

Scholarship of Teaching and Learning Grant Proposal

Show and Tell Fluid Mechanics: An innovative approach to Fluid Mechanics Instruction

Praveen Ramaprabhu – Assistant Professor, Department of Mechanical Engineering & Engineering Sciences

Russell Keanini –Professor, Department of Mechanical Engineering & Engineering Sciences

November 6, 2013

Show and Tell Fluid Mechanics: An innovative approach to Fluid Mechanics Instruction

P. Ramaprabhu and R. Keanini

Abstract

We propose a novel strategy to incorporate simple in-class demonstrations and experiments in to the undergraduate Fluid Mechanics course offered by the Department of Mechanical Engineering and Engineering Sciences. The live demonstrations will be used to introduce theoretical concepts discussed in the course, and will serve to engage the students in interactive learning, discussions, and experimental design. The tabletop experiments and demonstrations will be simple and inexpensive to assemble, comprised of elements that could be purchased at a local hobby store. This will enable and motivate the students to reproduce the demonstrations on their own, and experiment with variations. The effectiveness of the program will be closely monitored through carefully designed surveys, administered to both the control and treatment sections. The Show and Tell Fluids program will also establish a framework for a series of outreach and fluid mechanics popularization activities that include lectures and demonstrations at local middle- and high- schools, demonstrations at the North Carolina Science Fair Foundation, video demonstrations posted on the PIs' website as well as on YouTube. Data from research in to the program's effectiveness will be disseminated through relevant archival journals and presented at national and international conferences. The proposed teaching innovations will impact nearly 150 students that take the fluid mechanics course every year. However, if similar methods are implemented by other courses in the department, the techniques could result in a broad impact.

Budget Request for SOTL Grant Year _____

Joint Proposal? X Yes No

Title of Project Show and Tell Fluid Mechanics: An innovative approach to Fluid Mechanics Instruction

Duration of Project January 15 2014 – June 15 2015

Primary Investigator(s) Dr. Praveen Ramaprabhu and Dr. Russell Keanini

Email Address(es) pramapra@uncc.edu, rkeanini@uncc.edu

UNC Charlotte SOTL Grants Previously Received (please names of project, PIs, and dates) None

Allocate operating budget to Department of Mechanical Engineering and Engineering Science

Account #	Award	Year One January to June
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	\$ -
911250	Graduate Student Salaries	6720
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	
925000	Travel - Domestic	
926000	Travel - Foreign	
928000	Communication and/or Printing	
930000	Supplies	600
942000	Computing Equipment	
944000	Educational Equipment	
951000	Other Current Services	
GRAND TOTAL		\$ 7320

		Year Two
Account #	Award	July to June
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	\$ -
911250	Graduate Student Salaries	6720
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	
925000	Travel - Domestic	
926000	Travel - Foreign	
928000	Communication and/or Printing	
930000	Supplies	
942000	Computing Equipment	
944000	Educational Equipment	
951000	Other Current Services	
GRAND TOTAL		\$ 6720

Attachments:

1. Attach/provide a narrative that explains how the funds requested will be used.
2. Has funding for the project been requested from other sources? Yes No. If yes, list sources.
 Partial funding has been requested from the National Science Foundation's Early Career Program. This proposal is pending.

Budget Narrative:

Graduate student pay: The graduate student will be paid at the rate of \$ 14/hr (20 hrs/week), which is slightly less than the average rate for M.S. student Research Assistants in the MEES department (see attached letter from department chair). During spring and 1st summer session 2014, the graduate student will assemble the experiments and demonstrations. During the 2nd summer session and fall of 2014, the student will prepare the teaching modules centered on the experiments, prepare surveys, and make video clips of the experiments and demonstrations for posting on different websites.

Supplies: \$ 600 is requested for supplies required for the experiments/demonstrations. The supplies will be purchased from local hobby stores and include items such as beakers, food coloring (for visualization), stop watches, digital camera, etc.



UNC CHARLOTTE

The WILLIAM STATES LEE COLLEGE of ENGINEERING

Office of the Dean

9201 University City Blvd, Charlotte, NC 28223-0001
t/ 704.687.8244 f/ 704.687.8267 www.coe.uncc.edu

November 4, 2013

Dear SOTL Grant Selection Committee:

I am pleased to support the proposal "Show and Tell Fluid Mechanics: An innovative approach to Fluid Mechanics Instruction" submitted by Drs. Ramaprabhu and Keanini. The work will examine the effectiveness of using simple in-class experiments and demonstrations of fluid phenomena to enhance the student learning experience. The experiments will introduce an element of interactive learning where the students can participate in the experiments, suggest variations to try, and can even design their own experiments. I am also excited that these demonstrations can be filmed and disseminated through an online course module for broad outreach. This is very much in line with the recent emphasis at the College of Engineering and the university at large to support online components of traditional courses. The principal investigators will also work closely with Dr. Patricia Tolley to document and evaluate the effectiveness of these teaching approaches.

As a faculty member who has taught fluid mechanics many times, I am pleased to endorse this proposal. Fluid mechanics is a challenging subject for students, and the addition of a hands-on component will significantly enhance student learning by enabling the students to see phenomena firsthand. Please feel free to contact me should you have any further questions.

Sincerely,

A handwritten signature in black ink, appearing to read "Robert E. Johnson".

Robert E. Johnson
Dean



PROJECT NARRATIVE

A. Specific Aims: The purpose of this project is to introduce a novel framework for fluid mechanics education at UNC Charlotte by incorporating simple experiments and demonstrations into a theoretical course. The specific objectives that will be achieved as a result are to (i) introduce active learning methods in fluid mechanics instruction, (ii) help students make integrative connections between theoretical concepts, observable physical phenomena and engineering applications, and (iii) build an outreach program based on these tools to spur recruitment of K-12 students to engineering. We are particularly interested in answering questions related to the effect of such methods on student learning outcomes (set by ABET and MEES department), student retention and new student recruitment. These questions will be answered by administering carefully designed surveys that measure the effectiveness of the methods on students disposed to varied learning styles (visual, kinesthetic, auditory).

Rationale: A key challenge in undergraduate engineering education is to balance introduction of theoretical concepts with exposure to practical applications based on such concepts. Unfortunately, in traditional engineering curricula, there has been a stubborn firewall between theory and practice – students learn theoretical concepts in a classroom setting, while practical experiments are introduced in so-called lab courses. As a result, students have difficulty making a connection between these two distinct aspects of science. Furthermore, students find it difficult to understand the motivation behind a purely theoretical treatment of a scientific concept – why or how is this important to an engineering application? The separation between theory and demonstrations also leads to a passive classroom experience in theoretical engineering courses¹, where students do not have sufficient opportunity to participate. A more recent challenge to this paradigm has been the combination of widely available online courses coupled with rapidly rising tuition costs at universities. As a result, an increasing proportion of students opt for online-only courses, raising new questions on the relevance of conventional classroom instructional methods. In response to these trends and observations, we plan to develop a variation of the introductory

fluid mechanics course offered by MEES that features in-class demonstrations and simple fluids experiments that illustrate (and in some instances motivate) theoretical concepts.

B. Literature Review: In their article, “The future of engineering education”, Shuman et al². identify key demographic trends that they predict will constrain student recruitment to the STEM pipeline. One of their suggestions echoed the recommendations of [3], who predicted a “trend toward practice oriented instruction” in the 21st century. Such a trend was anticipated in [4] who proposed a modified Kolb model incorporating classroom activities. While the model by [4] was suggested for any baccalaureate program, engineering disciplines have been slow to adopt this approach, and have for too long maintained a separation between lab and theory courses. Notable exceptions include a first year introductory engineering course at CMU that incorporated elements of the school’s senior design program to great success⁵. Similar success was reported by the Aeronautics program at UW, who report that⁶ “Classroom demonstrations can be a very effective tool in energizing the student learning process”. Such a re-imagining of classroom time was also proposed by [7] who focused on challenges posed by recent trends such as online courses. In this work, we extend these early trends to propose a novel instructional paradigm for fluid mechanics courses that will include a significant outreach component to address the issue of increasing K-12 student recruitment to engineering⁸.

C. Methods: We will implement an innovative ‘*Show and Tell Fluids*’ program in the undergraduate fluid mechanics course “An Introduction to Fluid Mechanics”, to enhance student learning and participation within the classroom environment. The program is based on and inspired by consistent student feedback the PIs have received over several years of teaching this course. We have found in our experience that students respond favorably to short videos⁹ shown during the lecture that help them visualize key theoretical concepts. The ‘*Show and Tell Fluids*’ program is a natural extension of this concept⁴, and will include simple, inexpensive, tabletop experiments and demonstrations that will be integrated in to the lecture format. We provide three examples of such experiments and how they will be presented in conjunction with theory below:

1. Falling Sphere Viscometer: This simple experiment will be used to introduce the concept of fluid viscosity to students that have not been exposed to such a notion. The instructor will demonstrate the notion of different fluids having distinct values of viscosity by allowing a spherical object of known mass to settle under the influence of its weight in a liquid whose viscosity is to be determined. Using this framework, the instructor will derive (on the blackboard) the equations describing the balance of forces (weight of object, viscous drag forces), from which an expression for viscosity of the fluid will be deduced. The experiment will then be performed to determine the viscosity of the unknown fluid by measuring the settling time of the spherical object using a stopwatch, and using the equation written on the blackboard. The experiment can be repeated with a second “mystery” liquid, to get across the points that (a) different liquids have different viscosities, but (b) the same mathematical equation describes the behavior of all such liquids. The experiment is simple to perform in class, can involve active student participation, and can help establish in the student’s mind the notion of viscosity as a property that defines a fluid in a fundamental way.

2. Archimedes Experiment: The notion of buoyancy of a floating object will be introduced by repeating the famous Archimedes experiment of measuring the density of an object of irregular shape. The experiment will involve the task of determining the density of an unknown material using the principles of buoyancy. This provides the instructor an opportunity to explain the historical context of the experiments, and then to measure the density of an object shaped like King Herod’s crown! At this point, the instructor will derive the equations for buoyancy on the blackboard, from which an expression for the density of an unknown object will be developed. The instructor will then perform the experiment measuring the displaced volume of water, from which the density of the material will be inferred using the equation derived earlier.

3. Surface Tension demonstration: This simple experiment will introduce the concept of surface tension of a liquid as an invisible force that holds the surface of the liquid together under tension. The instructor will carefully place a Lincoln penny on the surface of a layer of water (in a drinking glass), and observe

that the penny floats on the surface (even though copper is nearly ten times as dense!). This observation will be used to launch a discussion of the fluid forces that are “holding up” the weight of the penny, leading to a mathematical derivation of the surface tension forces. For a second act, the instructor will add a drop of detergent to the water resulting in the sinking of the previously floating object. This observation will be used to explain how detergents break down the surface tension of water, a discussion of detergent chemistry that causes this effect, and the cleaning action of the common laundry detergent.

The three examples described above illustrate how an instructor might seamlessly integrate theoretical and experimental components in such an introductory engineering course. One requirement that all experiments must meet is that they be inexpensive to assemble and conduct. *This allows (and motivates) the students to try variations of these experiments on their own, and thus extends the learning process outside the classroom.* The experiments described in (1) – (3) are just three examples, while several similar demonstrations will be planned and designed as part of the course.

While there are a few engineering programs around the country where students are provided the opportunity to visit a fluid mechanics laboratory as part of their undergraduate introductory fluids course, the proposed program would be unique in integrating the experiments/demonstrations completely in to every lecture. *Thus, theory and experiment/demonstrations are presented together, and as distinct parts of the same conceptual reality.* Such experiments and demonstrations allow the students to internalize and retain key concepts, fostering an active learning environment in which the student can make suggestions for variations of the experiments as well as participate in the experiments themselves, thus introducing an *element of theatricality* to the lecture. As part of this program, the students will also be assigned homework (‘what if scenarios’) to develop their own experiments and report on their findings.

D. Evaluation: The PIs will work closely with Dr. Patricia Tolley in evaluating the efficacy of the ‘Show and Tell Fluids’ demonstrations on students’ perceptions and learning. Dr. Tolley’s area of expertise is quantitative educational research. She also provides leadership for measuring student learning outcomes

for the college. Students will be randomly assigned to either a treatment or control section of the course. The treatment section will integrate the fluids demonstrations so that students receive instruction that combines theory and experimentation. Students in the control section will receive conventional lecture instruction. Over the course of two semesters, PIs Ramaprabhu and Keanini will alternate in teaching the treatment and control sections. Attitudes and perceptions will be measured by pre- and post-surveys conducted at the beginning and end of semester. Differences in student learning outcomes will be evaluated based on performance on a common final exam administered to both sections. The surveys administered at the conclusion of the course will be designed to measure differences in student learning outcomes within each section based on visual, auditory or kinesthetic learning styles¹⁰.

Outreach: The PI will organize ‘Show and Tell Fluids’ lectures and demonstrations at local middle and high schools and science fairs in the Charlotte Mecklenburg school district. School visits will include informal lectures and experimental demonstrations by the PI. The PI will also work with the organizers of the annual Regional Science and Engineering Fair (see attached letter from Dr. Alisa Wickliff) held at UNC Charlotte to arrange for a display of the table-top experiments. The regional science fair is organized by the Department for STEM education at UNC Charlotte, for the North Carolina Science Fair Foundation (NCSFF) with the mission “to promote science and engineering research by elementary, middle, and high school students and partner with teachers to integrate scientific research in the classroom”¹¹. PI Ramaprabhu has been actively involved in this program, serving as a judge as well as reviewing research articles written by students. The Center for STEM education also organizes the NC Math, Science Educational Network (NC-MSEN) program at UNC Charlotte for middle- and high-school students, including the “Saturday Academy Days” events during which “students engage hands-on activities in math, science, communications and career awareness”¹². PI Ramaprabhu and the student hired on this project will partner with the NC-MSEN program to arrange for the “Show and Tell Fluids” demonstrations at these events. Finally, videos of the demonstrations with explanation in lay language will be made available through the PI’s research webpage, as well as a dedicated YouTube channel and

Facebook site. The purpose of the clips will be to foster a broader understanding of fluid phenomena among the general public, and to motivate a wider section of K-12 students to consider an education and career in engineering.

E. Dissemination: The novel instructional methods developed as part of this project, and the research findings on their effectiveness will be disseminated through lectures, talks at conferences, and journal publications. In addition to the “Show and Tell Fluids” lectures at local high schools described above, PI Ramaprabhu will participate in events such as UNC Charlotte’s teaching week and volunteer to deliver lectures at CTL events around the campus (including workshops on Motivating Active Engagement in Class, Collaborative Learning, Teaching with technology showcase). The quantitative results from the evaluations of student learning and outcomes associated with the above instructional techniques will be reported in the archival literature through journals such as the American Society for Engineering Education’s (ASEE) publications including the Journal of Engineering Education (JEE), and Advances in Engineering Education (AEE). The results will also be presented in the Education and Career Outreach: Teaching Methods session of the American Physical Society’s annual Division of Fluid Dynamics conference. Over the last six years, PI Ramaprabhu and his students have attended this conference every year. Since the PI’s travel to this conference will be supported by existing research funds, separate travel funds to this conference are not requested here. The PIs will also share their experiences, and results from the evaluations during the monthly meetings of the Focus Area Improvement Teams (FAIT) within the MEES department. These groups are constituted of faculty members teaching thematically related courses within Mechanical Engineering (e.g. Fluid Mechanics, Heat Transfer and Thermodynamics). The meetings serve as opportunities for faculty members teaching similar courses to compare notes, discuss common issues, and frame changes to syllabi, and will thus provide an ideal platform to describe the experiences of the “Show and Tell Fluids” program.

F. Human Subjects: We will apply for exemption certification from IRB under the federal category (and consistent UNC Charlotte interpretation), “Research conducted in established or commonly accepted

educational settings, involving normal education practices”. It is our intention to have this approval/exemption in place before the awarding of this project.

G: Extramural Funding: The results from this project will be used as a pilot initiative for funding proposals to organizations such as the National Science Foundation (NSF) or the Department of Education (DOE). In particular, the investigators will target the NSF’s “*Transforming undergraduate education in Science, Technology, Engineering and Mathematics*” funding opportunity, while applications to the DOE will be directed to the “*Fund for the improvement of post-secondary education-comprehensive program*” solicitation. In addition, PI Ramaprabhu has submitted an early CAREER proposal to NSF, in which a significant component of the educational program was the “Show and Tell Fluids” initiative described here. Thus, funding from the SOTL program will be pivotal in developing the requisite “preliminary results” for inclusion in the above proposals to increase their competitiveness.

H. Timeline:

Year 1 (January – June 2014): During Spring 2014 and the first summer session, the PIs will work closely with the research assistant to design and assemble the experiments and demonstrations. During this period, short video clips of some of the experiments will also be prepared and posted on the websites.

Year 2 (July – June 2015): During the 2nd summer session and Fall 2014, the PIs will work with the student to prepare separate teaching modules centered around each experiment and demonstration. The modules will provide guidance to the instructor on how to motivate and perform the experiments, and to introduce the accompanying theoretical concepts. The PIs will also collaborate with Dr. Patricia Tolley to design the pre- and post-surveys, and the testing methods.

The experiments will be incorporated in the fluids courses offered by the PIs during the Spring 2015 semester. During that semester, Dr. Ramaprabhu will teach the treatment section, while Dr. Keanini will teach the control section. These roles will be reversed in future course offerings.

References:

1. Felder, R.M., and Silverman, L.K., "Learning and teaching styles in engineering education", *Engr. Education*, **78(7)**, 674 (1988).
2. Shuman, L.J. et al., "The future of engineering education", 32nd ASEE/IEEE Frontiers in Education Conference, November 6-9, 2002, Boston, MA.
3. "A vision for the future of U.S. engineers", Task Force report of the American Engineering Society (2000).
4. M. D. Svinicki and N. M. Dixon, "The Kolb model modified for classroom activities", *College Teaching*, 35(4), 141, (1987).
5. Ambrose, S.A. and Amon, C.H., "Systematic design of a first-year mechanical engineering course at Carnegie Mellon University", *J. Engr. Education*, **86(2)**, 173 (1997).
6. Campbell, M., "Oh Now I get it!", *J. Engr. Education*, **88(4)**, 381 (1999).
7. Wallace, D.R. and Weiner, S.T., "How might classroom time be used given www-based lectures?", *J. Engr. Education*, **87(3)**, 237 (1998).
8. Seymour, E., "Tracking the Processes of Change in US Undergraduate Education in Science, Mathematics, Engineering, and Technology", *Science Education*, **85(6)**, 79 (2002).
9. D. Schweitzer and W. Brown, "Interactive visualization for the active learning classroom", SIGCSE'07, Mar 7-10, Covington, Kentucky, (2007).
10. A.F. Cabrera, C.L. Colbeck, and P.T. Terenzini, "Developing performance indicators for assessing classroom teaching practices and student learning: The case of engineering", *Research in Higher Education*, 42(3), 327 (2001).
11. <http://www.ncsciencefair.org/index.php/about-ncsef/nc-science-fair-foundation>
12. <https://education.uncc.edu/cstem/6-12-stem-student-programs/nc-msen-pre-college-program>

November 6, 2013

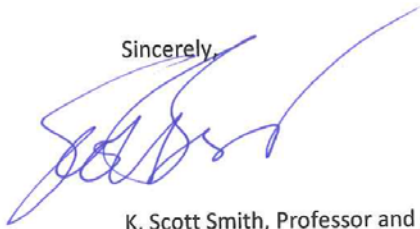
To Whom It May Concern:

This letter is to certify that the salary rate for graduate research assistant of \$ 14/hr quoted in the attached proposal, falls within the range of graduate student compensation paid by the Department of Mechanical Engineering and Engineering Sciences.

The average salary for MS students at the department is \$ 1200/month, while the corresponding average rate for Doctoral students is \$ 1700/month.

Should you have further questions, please feel free to contact me.

Sincerely,



K. Scott Smith, Professor and Chair



UNC CHARLOTTE

College of Education

Center for Mathematics, Science, and Technology Education

College of Education Bldg., Suite 222

9201 University City Blvd., Charlotte, NC 28223-0001

Center: (704) 687-8816 <http://education.uncc.edu/cmste> Email: cmsteuncc@uncc.edu

July 19, 2013

Dear Dr. Ramaprabhu:

We are very excited to have you present table-top demonstrations to our K-12 STEM teachers and students in the greater Charlotte region. Specifically, we welcome the demonstrations during our Annual Science & Engineering Fair, always held in February. We are very interested in promoting all areas of science and fluid mechanics will excite and interest our students and teachers. Please plan to present each year you are available. Additionally, demonstrations during the annual NC Junior Science & Humanities Symposium will be of great interest to the participants. The NC JSHS is an annual event and is a high school STEM research competition for students from across the state. There are close to 100 students that compete each year. The JSHS competition is funded by the office of Army, Navy and Air Force Research.

The Center for STEM Education provides professional development for K-12 teachers in a 10-county area surrounding the greater Charlotte region and hosts a number of K-12 science and math research competitions as well as student science and math programs. The Center for STEM Education runs the NC-MSEN Pre-College Program for approximately 300 middle and high school students. We would like to invite you to set up your table demonstrations during a NC-MSEN Pre-College Saturday Academy(s) (12 total during the academic year).

Again, we greatly appreciate your willingness to work with us in our K-12 teacher and student educational outreach activities.

Sincerely,

Alisa B. Wickliff

Assistant Director

Center for STEM Education

UNC Charlotte



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