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ΜΗΧΑΝΙΚΗ. – **Co-opetive Team Education and Learning: A New Paradigm for Higher Education**, by Corresponding member of the Academy of Athens James C. Seferis, Lambros B. Georgoulis, Louisa M. Seferis and M. Salouhou*, *University of Washington, Seattle, Washington.*

ABSTRACT

An innovative and interactive educational process is being developed at the University of Washington in engineering classes using newly devised learning strategies from industry and academia combined with a unique teaching approach: integrated teams. The teams have evolved in such a way that they currently consist of professors and industry leaders as integrators and catalysts; senior graduate students and field specialists as facilitators; and full and part time students with diverse experiences and backgrounds as students. They are fused together through experiential learning and projects in which all are stakeholders and have a chance to influence its outcomes in real time.

This non-traditional approach, based on "complete and collaborate" learning principles, creates a dynamic learning environment by incorporating teaming concepts into teaching, learning, and facilitation. The evolving methodology of this alternative has been applied in several undergraduate and graduate chemical engineering classes, placing emphasis on solving engineering and business problems through teamwork – a necessary skill for succeeding in today's workplace. The achievements of this new approach were; 1) increased student participation in the overall process, promoting a better retention of information; 2) more efficient and rapid learning of the fundamental course material; and 3) increased breadth of learning on related subject matter. The framework for this educational experience was inspired by the teaming concept system integration used by the Boeing company during the design and implementation of the Boeing 777 airplane. The current University learning processes were developed at the Polymeric Composites Laboratory, at University of Washington Department of Chemical engineering where they were used in conjunction with experiential learning to enhance both the speed and efficiency of education.

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1. Introduction

Industry is in a time of change. Technology and innovation have broadened the scope and talent needed by today's work force to deal with the increasingly fast pace of the business world [1-3]. The Polymeric Composites Laboratory located at the University of Washington has developed a network of elements that, when combined, teach and guide its students to simultaneously hone their technical skills, business, and communication. Other engineering education institutions across the country have developed similar guidelines. To effectuate a focus on teamwork, professors have turned to cooperative learning ideas and techniques. These ideas have already been successfully incorporated into primary and secondary education, and in some cases, college-level engineering classes [3, 4]. However, at the college level, most attempts to incorporate cooperative learning theory have been limited to small group experiments involving highly structured problem solving activities where individual performance is still valued more than total team performance. In contrast, the methodology presented here combines the concepts of cooperative learning and teaming to create a broader and more complete spectrum of knowledge and education. In order for students to be prepared for dealing with real-world industry problems, our methodology harnesses the "love-hate" relationship that is the standard practice in business used today as "compete and collaborate". Team members must compete against each other for individual recognition, but they must also collaborate to form an effective team that will ultimately put forth a product. From this idea comes the composite word "co-opetition," which is the root of our teaming philosophy.

This alternative methodology was developed and initially implemented in undergraduate and graduate chemical engineering courses. The information presented in the body of this work is based primarily on observations and feedback from the past seven years of experiential teaming classes. These classes had previously been taught in a traditional fashion for over ten years, thus providing an ideal database on which to build and expand teaching and learning concepts through teaming. This alternative teaching methodology has also been applied to Team Certificate Program classes, which tie in real-time projects with industry in a co-opetive learning environment.

2. Background and Theory

Methodology

Changes made by Boeing to traditional airplane design and manufacturing processes implemented for the 777 airplane had a significant influence on the development of our alternative methodology. Boeing's new tactics proved to be very successful in improving the efficiency of airplane design and contruction. The new approaches most responsible for the improved design efficiencies were 1) involving the custumer and the suppliers in the design, and 2) implementing "concurrent design".

When Boeing began to ask for the customers and the suppliers input at the start of the design process, the resulting end product proved to be exactly what both wanted. This new philosophy created greater understanding of the design process for everyone involved. The teamwork on the Boeing 777 airplane focused on understanding the relationships between the product, process, supplier, and customer. In academia, students are regarded as the product of their academic institution, having emerged with knowledge obtained from their academic experience there. However, students regard themeselves as the institution's customers, since they are soliciting and commissioning for the establishment's services to gain greater knowledge in a certain field. By considering the student as both the product and the ultimate customer of the acedemic institution, increased attention is paid to the process of learning as a means to satisfy the customer and to put forth an exemplary product. In this sense, both the student and the institution view the professor as the supplier.

"Concurrent design" means having the specialists from all the relevant departments in the same room at the same time deciding on the design together. At Boeing, traditionally the "Structures" department would design the airplane and then send it over to "Systems", which would do its part and return it to "Structures" for modifications [5]. The design would be sent back and forth several times, each time with detailed drawings, and these drawings would be revised on numerous occasions. In contrast, "concurrent design" was implemented in every aspect of the designing and building of the 777 airplane. Boeing's Design-To-Build teams were successful because of their heterogeneity and because they required normally competitive departments such as Manufacturing and Engineering or Structures and Systems to work in a closely collaborative environment. In addition, literally thousands of changes were made in the way the 777 airplane was built because the customers, suppliers and other stakeholders finally were asked what they wanted. To be sure, this was not the amicable process that is usually described in a cooperative learning environment. During the creation of the 777, departments vied for limited resources and had to justify their existence in the program on a competitive basis. However, the focus on the customer forced an unprecedented collaboration between the departments in a working environment that went beyond the traditional norms. This is what defined the "co-opetive" process concept derived from the notion of simultaneous competition and collaboration between organizations [6]. In academia, this process has created a competitive environment without sacrificing the ability of the environment to reward the excellence or express the incompetence of an individual, brought various departments and experts together to complete projects.

The above process has greatly influenced the development of our co-opetive team education methodology. Instead of attempting to guess the interests and level of knowledge of the students (customers) and lecturing at that level in the traditional academic approach, our methodology allows students to determine what they want and need to know, thereby increasing the breadth and depth of the educational experience. Students are actively encouraged to work together on solving the same homework problems, to experiment in the lab together, and to take tests together. However, individual assessment is still necessary, as it is within teams in industry, to gauge each person's abilities and provide appropriate rewards. This creates a true "compete and collaborate" environment: as individuals, students compete for the best grade, but as a team they collaborate to achieve the best results.

3. Concepts of Leadership, Learning, and Intellectual Challenge

This new era is phasing out the old and bringing in the new. The traditional ways of teaching engineering have become outdated as industry has evolved. Educators have realized that there are various types of qualities that an engineer must possess in order to be able to compete and thrive in today's market. While there is still the demand for the dense technical knowledge as in traditional engineering, there is also an urgent need to learn communication skills and the fundamentals of the business/social system. In both industry and academia how an employer or a professor challenges and educates employees or students will ultimately determine their learning and productivity [7]. The following models were employed to develop the co-opetive team-education methodology.

4. Trinity Model

Robert W. Keidel has established a Trinity model that encompasses aspects of Autonomy, Cooperation, and Control in a universal fashion [8]. We used a similar idea to create the double trinity Concept in 1986, which was based on concepts used in the development of polymeric composites to describe the relationship between sciences and economics. This idea was adapted to develop and characterize co-opetive team education, both on a cultural and personal level as shown in Figure 1 [9]. The "Personal Development" Trinity is composed of Communication, Specialization, and Psycho-Socialization. The trinity describes the process of personal development in everyday life as applied to both industry and education. For example, students in the same specialty are able to communicate effectively in problem solving because they have ultimately learned the same principles. A group of students from different disciplines have more difficulty communicating and therefore working together in student teams. This real-life situation results in introducing "psycho-socialization" into the classroom. Psychosocialization may be a result of cultural and personality differences. The Meyer's-Briggs Personality Type Indicator (MBTI) was used to select the mix of students to be gathered together in learning teams. A well-rounded variety of personalities increases a team's productivity because it can help remove the roadblocks barring communication; although it certainly remains true that the skills required to overcome communication difficulties take time to develop under even the best circumstances.

This "Personal Development" Trinity is joined with the aforementioned ideology of business culture containing a Product, Process, and Customer as shown in Figure 2 to create our Double Trinity of Leadership seen in Figure 3. This "cultural" aspect of teaming, as it combines a value base with education, allows each individual to bring his or her particular skills and expertise into a group environment and obtain desirable results as a team.

Psycho-Socialization Applied to Teaming

In developing this methodology and the different iterations of the classes, great sensitivity is required of the professor both as a leader and as a teacher. A key concept in the development of this methodology is the belief that the more the professor/teacher/leader leads, the greater the tendency for people to follow instead of thinking critically on their own. This concept is hard to implement because leaders have been taught to lead strongly and others have been taught

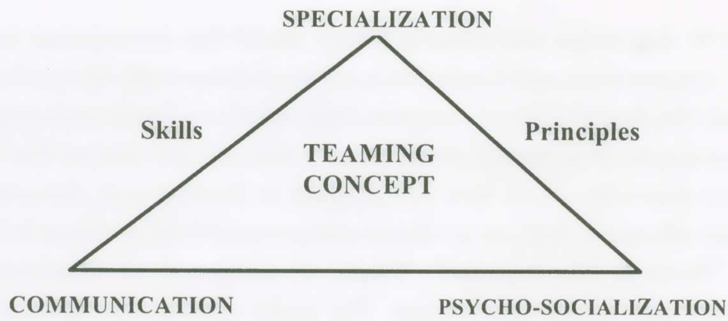

Figure 1: Trinity of Leadership - Personal Development.

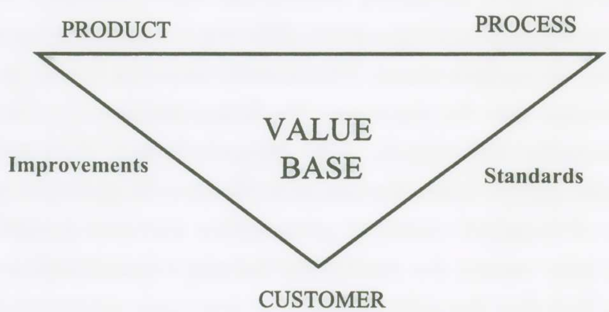

Figure 2: Trinity of Leadership – Cultural Development.

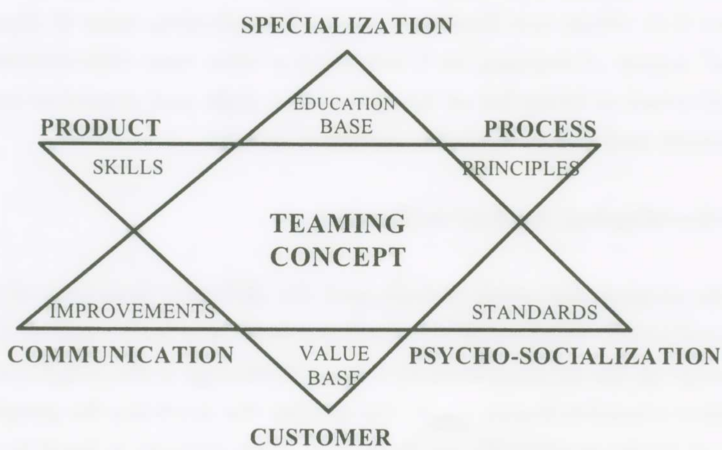

Figure 3: Double Trinity – Leadership Concept Integration.

to follow so the success is highly dependent on each individual's personality. It is always more difficult to facilitate education when the first step has to be "unlearning" something before a new concept can be learned, such as leadership skills. The goal is to empower people to be able to think critically on their own so that their minds are free from being the "follower" and for them to become equal, but different, contributors [10-12].

Another pertinent goal of this process is to transform the professor from an instructor to a catalyst. In a chemical reaction, the catalyst substance aids the reaction but does not take part in it. In the same fashion, the professor in a teaming environment must facilitate the students' learning process without taking part in shaping it; students must take charge of their learning experience.

Flow Model

In his book *Flow: The Psychology of Optimal Experience*, Csikszentmihalyi describes a process of learning new skills in relationship to the challenges we face and how that relationship influences our level of motivation. Csikszentmihalyi's psychological "flow" is of optimal learning, when the person is neither anxious nor bored as shown in Figure 4 [13]. In the classroom, when challenges for students exceed their skill level (for example, if the students are learning new fundamentals or communicating with students from different areas of study), anxiety results. As the model suggests, students who already understand the theory being taught or who have developed skills with no place to apply them, as in the traditional "lecture and repeat" classroom, will quickly become bored. In an environment where students direct the learning process, as in a "hands-on" laboratory, challenges increase to meet the student's level of skill and theoretical understanding, putting he or she back into an optimal learning area, the "flow". As students proceed with the tasks, they may encounter obstacles that require more knowledge than they possess to overcome, thus putting the students back into the anxiety region. With the acquisition of sufficient additional skills, students re-enter the flow area where optimal learning occurs.

5. Life-Long Learning Concept

The life-long learning concept stems from Csikszentmihalyi's Flow Model and pertains to experiential learning. It is graphically displayed in Figure 5, in the same fashion as the Flow Model and incorporates our concept of Life-Long

Teaming concept

- Heterogeneous
- Global
- Compete and collaborate

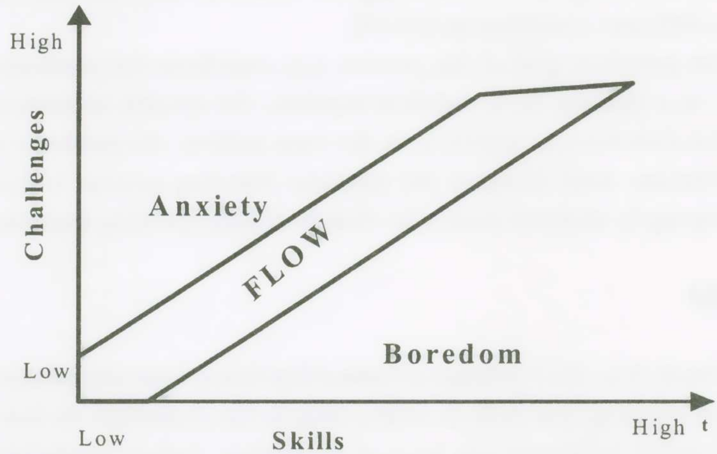

Figure 4: Flow Model of Optimal Learning.

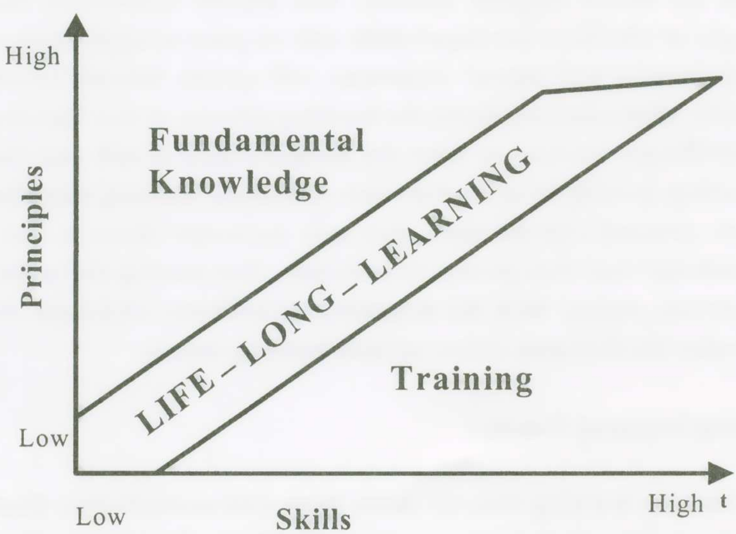

Figure 5: Flow Model of Life-Long-Learning.

Learning. In a teaming environment, the same problems of anxiety and boredom can arise. For example, if a student is given too much fundamental knowledge without sufficient training, he or she will become anxious. In contrast, if the student is given an excessive amount of training and no additional fundamental knowledge, he or she quickly becomes bored. It is this delicate balance of principles and skills that is essential for the student to be within the "flow" of Life-Long Learning. If students from different disciplines or backgrounds attempt to communicate, the differences in their fundamental sets of principles can create anxiety; but the necessary skills for successful interpersonal relations and the knowledge of the rudiments of other disciplines can be learned through training.

Training can take many forms, such as on-the-job training, short courses, and college laboratory courses. It is this balance of fundamentals and practice that is essential for life-long learning. Also essential to the co-opetive team education methodology is a balance of persons from industry and from various related disciplines in order for individuals to be able to work together as productive members of society. By providing individuals with the fundamentals from various areas in engineering, business, etc., and also the skills needed to uphold this knowledge, a constant learning process is introduced that evolves to produce valuable traits.

6. The PARTS Game Theory

"To find a way of bringing together competition and cooperation, we turn to game theory", Adam M. Brandenburger and Barry J. Nalebuff state in their book *Co-opetition*. They claim that "game theory focuses directly on the most pressing issue of all: finding the right strategies and making the right decisions." Thus they invented a scaling device to measure game theory-P.A.R.T.S. this acronym represents the Players of the game, the Added values they bring to the game, the Rules of the game, the Tactics, and the Scope [6].

We have adapted and incorporated Brandenburger and Nalebuff's philosophy into our teaming methodology. We use the acronym P.A.R.T.S., but instead of Scope we include the Strategy of each team. It is important to consider these five aspects of game theory in teaming because each one determines the shape and direction of the class. A simple example of this is changing the Rules; if the guidelines of the class or project are changed, the outcome will ultimately deviate from its initial counterpart. Similarly, if the Tactics employed by a team are suddenly altered, the product may change. Each modification of an aspect of P.A.R.T.S. triggers a change in the way the methodology is implemented in the classroom.

7. The Various Classroom Teaming Scenarios

Perhaps the most drastic change when dealing with P.A.R.T.S. is when the players' Roles are rearranged. Over the past few years a number of different scenarios have been implemented in the quest for the best combination of professor, graduate student, and undergraduate student involvement[14]. The rethinking of players' Roles has defined the way the teaching methods have evolved as shown in scenario's 1-5 in Figure 6.

Scenario 1 shows the relationship in a traditional classroom, where the professor is in direct contact with the students through lectures, and the teaching assistant plays a supporting role mainly outside of the classroom. The role of the teaching assistant –a graduate student– is to grade exams and assignments, and to hold office hours to help explain the professor's lectures. As a result, the students and the teaching assistants learn only about what the professor chooses to lecture and the material he or she passes on.

Scenario 2 represents the first attempt to change the traditional way the classroom was run in Scenario 1. The new format consisted of student learning teams, student facilitating teams comprised of senior graduate students, and professor/expert teams, the latter provided facilitation only; no formal lectures were given. If the students requested a lecture from the professor/expert, it was given in discussion format to maximize the learning process. The student facilitating teams and the professor/expert teams spent about the same amount of time assisting the learning teams. Students were largely encouraged to determine what they wanted to learn in addition to the fundamental material of the course. The resulting interactive learning environment encouraged all three teams to increase the breadth and depth of their knowledge. This scenario emphasized individual and team assessment; both the students and facilitating teams were evaluated. However, after an evaluation of the course it was determined that a communication gap existed between the student facilitating teams and the professor/expert teams, which did not provide adequate structure for technical education. The following scenario was created to form a more structured base for teaming classes.

Scenario 3. This scenario, modified by the professor/expert team, was designed so that the student facilitating teams could manage the class for the quarter, assigning reading, grading exams, and giving the course direction. The student learning teams' role was unchanged from the previous scenario; they were present to acquire knowledge and to stimulate their own learning.

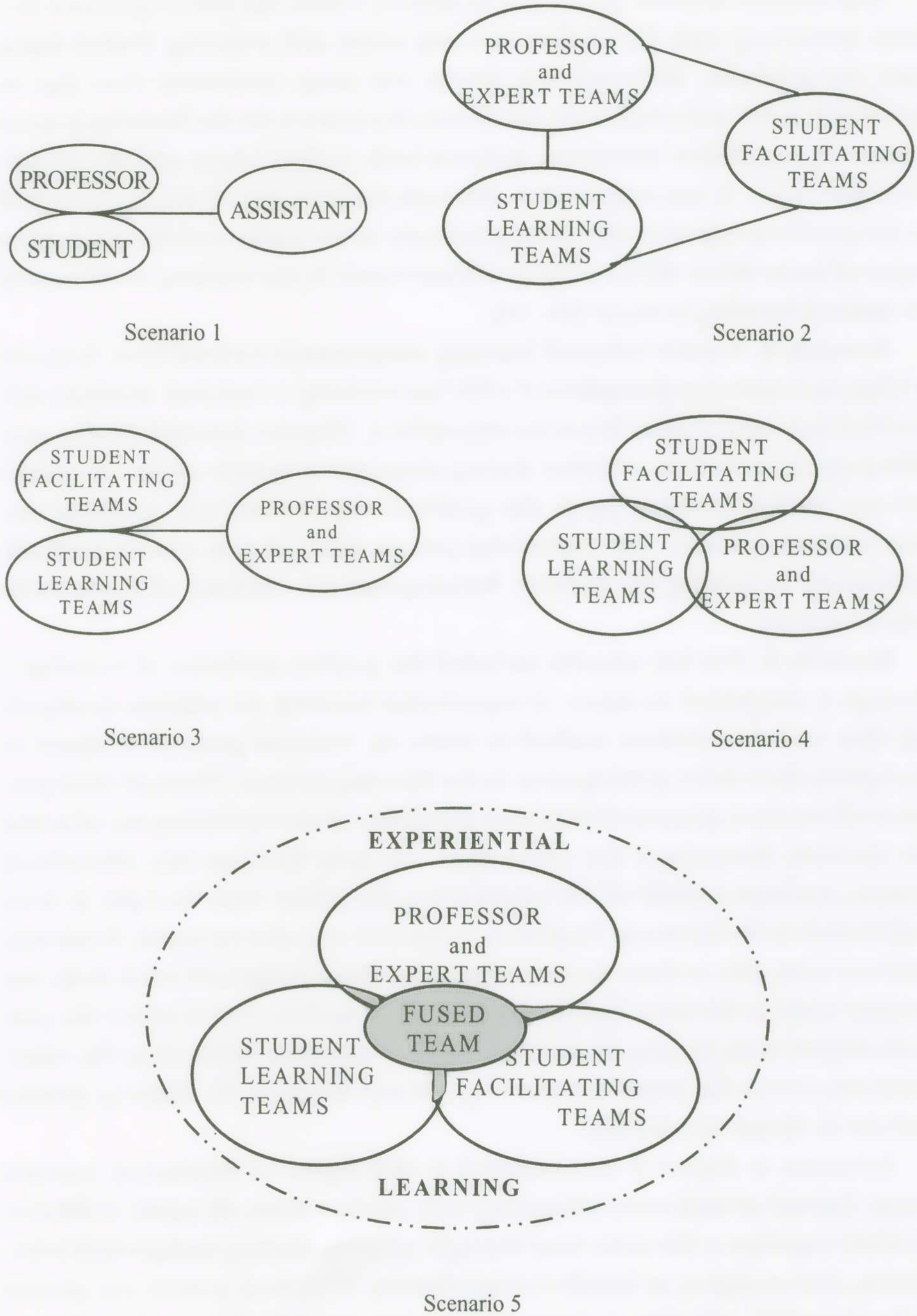

Figure 6: Various Classroom teaching Scenarios.

This scenario focused on student facilitating teams, the senior graduate students interacting with the student learning teams and receiving limited input from the professor. Although this system was more structured than that in Scenario 2, it still did not provide satisfactory framework for the learning process because of insufficient interaction between both student teams and the professor/expert team. It was realized that although students should not be controlled by the professor/expert as they were previously in the traditional classroom, they required more direct aid from the professor/expert in the teaming environment for optimal learning to occur [15, 16].

Scenario 4. A more balanced learning environment evolved from Scenario 3. Class structure was strengthened while maintaining a customer (student) driven learning environment in a team atmosphere. This was accomplished by providing equal interaction –whether during class time or outside of the classroom– between student learning teams, the professor/expert team, and graduate student facilitating teams. The educational process proceeded in a more methodical manner, increasing the students' learning and the efficiency of all the facilitation involved.

Scenario 5. The last scenario included the positive attributes of scenarios 1 through 4 and added an aspect of experiential learning. In addition to attending class sessions, students worked in teams on real-time projects designed to strengthen their active participation in the learning process. Through their project work students generated their own questions, again reinforcing the idea that the students determined the curriculum. To help facilitate this educational process, students outside of the engineering disciplines were brought in from majors such as Business and English to create rich and diverse teams. From this, students were able to draw on each other's core knowledge and learn from one another while at the same time learning together in class. This is where the professor/expert team became increasingly more of a catalyst rather than the omniscient educators; the team's job was to guide and facilitate the learning process and not to dictate its outcome.

Scenarios in Figure 6 also included a vital aspect of interaction between teams. Instead of each team interacting with another team, all teams could now associate together at the same time through projects, sharing background information, and engaging in hands-on-experiments. This final process has proved to be extremely effective at increasing student participation, teamwork, and communication skills, all while strengthening their traditional fundamental knowledge. The scaling for this process –and for teaming in general– is in the form of a trinity. It is comprised of Co-opetition as defined by the acronym P.A.R.T.S.; heterogeneity, which is enforced and insured by the Meyers-Briggs Personality Type Indicator Test; and Globalization achieved by forming a body of students with diverse backgrounds and knowledge. Thus our methodology embodies the fundamental principles of creating a successful teaming endeavor in order to better prepare students for competition and collaboration in the real world.

8. Application of Co-opetive Team Education Theory

Implementation. There has been a growing concern from industry that engineering graduates and graduate students are coming out of school without the skills necessary to succeed in the modern workplace [3, 17]. They lack a sufficiently broad knowledge base and many have poorly developed communication and teamwork skills. To develop students who are more marketable, a class that shares many elements with the industrial workplace was designed. The following framework provides the basis for redesigning the course.

- Students are considered not only as the product but also as the customer of the learning process.
- Students work in teams.
- Students are held accountable for their learning.
- Students are to teach their peers.
- Students should design their own learning process in addition to learning the fundamentals of the class.

Developing the Student Groups. Team sizes varied from five to nine members, and the number of teams per class varied due to total enrollment. To accommodate differing personalities, the Meyers-Briggs' personality type indicator test was completed by each individual and groups were arranged accordingly. Primarily this test was used to determine rankings on an introvert/extrovert scale, and based on those rankings, students were put into groups so that no one type dominated. Additionally, some instruction was given regarding the application of knowing how to work with one another [18].

Class Facilitation. Classes were facilitated collectively by senior graduate students, professors, and industry experts. A team of experts in the community, together with the professor, facilitated the specific direction of the course. Currently, the curriculum contains class work that includes both engineering and business courses taught in tandem every quarter. Each contains a series of lectures from industry representatives and from the students. This format allows both disciplines to be taught in such a way that they are tied together, which collectively adds to the breadth of the overall educational experience. Students are able to receive in-depth material on both subjects in an efficient, fast-paced, and innovative environment.

During the quarter, graduate student teams were selected to help facilitate the class. They were responsible for providing the material to be read before each class session, determining laboratory projects, constructing the collaborative assignments, and designing and grading the tests. For example, the facilitating team working with the advanced polymeric composites class selected several graduate students and experts in the community to present lectures and lead discussions.

One benefit of this approach is that several levels of learning occur within the facilitating/teaching teams. The facilitating students must master their material in order to effectively present their lectures and field the teams' questions. On another level, having to work smoothly within the presenting team makes these students aware of the importance of good team skills. Facilitating students receive credit and instruction on teaming as part of their education outside the classroom.

Homework and Projects. Throughout the development of the curriculum, the five main elements of cooperative learning form the basis for the homework and group projects. Students are given assigned readings and individual quizzes as in a traditional class; however, these quizzes were given over the Internet and were taken on a student's own time. This accounts for part of the students' individual portion of their grade. This individual portion is weighted as fifty per cent of a student's final grade, with the team grade comprising the other half. Tests are commonly given in groups where the students depend on each other to collectively and successfully complete the exam.

The projects assigned, determined by the professor/expert team, vary from class to class, and they are not the typical projects to which most students are accustomed. These are hands-on, real-time projects that industry has introduced or that the professors/experts have developed. Historically, a roadblock in assigning group projects has been that teams tend to break off in parts, do the work independently, then put their ideas together [19-21]. To overcome this, the facilitators have designed projects that require the skills of each team member. Thus, students get to participate in a group project where there is the feel of a real job, with deadlines, stakes, and individual responsibilities. Group leaders are chosen and are responsible for the group as a whole. Although this individual is in charge of the group, all the members of the team must decide how to break the project up, assign tasks, make deadlines, etc. In effect, this aids in the development of the students' individual and teamwork skills.

In order to summarize and evaluate how the teams work together, as well as to evaluate technical proficiency, a collective report and presentation are required. This collaborative effort creates strong interdependence of the student team members by compelling them to research and develop an original proposal and to write and present a report together.

Performance Assessment/Grading. In school, just as in industry, rewarding the work of a team as a whole versus individually is a difficult process [19, 20, 22]. To embrace the philosophy of co-opetive learning and to achieve the course goals, equal emphasis of the individual score is placed on the team grade for a majority of the examinations. This fosters a sense of interdependence that requires the students who are strong in some subjects to work with those needing help. In these classes a number of different testing techniques are used. For example:

- The tests given ask broad questions that require the strengths of all the team members, and only one grade is assigned to the team as a whole.
- Quizzes or tests are given individually, then averaged into a team grade.
- Individual tests and quizzes taken by each student are used to determine individual levels of understanding.
- Individual tests are given where a team score is an average of individual members' scores, and a student's final individual grade is a weighted combination of his or her score and the team's score.

At the beginning of most classes, students were uncomfortable with the team testing techniques, having previously only taken individual tests during their education. However, they found that as the quarter progressed, the team tests allowed them to be more relaxed and focused. Students discovered that through sharing their ideas with their team, they were able to build on each others' ideas and finish the tests in less time and with better results. In fact, toward the end of the quarter, when faced with an individual quiz, they felt anxious knowing they didn't have the support of their teammates.

Scores for the individual tests varied only fifteen percent from the mean. This may be due to the fact that the students worked so closely with one another through the quarter doing collaborative homework and group projects. This was contrary to previous averages from the last ten years involving the traditional "lecture and repeat" teaching method. On individual/team tests the average scores were even closer because team members tutored each other to attain the highest possible average grade.

9. Observations

About the Curriculum. One of the most notable successes of these classes is the speed at which material is covered. For example, the fundamental material in the class "solid state materials and chemical processes", which normally takes ten weeks to cover, took only six weeks. This acceleration is primarily due to the motivation level of the students [14]. Through the homework and the assigned reading it is possible for the students to realize what they know and what they do not. Therefore, class time is spent only on material the students do not understand, leaving ample scheduling for discussion. However, covering the material quickly in these classes is only possible by ensuring that the students are motivated to thoroughly read the material outside of class. For the students to direct the course of the learning process it is necessary that they read and recognize their level of understanding of the material before moving on [23, 24]. In addition, quizzes and homework are given via the Internet, so these pastimes do not occupy class time. This also facilitates the ability to have a global classroom where students may come from or be in different countries and still take the course.

Some difficulties can arise during the experiential learning process as well. It is noted that the essential desire to work as a team is not always present, and that the final outcome can be less than satisfactory if the members of a team do not interact well. In addition to this, the team's speed and efficiency are sometimes dependent on its slowest member. On an individual basis, when students are not motivated to do the independent background reading and other preparations, the class does not proceed as smoothly. As these negative aspects surface, however, the underlying idea of the students being responsible for their own learning is reiterated and reinforced. This concept is of utmost importance in order for the class to function as a useful educational resource.

In evaluating the course, students often point out that there is greater satisfaction in learning what they want to know rather than what they are dictated to learn; instead of the traditional method of opening the students' brains and dumping in information, the students feel fulfilled and involved by thinking about the material, discussing it, and digesting it in an interactive learning environment. Students have also commented that both the breadth and depth of their learnig is greater; and because of their hands-on experiences, their motivation level increases, which directly affects the length of time they retain the information.

About the Student Teaming Process

- **Teaming takes time.** It is unrealistic to expect effective teaming behavior from a group of people unless the group is given some education about the teaming process and an appropriate amount of time to come together. It is not sufficient for teams to meet 50 minutes on a Monday, Wednesday, Friday basis. In order for co-opetive learning to subsist, there must be intense, continuous interaction between team members and feedback from the facilitating teams. For this reason, teams often meet once a week for three hours to insure optimal productivity. However, we now have experimented with teams meeting one week countinuously from nine to five –homework and quizzes still administrated over the Internet– and we have found it promotes efficiency*.
- **A greater amount of collaborative work leads to the success of a team.** The more closely and often a team works together, the more likely it will succeed.
- **Becoming personally comfortable with teammates in necessary for success.** If a team of students is asked to learn together, the students must be given structured time before the project to start working and feeling like a team.
- ***It is imperative to understand the educational background of team members.*** Differences in previous education and curriculum affect significantly the dynamics of learning in teams. Furthermore, understanding the strengths and weaknesses of each individual allows for more efficient teaming and, therefore, learning.
- **Differences in work and learning styles affect outcomes.** Personality differences affect the dynamics and sucess of teams far more than is generally believed[25]. Small workshops on interpersonal skills can increase the awareness of differences and prevent problems by encouraging conversations about dealing with differences between students.

About the Facilitation. The graduate engineering students, i.e. the student facilitating teams, are responsible for responding to or developing resources that answer the questions brought up in class. This requires the facilitators to master the material and present it effectively. Because of their active role in creating

* These new developments will be reported in an upcoming publication.

these classes, facilitators' observations will continue to influence the development of future courses.

This approach has changed the nature of the work required from the professor. Since the questions that arise in class can originate from anywhere along the spectrum of materials and ideas, the professor as well as the facilitators often end up learning just as much as the students.

10. Conclusions

Combining the ideas of co-opetive learning and teaming concepts in a rational and applicable fashion has been a challenging process for all those involved. The co-opetive team education methodology is still under development. This system has been applied to both undergraduate and graduate classes and is an evolving process, changing from quarter to quarter and year to year. Ultimately the learning and facilitation techniques derived from this methodology can be appllied at all levels of education to better prepare learners of all ages with the skills needed in today's socio-economic environment.

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ΠΕΡΙΛΗΨΗ

Ἐκπαίδευση καὶ μάθηση ὁμάδων σὲ περιβάλλον ἀνταγωνισμοῦ καὶ συνεργασίας: ἕνα νέο παράδειγμα γιὰ ἀνώτατη ἐκπαίδευση

Μία καινοτόμος καὶ διαδραστικὴ ἐκπαιδευτικὴ μέθοδος ἐξελίσσεται στὸ Πανεπιστήμιο τῆς Οὐάσιγκτον στὸ τμῆμα τῶν Μηχανικῶν. Χρησιμοποιεῖ νέες ἐκπαιδευτικὲς στρατηγικὲς ἀπὸ τὴν βιομηχανία καὶ τὸν ἀκαδημαϊκὸ χῶρο σὲ συνδυασμὸ μὲ μία μοναδικὴ ἐκπαιδευτικὴ προσέγγιση, τὶς ἀνομοιογενεῖς ὁμάδες. Οἱ ὁμάδες δημιουργοῦνται μὲ τέτοιον τρόπο ποὺ οἱ καθηγητὲς καὶ οἱ ἐκπρόσωποι τῆς βιομηχανίας λειτουργοῦν σὰν καταλύτες στὴν ὁμάδα, οἱ μεταπτυχιακοὶ φοιτητὲς καὶ οἱ ἐξειδικευμένοι ἐπιστήμονες ὡς ἀρωγοὶ καὶ οἱ φοιτητὲς μὲ τὶς διαφορετικὲς καταβολὲς καὶ ἐμπειρίες ὡς μαθητές. Μαθαίνουν νὰ λειτουργοῦν ὡς ὁμάδα μέσα ἀπὸ τὴν διαδικασία τῆς ἐμπειρικῆς γνώσης καὶ τῶν ἐργασιῶν, ὅπου ὅλοι οἱ συμμετέχοντες ἔχουν τὴν δυνατότητα νὰ ἐπηρεάσουν τὸ τελικὸ ἀποτέλεσμα σὲ πραγματικὸ χρόνο.

Αὐτὴ ἡ νέα ἐκπαιδευτικὴ προσέγγιση, ποὺ στηρίζεται στὴν ἀρχὴ τοῦ ταυτόχρονου ἀνταγωνισμοῦ καὶ συνεργασίας δημιουργεῖ ἕνα δυναμικὸ μαθησιακὸ περιβάλλον ἐφαρμόζοντας τὶς ἀρχὲς λειτουργίας τῶν ὁμάδων στοὺς τρόπους διδασκαλίας καὶ ἀπόκτησης γνώσης. Ἡ νέα αὐτὴ μέθοδος ἔχει ἤδη ἐφαρμοστεῖ σὲ ἀρκετὲς προπτυχιακὲς καὶ μεταπτυχιακὲς τάξεις Χημικῶν Μηχανικῶν μὲ ἔμφαση στὴν ἐπίλυση μηχανικῶν καὶ ἐπιχειρηματικῶν προβλημάτων μέσα ἀπὸ τὴν ὁμάδα, προσὸν ποὺ κρίνεται ἀναγκαῖο γιὰ τὴν ἐπιτυχία στὸν χῶρο ἐργασίας, ὅπως αὐτὸς διαμορφώνεται σήμερα.

Οἱ ἐπιτυχίες αὐτῆς τῆς νέας προσέγγισης ἦταν ὅτι:

- Αὐξήθηκε ἡ συμμετοχὴ τῶν φοιτητῶν στὴν ὅλη ἐκπαιδευτικὴ διαδικασία ἐξασφαλίζοντας μιὰ ἀποτελεσματικότερη ἀφομοίωση τῶν πληροφοριῶν.
- Αὐξήθηκε ἡ ποιότητα καὶ ἡ ταχύτητα ἀφομοίωσης ἀπὸ τοὺς φοιτητὲς τῶν βασικῶν στοιχείων τοῦ μαθήματος.
- Διευρύνθηκε τὸ φάσμα τῶν γνώσεών τους.

Τὸ πλαίσιο γιὰ τὴν συγκεκριμένη ἐκπαιδευτικὴ ἐμπειρία δόθηκε ἀπὸ τὴν ἀντίληψη περὶ λειτουργίας τῆς ὁμάδας ἀπὸ τὴν ἑταιρεία Boeing κατὰ τὴν διάρκεια σχεδίασης καὶ κατασκευῆς τοῦ ἀεροσκάφους Boeing 777. Ἡ παροῦσα ἀκαδημαϊκὴ διαδικασία ἀπόκτησης γνώσης ἔλαβε χώρα στὸ Ἐργαστήριο Πολυμερῶν Ὑλικῶν (Polymeric Composites Laboratory-PCL) τοῦ τμήματος Χημικῶν Μηχανικῶν στὸ Πανεπιστήμιο τῆς Οὐάσιγκτον, ὅπου χρησιμοποιήθηκε σὲ συνδυασμὸ μὲ τὴν ἀπόκτηση γνώσης μέσω τῆς προσωπικῆς ἐμπειρίας τῶν φοιτητῶν γιὰ νὰ ἐνισχύσει ταυτόχρονα τὴν ταχύτητα ἀλλὰ καὶ τὴν ἀποτελεσματικότητα τῆς ἐκπαιδευτικῆς διαδικασίας.

REFERENCES

1. Dixit, A.K. and B.J. Nalebuff, *Thinking Strategically*, Norton, New York 1991.

2. Lewis, M., *The New New Thing*, Norton, New York 2000.

3. Griffiths, P.A., «Breaking the Mold» *ASEE Prism*, Nov. 1995, pp. 27-30.

4. Goldstein, H., «Learning through Cooperative Groups.», *Engineering Education*, Vol. Nov., no. 1982, pp. 171-174.

5. James C. Seferis "The airplane as a vehicle for bringing people together for technological education, and social developments" presented at the National Academy of Athens, Greece, March 15, 1994.

6. Keidel, R.W., *Seeing Organizational Patterns*, Berrett-Koehler Publisher, San Francisco, CA, 1995.

7. Thurow, L.C., *Building Wealth*, Harper Collins, New York 1999.

8. Brandenburger, A.M. and B.J. Nalebuff, *Co-opetition*, Bantam Doubleday Dell Publishing Group, Inc, New York 1996.

9. Seferis, J.C., "Scaling Concept for Composite Material Developments," *SAMPE Journal*, Vol. 24, no. 6, 1988.

10. Fraser, B.L., J. Oppenheim and W. Rall, *Race for the World*, Harvard Business School Press, Boston 1999.

11. Freedom, L.M., *The Horizontal Society*, University Press, Yale 1999.

12. Maxwell, J.C., *The 21 Irrefutable Laws of Leadership*, Thomas Nelson, Nashville 1998.

13. Csikszentmihalyi, M., *Flow: The Psychology of Optimal Experience*, Harper and Row, New York 1990.

14. Gleik, J., *Faster*, New York 1999.

15. Burroughs, R., "Technology and New Ways of Learning" *ASEE Prism*, Jan. 1995, pp. 20-23.

16. Sears, Williams R., "Implementing cooperative Learning in a Well-Established EET Curriculum." Proceedings, 1995 ASEE Annual Conference: pp. 1009-1014.

17. Rhinehart, R., "Experiencing Team Responsibility in Class.," *Chemical Engineering Education*, Vol. Winter, no. 1989, pp. 38-43.

18. Wheeler, D. and M. Sillanpaa, *The Stakeholder Corporation*, Pitman Publishing, London 1997.

19. Howell, K.C., "Introducing Cooperative Learning into a dynamics Lecture Class," *Journal of Engineering Education*, Vol. 85, no. 1, 1996, pp. 69-72.

20. Ward, R.L. "Mastery Quizzes as a Teaching Tool in the Mechanics Series." Proceedings, 1995 ASEE Annual Conference: pp. 1015-1020.

21. Koehn, E., "Practitioner and Student Recommendations for an Engineering Curriculum," *Journal for Engineering Education*, Vol. 84, no. 2, 1995, pp. 241-247.

22. Lumsdaine, M. and E. Lumsdaine, "Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring," *Journal of Engineering Education*, Vol. 84, no. 2, 1995, pp. 193-204.

23. Glasser, W., *Choice Theory*, Harper Trade Publishers, New York 1998.

24. Schumacher, E.F., *Small is Beautiful*, Harper, London 1973.

25. Felder, R.M. and L.K. Silverman, "Learning and Teaching Styles," *Engineering Education*, Vol. 78, no. 7, 1988, pp. 674-677.