Session 1566

Developing Assessment Tools for Outcome Based Engineering Courses

Drs. Z.T. Deng, Ruben Rojas-Oviedo and Xiaoqing (Cathy) Qian
Mechanical Engineering Department, Alabama A&M University
P.O. Box 1163, Huntsville, AL 35762
Voice: (256) 858-4142, E-Mail: AAMZXD01@AAMU.EDU

Abstract

The implementation of the Accreditation Board for Engineering and Technology (ABET) Engineering Accreditation Criteria 2000 (EAC 2000) into Mechanical Engineering undergraduate curricula is critical to the success of the education program. The EAC Criteria 2000 emphasizes an outcome based system approach to engineering education. The basic level criteria for engineering program outcome and assessment requires that graduates must have demonstrated abilities (a-k) [1], in math, science, engineering, design, teamwork, ethics, communication, and life-long learning. In addition to ABET accreditation criteria 3(a-k) requirements, the Mechanical Engineering (ME) program at Alabama A&M University (AAMU) was designed to meet additional requirements by American Society of Mechanical Engineer, such as (l) an ability to apply advanced mathematics through multivariable calculus, and differential equations; (m) a familiarity with statics, linear algebra and reliability; (n) an ability to work professionally in both thermal and mechanical systems areas including the design and analysis of such systems; (o) a knowledge of contemporary analytical, computational, and experimental practices; (p) a competence in experimental design, data collection, and data analysis; (q) a competence in the use of computational tools; (r) a knowledge of chemistry; and (s) knowledge of calculus-based physics.

Under the criteria (a-s), Mechanical Engineering Faculties at AAMU are being challenged to revise the course content, depth and perspectives of the engineering curriculum. To ensure the quality of the outcome based mechanical engineering program, faculties adopted a system approach, denoted by the acronym SEAARK for instruction and teaching. SEAARK stands for Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis in reverse order. It was based on Bloom's taxonomy [2]. SEAARK starts from the basic to the complex levels or learning. Faculties need to provide assessment matrices that map these criteria to each undergraduate engineering course. Those matrices should also provide assessment tools for the corresponding mapped course contents and criteria.

This paper describes, in details, the development of assessment matrices and tools for a particular undergraduate mechanical engineering course, Fluid Mechanics, at Alabama A&M University. Development of SEAARK teaching method, mapping of course objective to ME program objective and outcomes, mapping of the course contents to criteria (a-s) and assessment tools are discussed. The procedure to implement the criteria in class teaching and assessment tool is discussed in details.

I. Background about Alabama A&M University's Mechanical Engineering Program

Alabama A&M University (AAMU), is a land grant historically black university. It is located in the northeast outreach of Huntsville, Alabama, an important world center of expertise for advanced missile, space transportation and electronic research and development. Among the leading industry and government agencies located in this area are NASA Marshall Space Flight Center, the Army Aviation and Missile Command Center (AMCOM), Redstone Arsenal Testing Center, The Boeing Company, Northrup Grumman, Lockheed Martin Aerospace and many others associated with high-tech. endeavors. These industries and government agencies require large numbers of highly trained engineers, both in the areas of manufacturing and propulsion.

In 1997, the Mechanical Engineering program at AAMU was created as the results of the legal desegregation law suit resolution in the civil case CV 83-M-1676. To respond what is important around north Alabama, the Mechanical Engineering program at AAMU was formulated into two options: Manufacturing and propulsion system. The Mechanical Engineering Program mission is to provide an environment conductive for students to build their self-confidence, develop engineering and professional competences, and elevate the quality of their scholarly and professional endeavors. The ME program is aimed to develop engineering core competencies in manufacturing and propulsion systems to better serve industry and government organizations and corporations with relevant engineering activities in aerospace, automotive, power generation, industrial manufacturing, and related emerging technologies. In both options, areas such as system performance, reliability, safety, concurrent engineering, team works and communication are given special considerations. Each course syllabi was required to map course contents to the aforementioned requirements (a-s). Although certain courses do not provide the trainings for (a) through (s), but the overall curricula will provide comprehensive covering of these elements.

In the summer of 2000, the Mechanical Engineering program at AAMU was successfully accredited by ABET under the EAC 2000 criteria.

II. Developing Course objectives to Meet ME Program Objective and Outcomes

Based on the aforementioned criteria (a-s), the outcome of each engineering course has to be measurable. The objective of each course has to be designed to meet the overall program objective and outcomes.

The educational objective of the Mechanical Engineering program at AAMU is to provide students with the necessary preparation in mechanical engineering to compete effectively for professional careers in this field and with the motivation for personal and professional growth through lifelong learning.

The educational outcomes of the ME program are:

[1]. The student will demonstrate the necessary competencies in fundamental education in areas of mechanical engineering, such as thermal and mechanical sciences and system design.

[2]. The student will demonstrate competencies in experimental testing, error analysis, laboratory safety, data acquisition, instrumentation and laboratory report writing.

[3]. The student will demonstrate computer competency and an intelligent use of computers as a tool for developing solutions to engineering problems.

ME 360 Fluid Mechanics class is designed to provide the student a basic working knowledge of engineering fluid mechanics with the inclusion of open ended problems in the design of fluid systems and consideration to the economics of fluid systems performance. The student will be able to identify the parameters that characterize the operation of fluid flow in incompressible and compressible flow problems and its application on turbo-machinery systems. Computer program in FORTRAN or in C, MATLAB, and Lab View will be developed and used to support design and Lab projects and analysis.

III. Developing Teaching Strategies: SEAARK Teaching Approach

The faculty of the mechanical engineering department at Alabama A&M University adopted SEAARK system approach for instruction and teaching. It starts from the basic to the complex levels or learning. SEAARK stands for (in reverse order) Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis. At the “Knowledge” level, students need to define, introduce, describe, name, relate, explain, identify, and remember concepts and principles. At the “Repetition” level, students need to repeat and discuss concepts and principles. At the Application level, students need to apply, demonstrate, interpret, and illustrate concepts and principles learned. At the “Analysis” level, students need to learn to calculate, solve, compute, compare and to derive. At the “Evaluation” level, students need to learn to evaluate, decide, recommend, justify and to assess. At the “Synthesis” level, students need to learn to design, conduct, perform, create, produce and propose new tasks. The SEAARK approach was implemented in the ME program and was discussed in earlier papers by Dr. Ruben Rojas-Oviedo [3,4,5].

The development of course contents need to consider the complexity level and teaching strategies. Table 1 shows the sample Fluid Mechanics course contents and its teaching methods. The instructor will present the materials through the use of visual aids, lectures, illustrations, and demonstrations. The instructor will offer free study session during his office hours. This study session is not mandatory for student to participate. Instructor will solve problems and review class teaching materials in the study session. No new class teaching materials will be presented in this special session. The SEAARK approach for lectures is also utilized for class projects. As part of the vertical and horizontal integration of design and project development, a project is required in each course. The ME program strongly encourage teamwork on a class project for courses in the major. This allows students to develop a design portfolio starting from the freshman year [3]. Project training continues through their capstone design course. The projects assigned to students are often combined with on-going faculty externally funded research. This aspect of program keeps the students in touch with leading-edge technology and current research activities in the real world. At the end of the course the student are expected to learn at a level of analysis and synthesis, i.e. beyond repetition.

Table 1. Fluid Mechanics Course Contents and Teaching Methods.

#	Course Topic and Contents (SEAARK Keyword)	Teaching Methods	Level of Complexity
1	Introduction to fluid mechanics: **DEFINE, REPEAT, REMEMBER, DESCRIBE, EXPLAIN, AND DISCUSS** the concepts of Incompressible, compressible, subsonic, transonic, supersonic and hypersonic flows. **EXPLAIN** continuum and rarefied fluid.	Lecturing, video presentation and questioning.	Knowledge Repetition
2	**DEFINE, RELATE, EXPLAIN, and DISCUSS** Fluid properties. **REMEMBER** System units. **ILLUSTRATE and DISCUSS** extensive and intensive properties, viscosity and elasticity, surface tension, vapor pressure.	Lecturing, problem solving.	Knowledge Repetition
3	**EXPLAIN, DEFINE, REMEMBER, ILLUSTRATE, INTERPRET, ANALYZE, DERIVE and APPLY** the fundamental principles governing fluid motion. **DEFINE and COMPARE** control volume and control mass approaches. **DERIVE and APPLY** conservation of mass (Continuity equation), viscous stress, pressure measurements, momentum equations, and energy equation to **SOLVE** one-dimensional application problems. **APPLY and DISCUSS** Bernoulli's equation to incompressible and compressible fluid and its application. **DEFINE and REMEMBER** equation of state.	Lecture, supplemental reading, problem solving, study session, multiple laboratory experiments.	Knowledge Repetition Analysis Application
4	**APPLY** the fundamental principles to pipe and channel flows for incompressible fluid: **CALCULATE** pressure drop in Pipe flow. **ANALYZE** flow pattern, APPLY to channel flow. **DEFINE and CALCULATE** drag and lift. **ANALYZE and COMPARE** laminar flow, turbulent flow. **SOLVE** pressure drop for laminar and turbulent flows.	Lecturing, supplemental reading, virtual laboratory experiment (LABView), computer simulation, simulation tutoring, projects, problem solving, study session, photograph of flow visualization.	Knowledge Repetition Analysis Application Evaluation
5	**DISCUSS** Compressible fluid flow. **DEFINE** Mach number, static and stagnation properties. **DERIVE** relationships between total and stagnation properties. **IDENTIFY** subsonic, transonic, supersonic, and hypersonic flow. **INTERPRET** its flow characteristics.	Lecturing, problem solving, study session.	Knowledge Repetition Analysis Application
6	**PERFORM** Turbo-machinery applications: Flow through turbo-machinery system one-dimensional **ANALYSIS**.	Lecturing, problem solving, scientific presentation. ME ANNEX Helicopter tour.	Knowledge Repetition Analysis Application Evaluation Synthesis
7	**DESIGN** for experiment. **DISCUSS** Flow measurements: **APPLY** Instrumentation system and data analysis. Error analysis, linear regression.	Lecturing, laboratory experiment, ME ANNEX tour.	Knowledge Repetition Analysis Application Evaluation Synthesis
8	**APPLY** principles to computational fluid mechanics. **ILLUSTRATION** of grid generation. **DESIGN, PROPOSE, PRODUCE, EVALUATE, and JUSTIFY** results for design project. Project Report, Oral Presentation.	Lecturing, extra special scientific seminar from industry expert on CFD. Numerical simulation lab. Report, Oral presentation.	Knowledge Repetition Analysis Application Evaluation Synthesis

IV. Mapping of the Course Contents to Criteria (a-s) and Assessment Tools

The outcome based course assessment and evaluation tools should consist student learning and instructor teaching. These tools can be a combination of the following:

(1) Homework assignments,
(2) Quizzes,
(3) Exams,
(4) Class Attendance,
(5) Design Project and laboratory written reports,
(6) Design Project Oral Presentation,
(7) Computer Simulation using FORTRAN, C, MatLab, Labview,
(8) Prototype development,
(9) Laboratory Testing / Project teamwork.
(10) Course assessment (by students),
(11) Instructor's teaching performance evaluation (by students).

To guarantee the outcome of the course, the teaching of each topic in the course contents was designed to meet aforementioned criteria (a-s) and evaluated by a set of assessment tools selected from the above (11) tools. Table 2 shows the mapping of the sample fluid mechanics course topics to criteria (a-s) and its corresponding assessment tools.

Table 2. Mapping of the Fluid Mechanics Contents to Criteria (a-s).

	ME 360 Fluid Mechanics: ABET Criteria 3(a-k) and ME Program Criteria (l-s)																			Course Outcome Assessment Tools
#	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	
1	X				X						X	X								1,2,3,4,10,11
2	X				X						X									1,2,3,4,10,11
3	X		X	X	X	X	X				X	X	X	X	X	X	X		X	1,2,3,4,5,7,9,10,11
4	X	X	X		X						X	X			X					1,3,4,5,7,10,11
5	X	X	X		X						X	X			X			X		1,2,3,4,10,11
6	X	X	X		X		X		X		X	X		X	X					4,5,7,9,10,11
7	X	X	X	X	X						X	X			X	X				3,5,7,9,10,11
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3,4,5,6,7,8,9,10,11

ABET Criteria 3(a-k) and Additional Local ME Program Criteria (l-s)

a. an ability to apply knowledge of mathematics, science and engineering;
b. an ability to design and conduct experiments, as well as to analyze and interpret data;
c. an ability to design a system, component, or process to meet desired needs;
d. an ability to function in multidisciplinary teams;
e. an ability to identify, formulate and solve engineering problems;
f. an understanding of professional and ethical responsibility;
g. an ability to communicate effectively;
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i. a recognition of the need for and an ability to engage in life-long learning;
j. a knowledge of contemporary issues;
k. an ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
l. an ability to apply advanced mathematics through multivariate calculus and differential equations;
m. a familiarity with statistics, linear algebra and reliability;

n. *an ability to work professionally in both thermal and mechanical systems areas including the design and analysis of such systems;*
o. *a knowledge of contemporary analytical, computational, and experimental practices;*
p. *a competence in experimental design, data collection, and data analysis;*
q. *a competence in the use of computational tools;*
r. *knowledge of chemistry;*
s. *knowledge of calculus-based physics.*

As indicated in Table 2, the tools to evaluate student-learning quality include: homework and quiz 15% of the overall grade, attendance 5%, three exams 60%, project oral presentation and written reports 20% of the overall class grade. On design project, student performance will be evaluated based on written report and oral presentation. Appendix 1 shows the key elements that student project should demonstrate. Student oral presentation will be evaluate by ME faculty and students participating the class. Student presentations are videotaped and compared to other ME course project oral presentation. Suggestions to improve communication and presentation will be made to students. This assessment also provides student observation on their team member's performance. Figure 1 shows the performance assessment sample of the best (A) and passing (C) students taking Fluid Mechanics in the Fall 2001 semester. Laboratory experiments are assessed based on Laboratory testing, and written reports, which are not included in this figure. Figure 2 shows the Fluid mechanics class overall student performance and passing (C or above) percentage in the Fall 2001 semester. To make the evaluation a continuous improvement process, students will evaluate course contents (assessment tool) in terms of teaching time allocation. This evaluation is designed to make instructor aware of student's suggestions to spend more or less time on course topics. Appendix 2 shows the course contents (time allocation) review by students (Assessment Tool #10). Faculty teaching quality will also be evaluated by student observation (Faculty teaching style assessment tool). This evaluation is designed to make instructor aware of the ways to improve their teaching methodology. Table 3 shows the results of an instructor's evaluation in Fall 2001. The instructor's performance is well above the average of the engineering school. This indicated that the SEAARK teaching method is well accepted by students. Feedback from these evaluations were analyzed and applied to enhance faculty teaching effectiveness.

Table 3. Student Evaluation of Instruction

Question	Student Observation % High (5), Low (1)					Instructor's Mean	Standard Deviation	School Mean
	5	4	3	2	1			
Appears to know subject	100	0	0	0	0	5.0	0.0	4.3
Clearly Explains concepts and ideas	100	0	0	0	0	5.0	0.0	3.7
Advise student concern	100	0	0	0	0	5.0	0.0	3.5
Is concerned with student progress	100	0	0	0	0	5.0	0.0	3.6
Uses various assessment devices	100	0	0	0	0	5.0	0.0	3.5
Clearly explain the course requirements	100	0	0	0	0	5.0	0.0	3.7
Generate enthusiasm in the class	100	0	0	0	0	5.0	0.0	3.6
Involving students in question/Answer	100	0	0	0	0	5.0	0.0	3.8
Is prepared for class discussion	100	0	0	0	0	5.0	0.0	4.0
Meet class at scheduled time	93	7	0	0	0	4.9	0.3	4.0
Develop positive working relationship	93	7	0	0	0	4.9	0.3	3.7
Is innovative in developing and Presenting materials	100	0	0	0	0	5.0	0.0	3.6

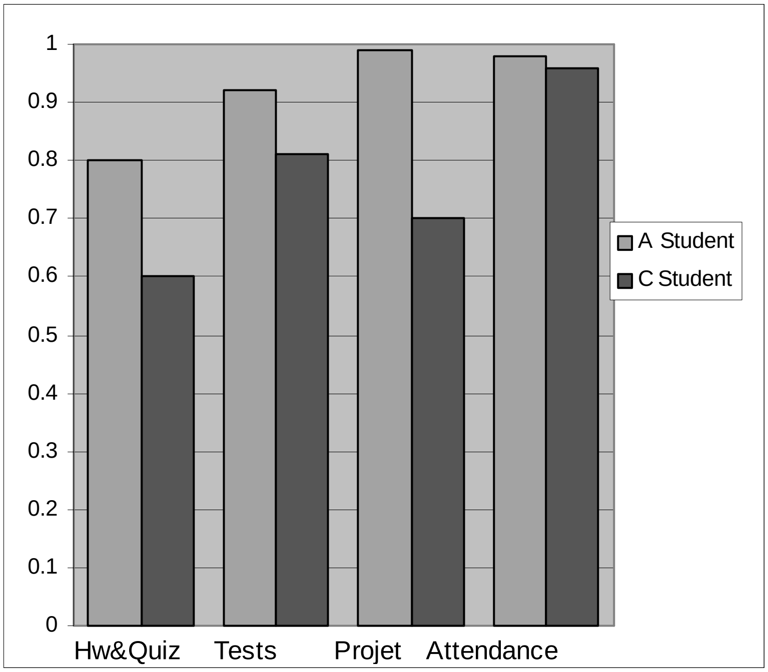

Figure 1. Student's performance assessment. (Fluid Mechanics Class, Fall 2001).
1=100%, 0.9=90%, 0.1=10%.

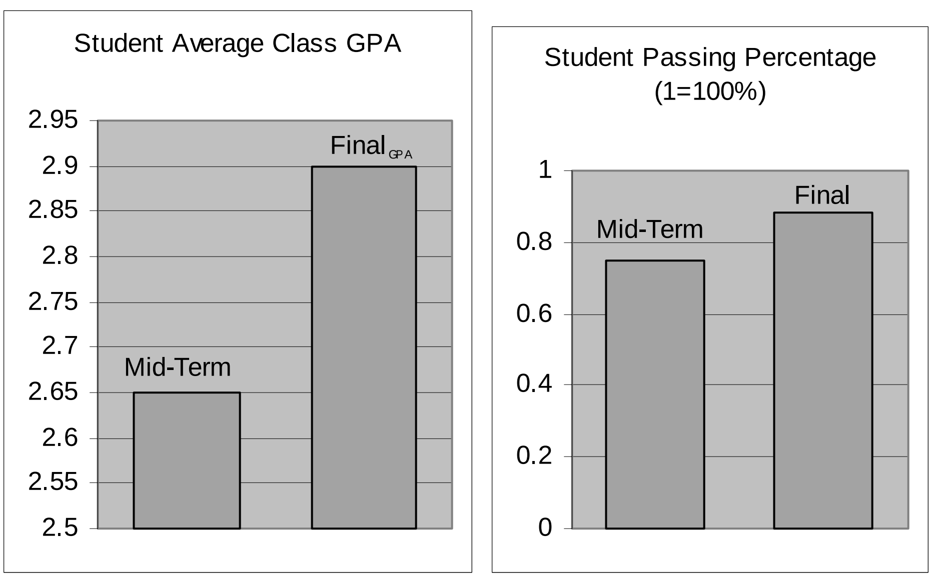

Figure 2. Students averaged class grade and passing percentage in Fluid Mechanics Class.
(Fall 2001 Data, Averaged class GPA is obtained based on A= 4.0)

V. Conclusions

This paper describes, in details, the development of assessment matrices and tools for an outcome based engineering undergraduate mechanical engineering course, in particular, Fluid Mechanics, at Alabama A&M University. Development of SEAARK teaching method, development of course objective to meet ME program objective and outcomes, mapping of the course contents to criteria (a-s) and assessment tools are discussed. The procedure to implement the criteria in class teaching and assessment tool was also discussed in details. Sample data collected from Fluid Mechanics class in the Fall 2001 indicated that the student learning performance was improved in the process. The data give us confidence that the development of assessment tool for the outcome based engineering courses is working in the positive direction. More data need to be collected to enhance and improve the assessment tools. The data collection is a long-term process. More data are needed to analyze the tools statistically in order to enhance student-learning performance and enhance instructor-teaching performance.

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ZHENGTHAO DENG

Dr. Z.T. Deng is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Deng has an extensive background and research experience in Computational Fluid Dynamics numerical simulation in particular high-speed aerodynamics/flows with heat transfer phenomena. He earned his Ph.D., Aerospace Engineering, University of Tennessee, 1991, and his Bachelor of Science, Aerospace and Mechanical Engineering, from Beijing University of Aeronautics and Astronautics in 1985.

RUBEN ROJAS-OVIEDO

Dr. Ruben Rojas-Oviedo is Chairperson and Associate Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville AL. Dr. Rojas-Oviedo has international engineering experience working both in academe and industry. He has an engineering consulting company and conducts applied research. He earned a Ph. D. In Aerospace Engineering from Auburn University, he has two Masters degrees one in Mechanical Engineering from N.C. State at Raleigh and the other in Applied Mathematics from Auburn. He earned a B.S. degree in Aeronautical Engineering from the National Polytechnic Institute – Escuela Superior de Ingenieria Mecanica y Electrica - in Mexico City, Mexico.

XIAOQING (CATHY) QIAN

Dr. Cathy Qian is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Qian earned her Ph.D. and M.S. in Mechanical Engineering from the University of Tennessee. Dr. Qian has been working at industry for five years as a Senior System Engineer. She has an extensive experience in instrumentation, measurements, and numerical simulation in particular heat transfer phenomena, and system engineering.

Main Menu

Appendix 1
Project Oral Presentation Evaluation Form

Project Oral Presentation Evaluation Form

Class: ______________________
Presenter(s): ______________________
Team Members: ______________________
Project Presented: ______________________
Date:

Rating:		Poor (1); Fair (2); Good (3); Excellent (4)
Technical Presentation Contents	Were the objectives and purpose clearly stated?	
	Was the problem well defined?	
	Was the project properly justified (Why?) (Scientific, economic, political, value?)	
	Was the design, analysis and modeling understood?	
	The approach taken was reached as part of a selection process?	
	Are the results technically and economically feasible?	
	Effective conclusions / recommendations?	
	Quality of the work or design.	
Presentation Methods	The content was well organized?	
	Appropriate use of graphs, charts, board, audio-video.	
	Was the message clearly delivered?	
	Teamwork was evident in the presentation	
	Overall Score:	

Comments to improve the presentation:

Appendix 2

Course Contents Review and Suggestions

Class: ME 360 Fluid Mechanics, Fall 2001

Instructions: *Dear students, please take some time to tell us your opinion about the time and effort spent in the following topics. If you feel that in this class more time need to be spend on a topic, write a "+" on it. If you feel that in this class less time should be spend on a topic, write a "-" on it. Leave it blank if you feel that in this class the amount of time spent on a topic is adequate. Thanks.*

Topics Covered	**Time Allocation (+, -)**
Introduction to fluid mechanics: Incompressible, compressible, subsonic, transonic, supersonic and hypersonic flows. Introduction of continuum and rarefied fluid.	
Fluid properties: System units, extensive and intensive properties, viscosity and elastivity, surface tension, vapor pressure.	
Fundamental principles governing fluid motion: Control volume and control mass approach.	
Conservation of mass (Continuity equation)	
Viscous stress, pressure measurements.	
Momentum equations, Bernoulli's equation and its application.	
Energy equation, incompressible and compressible.	
Combined One-dimensional applications, equation of state.	
Application to pipe and channel flows for incompressible fluid: Pipe flow, flow pattern, channel flow. Friction coefficient, head loss.	
Drag and lift, wake, laminar flow, turbulent flow concept.	
Compressible fluid flow: Mach number relationships, total and stagnation properties, subsonic, transonic, supersonic, and hypersonic flow concepts and characteristics.	
Turbomachinery applications: Flow through turbomachinery system one-dimensional analysis.	
Flow measurements: Instrumentation system and data analysis.	
Introduction to computational fluid mechanics. Design Project.	

Additional Comments:

Developed by Dr. Z.T. Deng

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