	11	4.45
26. guest speaker interesting addition to ESP	11	4	1	2	4	2.27
total averages						4.26

*5 & *7 there were only 21 responses to this question

SD = Strongly Disagree
D = Disagree
N = Neutral
A = Agree
SA - Strongly Agree