Solutions of the 21st Century – Teaching Computer-Aided Conceptual Design

Zbigniew M. Bzymek[1], Siamak Vahidi[2] and Heather Spottiswoode[3]

[1]University of Connecticut, School of Engineering, Zbigniew.Bzymek@uconn.edu
[2] University of Connecticut, Neag School of Education, Siamak.Vahidi@uconn.edu
[3] University of Connecticut Neag School of Education, Heather.Spottiswoode@uconn.edu

ABSTRACT

In this paper the authors share some experience from the seven years of offering Computer-Aided Design tutorials to selected top high school students in the scope of the UConn Mentor Connection program at the University of Connecticut. UConn Mentor Connection is a three-week, residential, summer enrichment program for young people entering the last two years of high school. The program has been designed to provide rising high school juniors and seniors with opportunities to participate in cutting-edge research investigations and creative projects under the supervision of university mentors. This paper describes "Design Site" activities. In the first part of these activities students have learned the method of solving conflicting problems with BTIPS (Brief Theory of Inventing Problem Solving). The method is used with IM (Invention Machine™) and TO (TechOptimazer™) software packages. Using these two packages the students have to solve three problems and learn Computer-Aided Report Generation. In the second part of activities the students solve design problems for future needs. These are problems connected with space travel, improvement of the Connecticut highway transportation and design of nano-machines. In the past the students have done conceptual designs of a space communication racket, flying cars, nano-robots and nano-motors. The students worked with the Engineering Computer and CAD Laboratories equipped with DELL PC's and SGI stations, as well as with Stereo3D Eyeviewer systems, and the SGI Inventor package.

Keywords: UConn Mentor Connection program, Design education of outstanding high school students, Problem solving, Solving conflicting problems, Computer-Aided Report Generation, Computer-Aided Conceptual Design, Solutions for future needs, Design of Nano-machines.

1. INTRODUCTION

1.1 University of Connecticut Mentor Connection Program

Each year, accomplished university professors and advanced graduate students work side-by-side with Mentor Connection Program participants on research projects, creative productions, and other works-in-progress in shared areas of interest. Participants and mentors become a community of scholars of all ages working together on important projects that are on the cutting edge of various fields of study in the arts, sciences and technology. The main goals for UConn Mentor Connection are to allow participants to achieve to their highest potential by participating in experiential research projects that provide direct, apprentice-based involvement with faculty members who are conducting research in their respective disciplines; to increase each participant's awareness about his or her personal strengths and options to nurture personal talents and to demonstrate that high-level talent potential can be found and developed across cultural, ethnic, and socioeconomic groups.

1.2 Goals and Assumptions of the Mentor Connection Program

The Program has been operating for over ten years and its popularity is very high. The participants are top ranked students from Connecticut high schools. The popularity of the Program continues to grow and there are many applications from students from other states as well. The Program is run by the Neag School of Education and offers students the opportunities to work in mentorship sites in numerous fields that are available at the University. The students can view the application and mentorship sites on the website and choose their mentors from the professors who have agreed to put the description of their teaching and research interests on the Web. Many students from Connecticut have state and private scholarships. About 50% have to pay the full fee of $3,100. The program lasts three weeks and contains daily activities in the classrooms, laboratories and in the library as well as evening general education activities and entertainment. The students are at their mentorship site for about six hours a day (9 AM to 12 Noon and from 1 PM to 4 PM). Weekends are devoted to leisure. As one can see (Tab. 1) many students are interested in engineering and a number of them in Engineering Design.

Year	Total number of students in the program	From Connecticut	From other states	Bio-medical Engineering	Electrical and Computer Engineering	Chemical Engineering	Natural Resources and Engineering	Engineering Design	None engineering sides
2000	75⁺	70+	5+	2+	3+	3+	3+	6	52+
2001	81	69	12	4	*	*	2	3	71
2002	87	69	18	3	1	*	1	2 and 1 from NY	79
2003	77	55	22	N/D**	N/D**	N/D**	N/D**	2 and 1 from NY	N/D
2004	70	58	12	5	2	*	*	2 and 1 from Ca	59
2005	70	59	11	2	1	*	*	5	62
2006	84	69	15	8	*	2	*	6	68

⁺) Estimated data, +) the quoted number was exceeded, *) Mentorship site not offered that year, **) N/D – No data available.

Tab. 1: Number of Students in the UConn Mentor Connection Program.

2. DESIGN SITE IN MENTOR CONNECTION

This paper describes in particular some experiences of seven groups of students who have participated in the Mechanical Engineering design site from 2000-2006 entitled "Calling all Young Inventors". In this site, engineering design is presented as a problem-solving process that requires personal talent, imagination, and knowledge of physics, chemistry, mathematics, and engineering sciences. The site offers students Computer-Aided tools to solve elementary design contradictions, formulate concepts, and present them to others. It also teaches how to pursue an idea through general shape design of objects by using the software systems such as Invention Machine, TechOptimizer and SGI Inventor. Personal computers and Silicon Graphic stations equipped with the best graphics software and stereo view hardware are available for students.

3. SOLVING MACRO PROBLEMS OF TECHNOLOGY

There are several methods available for problem solving. Generally, they can be classified as psychological and algorithmic. B.S.M. (Brain Storming Method) represents the psychological approach [1]. There are also several algorithmic approaches sometimes called engineering methods [2, 3, and 4]. Only a few of them can be applied to conceptual design in the situation where only customer's general description of a problem is known. Such a description is usually available in a colloquial language and must be translated into engineering terms. The number of algorithmic methods is not large.

Out of this group the BTIPS method [5] was chosen for the Mentor Connection design side. BTIPS was developed from Invention Machine TIPS [3]. TIPS is similar to TRIZ [2] but formalized through the programming routines and structures. BTIPS is based on TIPS [3] and contains three modules as well however they are slightly changed. The slightly changed module "Principles" contains three new principles organized in a matrix of 44 by 44. Its general application algorithm is a little shorter than in TIPS. The module "Effects is a little enlarged. The "Prediction" module is simplified.

Each year the students are given different problems to solve. They have to find contradictions, choose the BTIPS module, and find a solution. Last year (2006), the following three problems were issued: Oil fire extinguishing [6] based on IM v. 2.1 and TechOptimizer [7, 8]; Removal of sand particles from intake air in a jet engine [7, 8]; and conceptual design of a Safe diving pool [3].

4. EXAMPLES OF PROBLEMS SOLVED BY STUDENTS

4.1 Oil Fire Extinguishing During Quenching

The example of preventing oil fire in quenching is based on [4, 5, 6, 7, 8 and 9]. Problem statement is generally described as "Prevention of oil fire in the process of quenching" [7, 9] (Fig. 1). As a Preliminary Solution it was proposed to cut oxygen supply by covering the oil container with a lid. The Basic Contradiction is: "The lid should be there to cut the oxygen supply but not should be there for the operation of sinking the part into the oil". This can be summarized in the following sentence: "there is a lid and there is no lid". All the students chose cutting the oxygen supply with a lid as preliminary solutions. The lid did cut the oxygen supply but created an obstacle for the crane operator. The basic contradiction stating that "the lid should or should not be there" was correctly identified by students. The Preliminary Solution "a lid to cover the container" is not an Ideal Solution. The Matrix of Principles was applied to find the Ideal Solution. The "area of stationary object" was chosen as an Improving Feature [3, 4, 7, 10]. Since the lid makes crane operation difficult, the "device complexity" was chosen as a Worsening Feature [3, 4, 7, 10]. The Matrix of Principles suggested three principles: Segmentation, Mechanical Vibration, and Phase Transitions. Using those principles several solutions were derived. The solutions were: hanging lid, sliding lid, and based on the phase transition gas or liquid lid. One solution that used flexible lid made of a memory material that would change the shape sensing the heat was also derived (Fig. 2). The gas lid (Fig. 3) made of carbon dioxide (CO_2) was chosen as an Ideal Solution. This solution is also known from volcano eruption disasters [11] and also used by IM [7] as a teaching example. The lid made of gas is solving the contradiction "the lid is there and the lid is not there". This solution can not be trimmed. The problem solving process is described in detail in [4] and practical example is given in [7].

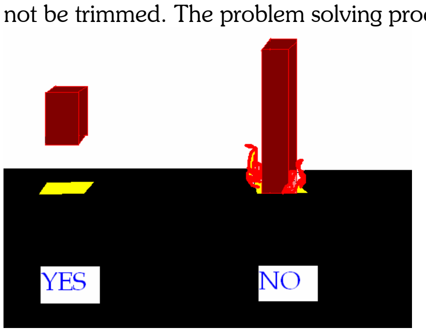

Fig. 1: Undesired oil fire in quenching.

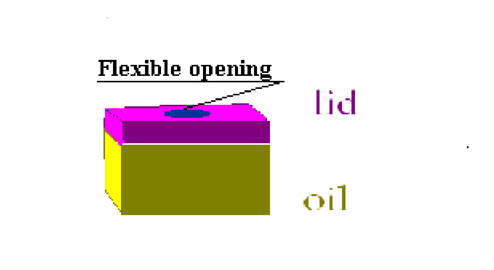

Fig. 2: Flexible opening that prevent the access of oxygen.

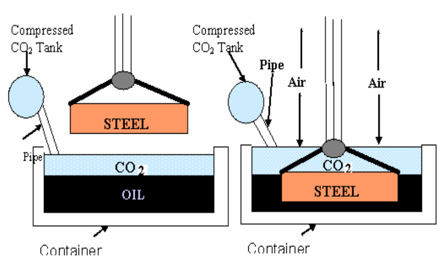

Fig. 3: Quenching with a gas lid made of carbon dioxide.

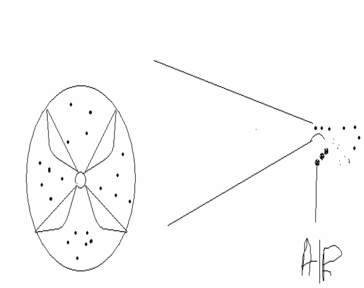

Fig. 4: The preliminary hand sketch of sand elimination from the jet engine air intake.

4.2 Removing Sand from the Intake Air in a Jet Engine

Working with Effects one should look for the effect that would generate the primary solution on the basis of the effects known. The primary solution should solve the problem at once, satisfy the desired function and solve the basic contradiction. The module Effects contains functions of the first order indicating the general action as for example “eliminate” and functions of the second order indicating objects as for example “the loose particles”. On the basis of this two functions the problem of eliminating sand particles from the jet engine was solved and two solutions given. The solution derived by students was based on the centrifugal force effect (Fig. 4, Fig. 5). Module Effects, a very helpful tool in problem solving process, requires an extensive knowledge of mathematics, physics, chemistry, biology, and other sciences to allocate the needed effect. It is a very educational and awarding module to work with.

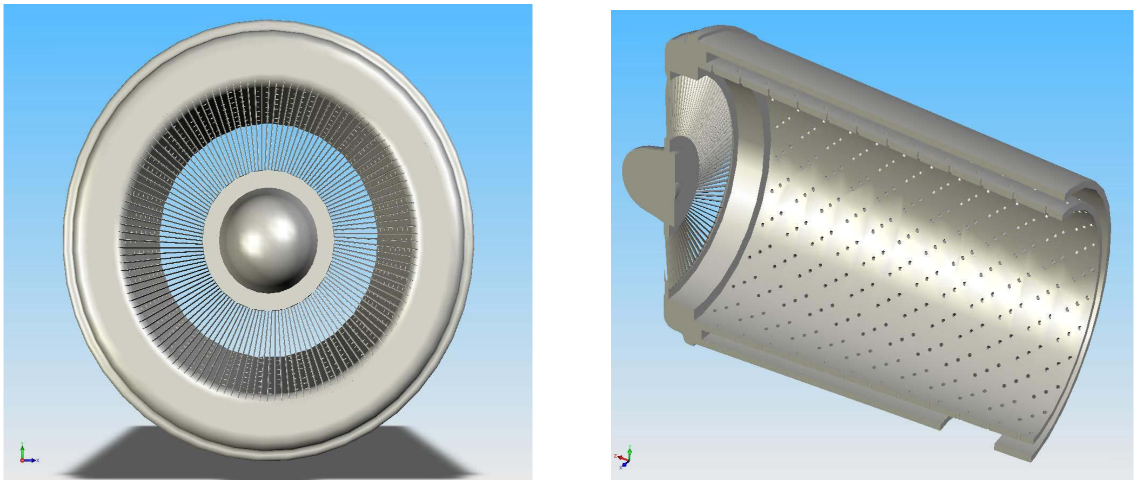

Fig. 5: The solution generated on the basis of the hand sketch in Fig. 4 (the front view on the left and side view on right).

4.3 Save Diving Pool

BTIPS module Prediction is based on the analysis of the designed system. To perform such an analysis the hierarchical model of the Designed System should be built. In the example presented below, the existing diving pool will be improved to make it safe for “bad” dives in which the diver hits the water surface in a flat position. The super-system is the system that is superior to the designed system. In the pool problem it is usually the building housing the pool. The designed system is the pool. Its subsystems are: the pool’s shell, the water, the tower and the diver. The objects are: the board, the diver’s swimming trunks, and other objects connected with pool and the diver. The elements are: board hinge, supports, and other elements that objects consist of. The structure of the Designed System should show the negative, positive, and neutral interaction between the parts of the system; water surface has the negative influence on the diver in the incorrect dive but water below the surface has positive influence preventing him/her from hitting the bottom. The hierarchy of subsystems, objects and elements shows their influences. On the basis of this the students have to figure out where and when it is necessary to introduce additional parts as well as substances or fields to the designed system that will change the relation between the parts of the system. Prediction helps to identify the relations and eliminates or reduces the negative actions, intensify positive actions and change the neutral actions into positive. In the problem solving cases the Designed System should be isolated in such a way that the isolation should not eliminate resources. Without resources, it may be impossible to change the interactions between parts of the system. The available resource in the Safe Diving Pool problem is the air [3]. In solving the safe diving pool problem an Ideal Solution was found. It is an air bubbles generator used to break the surface tension (Fig. 6, Fig. 7, Fig. 8 and Fig.9) of the pool water.

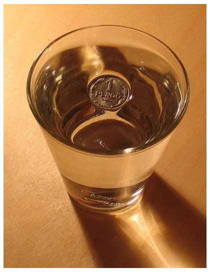

Fig. 6: Water surface tension [12].

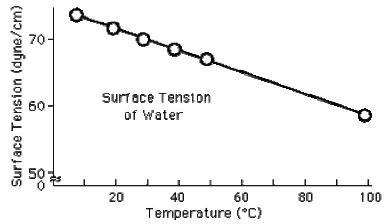

Fig. 7: Water surface tension vs. temperature [12].

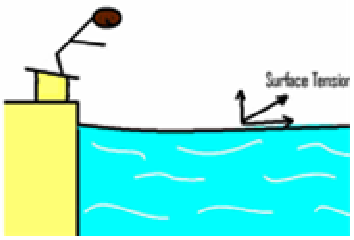

Fig. 8: Water surface tension dangerous for the diver.

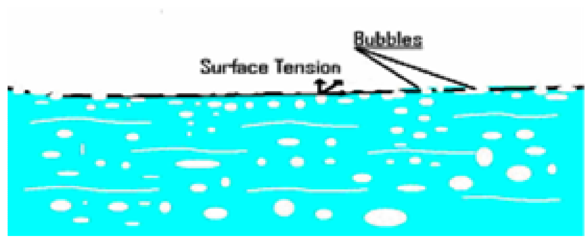

Fig. 9: Water surface tension broken by air bubbles.

4.4 Computer-Aided Report Generator

The students were generating a first version of the report on their design using a special tool of the IM [7] and the TO [8] called Report Generator. Using this tool the text and the figures can be inserted into the generated report creating this way the first draft. In spite of the fact that such a first draft has to be edited in MW, it is always a great help for the user. All the icons drawings and the text can be edited or changed. The first version of the report can be printed using the IM or TO software and saved as a word processor file.

5. DESIGN OF FUTURE SYSTEMS

5.1 Design for the Future

Each year the Mentor Connection students work side-by-side with the instructor on the "design for the future" projects. The topics are numerous, for example, the space travel system, nanotechnology structures, water and land travel systems. The students study the website information and university library materials to predict the future problems and come up with needs that will be created by such problems. One of the problems that drew students' attention is the fast growing number of cars, greater than the number of road miles in Connecticut (Tab. 2). This brought into attention the problem of transportation and kind of cars that will be used in the future.

Col numb.	Year *)	Population M=1 million	Number of cars Registered in the State M= 1milion	Federal Highways (1,000KM)	State Highways (1,000 KM)	Municipal roads (1,000 KM)	Cars per person	Roads (KM per person)
1	2000	3.40 M	2.85 M	0.56	0.99	33.5	0.84	0.0103
2	2001		2.92 M	0.56	0.99	33.7		
3	2002		2.91 M	0.56	0.99	33.9		
4	2003		2.96 M	0.56	0.99	33.9		
5	2004		3.04 M	0.56	0.99	34.0		
6	2005	3,51 M**	3.07 M	0.56	0.99	34.2	0.87	0.0102

*) National census was taken in years of 2000 and 2005 only.
** All the data is from Federal Highway Administration's annual reports available on-line from www.fhwa.dot.gov .

Tab. 2: Some transportation data in Connecticut.

5.2 Connecticut Highways Traffic Problem

The students came up with a need for a car that can move even if the roads are jammed. Such a car could be a car flying through the air. The roads for such cars however should be air roads located not too high above the ground. Air vehicles should begin and end their journey on starting/ending plaza (Fig. 10). They should be built accordingly and equipped with engines for the vertical start and landing. The engines made not only for the purpose of start/land but also for travel (Figs. 11 and 12). Except for starting, ending and resting plazas on the ground the safety installations have to be located some place along the air highways. Figures 10, 11 and 12 show examples of the students' designs. They were rendered using the IGS Inventor and run dynamically on the IGS Octane and Indigo 2 stations with Stereovision.

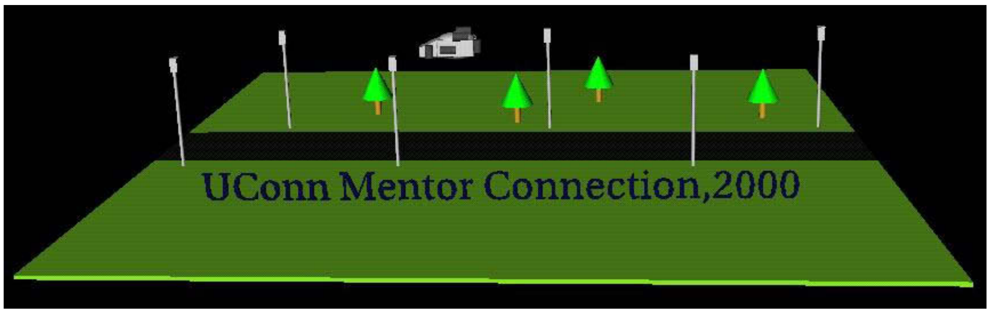

Fig. 10: A view of an air- highway starting and landing highway plaza.

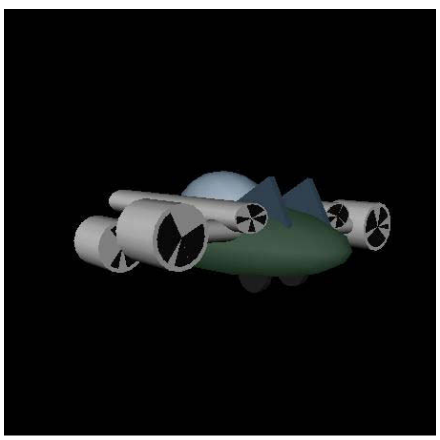

Fig. 11: The engines of the flying car.

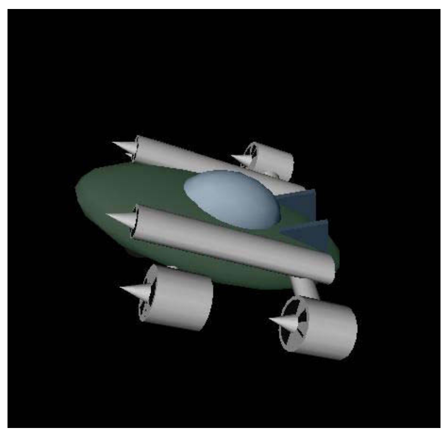

Fig. 12: The general view of the flying car.

6. DESIGN OF FUTURE NANO-SYSTEMS AND OTHER DESIGN ACTIVITIES

Each year in this category the nano systems like nanotubes, nano-motors and nano-robots are rendered on by students including the new information gathered and images obtained from the University of Connecticut high power electron microscopes. Every year on the design site there are also other design activities not described here i.e., modeling gliders and gyroscopes, performing experiments with fast expansion of gazes, like diet Coca-Cola/Menthos experiment, and others.

7. CONCLUSION

The Mentor Connection Program has been operating for over ten years and its popularity is very high. For the last seven years, the design site, "Calling all Young Inventors" has been very active. Because of the CAD laboratory constraints, a maximum six students can be accepted each year to this design site. Enlarged admission would be possible only if the expansion of the laboratory could be done. The students benefit much from the contact with the site mentor and are learning how to solve conflicting problems in technology. They develop a unique way of thinking, apply the methods of problem solving, identify conflicts and use design guides to solve them. They learn how to apply computers and software in CAD process.

The study of the future technology and predicting future needs is exciting, interesting, and develops students' creativity. Especially, designing air roadways, air vehicles, robots, and equipment for the future needs is exciting and develops imagination of designers. University of Connecticut also benefits from the Mentor Connection program by attracting the top students from the state of Connecticut and other state as well. A significant number of them come later to the university as students. The use of problem solving philosophy and tools, as well as Computer-Aided Design methods and equipment plays here the most important role.

8. ACKNOWLEDGEMENTS

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