Initial Experiences in the Development of Classroom Demonstration Devices for Hydraulics and Fluid Mechanics Courses in Engineering and Engineering Technology

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Abstract

A cross disciplinary project to develop and evaluate a repertoire of educational materials to address different learning styles of undergraduate engineering and engineering technology students is currently ongoing at New Mexico State University (NMSU)[1]. One of the three types of tools under development consists of easily portable physical devices for demonstrations in the classroom. These devices are to be integrated into junior- and senior-level courses in Civil Engineering, Mechanical Engineering, and Engineering Technology. Their primary function is to help students in introductory courses grasp the engineering concepts and fundamental principles associated with the behavior of stationary and moving fluids. They also offer an ancillary function as aids for on- and off-campus recruitment presentations to prospective students.

The classroom demonstration devices are being designed and fabricated by a cross-disciplinary team of students in Civil Engineering, Engineering Technology, Electrical Engineering, and Industrial Engineering, in collaboration with faculty members in Civil Engineering, Engineering Technology, and Mechanical Engineering.

Presented here are a project overview and the initial experiences gained by the project team in the realization and preliminary testing of approximately one-half of the foreseen total of sixteen devices.

Introduction and Project Overview

The goals of the ongoing project fall into two main categories, development and evaluation. To be developed are educational tools consisting of on-line tutorials and exams [2], numerical simulations of fluid dynamic phenomena, and classroom demonstration devices. It is anticipated that these tools will optimize teaching efforts and improve student achievement by stimulating critical thinking, cultivating problem-solving skills, and enhancing the learning experience through increased student-faculty and student-student interactions.

The evaluation phase will involve assessing the effectiveness of the new materials by staff of the New Mexico Space Grant Consortium associated with the GRASP (**G**aining **R**etention and **A**chievement for **S**tudents **P**rogram). Assessment will take place first at NMSU within three academic departments in the College of Engineering and subsequently at collaborating institutions where faculty members have agreed to implement and evaluate the materials developed.

Demonstration Devices: Initial Experiences in Their Development and Use

The portable physical devices for demonstrations in the classroom are to be integrated into junior- and senior-level courses in Civil Engineering, Mechanical Engineering, and Engineering Technology. Their primary function is to help students in these introductory courses grasp the fundamental engineering principles and physical concepts associated with the behavior of stationary and moving fluids. They also offer an ancillary function as aids for on- and off-campus recruitment presentations to prospective students.

The classroom demonstration devices are being designed and fabricated by a cross-disciplinary team of undergraduates majoring in Civil Engineering, Engineering Technology, and Electrical Engineering, in collaboration with faculty members in Civil Engineering, Engineering Technology, and Mechanical Engineering. An Engineering Technology graduate, currently a graduate student in Industrial Engineering, is documenting the designs and coordinating the development of instructor's support notes for each device. Development of computer simulations for some of the devices is also in progress.

Sets of criteria were developed both for the selection and for the design of the demonstra-tion devices. Selection of a device as suitable for realization was based upon its potential to effectively illustrate at least one important engineering concept or fundamental engineering principle. With few exceptions, however, it has been more the need to demonstrate engineering concepts that has driven the device selection process: for the devices fabricated so far (see Table I), as well as for those yet to be realized (see Table II). Of particular interest during the selection process were the concepts and principles that explain frequently encountered counterintuitive phenomena associated with the behavior of fluids.

A search of the World Wide Web for existing educational demonstration devices in the area of Fluid Mechanics showed that almost all have been developed from the perspective of physicists for Physics lectures and usefully categorized by the Physics Instructional Resource Association (PIRA) [3-5]. It is, therefore, not surprising that four of the devices in Table I represent classical types in the field of Physics, though, their associated lecture support notes are being developed from the engineering and technology perspectives (see Ref. 6-11).

Animations and video clips furnished with more recent Fluid Mechanics textbooks [6,7] provided additional ideas for prospective devices, as did textbooks themselves [6-11]. Apparatus typically found in undergraduate Hydraulics and Fluid Mechanics laboratories also furnished a basis for the discussion of ideas during device selection. The classical educational video films in the Fluid Mechanics area, produced during the 1960's - 1980's [12], were also kept in mind, such that devices selected would augment rather than duplicate the concepts and demonstration methods presented in them.

Table I: Summary of completed demonstration devices and relevant principles, concepts, and phenomena.

Demonstration Device	Fundamental Principle(s)	Physical or Engineering Concepts	Phenomena	Practical Applications
water retaining dam	static equilibrium of a body	resultant forces on submerged planar surfaces, dam failure modes	tipping and sliding motions of dams	design of dams
sphere falling in a liquid within a long cylinder (A), (2 fluids)	static equilibrium of a body	viscosity, large variation in viscosity between liquids, terminal velocity, drag force, buoyancy force, *Reynolds* No., data reduction equation, creeping flow	sphere falls faster in liquid of lower viscosity	measurement of viscosity
sphere falling in a liquid within a long cylinder (B), (1 fluid, 2 temp's.)	static equilibrium of a body	viscosity, large influence of temperature on the viscosity of a liquid, terminal velocity, drag force, buoyancy force, *Reynolds* No., data reduction equation, creeping flow	sphere falls faster in liquid at higher temperature	explanation of need for multi-viscosity engine oils
water jets falling in air from different elevations (3 ea.)	conservation of mass, conservation of energy	horizontal distance traveled by jet varies with *both* head *and* elevation of discharge above impact plane, *Torrecelli*'s theorem	jet with highest driving pressure does not traverse greatest horizontal distance	design of sprinkler and spray systems
tanks with a falling head (2 ea.)	conservation of mass, conservation of energy	orifice, flow through an orifice, *vena contracta*, discharge coefficient, *Torrecelli*'s theorem	influence of geometry of orifice inlet on flow through orifice	design of tank drainage systems
manometers of various designs (4 ea.)	pressure height relation for a static fluid	manometer sensitivity	variation of liquid column heights with density and manometer leg geometry	design of manometers, measurement of pressure

water-filled contain-ment vessels of different profiles, (3 ea.)	pressure height relation for a static fluid	*Pascal*'s paradox	pressure in a fluid varies with fluid height only: it is independent of fluid volume or container geometry	constant head tank and water tower design and placement
rotating wires, that shed vortices in air (2 ea.)	vortex frequency propor-tional to relative velocity between body and fluid	vortex street, variation of *Strouhal* No. with *Reynolds* No., resonant frequency	vortex shedding at frequency proportional to relative velocity	flow measurement, wind noise abatement

Table II: Summary of some prospective demonstration devices currently under consideration for realization.

Demonstration Device	Fundamental Principle(s)	Physical or Engineering Concepts	Phenomena	Practical Applications
airflow through venturi with multi-tube reservoir type water manometer	conservation of mass, conservation of energy	*Bernoulli* equation	decrease in pressure with decrease in cross-sectional area of flow	flowmeters, liquid sprayers, carburetors
open channel flow through a sluice gate	conservation of mass, conservation of energy	hydraulic jump, specific energy, alter-nate depths, sequent depth, *Froude* No., turbulence, channel erosion	formation of hydraulic jump between super- and sub-critical flow	design of open channels downstream of dams and sluice gates
systems of vertical capillary tubes of various diameters, reservoirs (2 ea)	*Young-Laplace* equation	capillary pressure, surface tension coefficient, contact angle	variations of the column height of a liquid with the diameter of the enclosing vertical tube	minimizing shrinkage cracking of concrete, soil remediation, tertiary crude oil recovery
variable area manifold	conservation of energy	axial pressure distribution in a manifold	decrease in cross section of manifold can be used to maintain constant static pressure along manifold axis	flow conditioning in windtunnels and water channels
TBD†		non*newtonian* fluid behavior	nonlinear relationship between shear stress and strain rate	processes in food, paint, and consumer products industries

TBD	conservation of mass and of momentum	linear momentum, forces of moving fluids on solid surfaces	dynamic loads acting on pipes due to fluid flow	c s
TBD	*Archimedes* principle	buoyancy, center of buoyancy, fluid displaced	weight of body is less in air and water than in a vacuum	c v
TBD	*Bernoulli* equation	aerodynamic lift and drag	vertical and horizontal forces on bodies in fluid streams	c v a

† TBD: to be determined.

During the design phase, some of the important device performance characteristics were considered to be cost-effectiveness, simplicity, aesthetics, reliability, and repeatability. The most limiting performance characteristics were device portability - for transport to the class-room by one person - and device visibility from a distance of up to 6 m: two mutually opposing constraints. The visibility requirement led to the extensive use of plexiglass and brought bright colors, backdrops, and color coordination into consideration to improve contrast.

The initial intent was to avoid having to rely on external power sources. However, it soon became evident that this was too stringent of a constraint and it was relaxed in order to realistically accomplish project goals. One-half of the devices already built, thus require an external 115- VAC power source.

Preliminary, informal evaluations of the effectiveness and appeal of several demonstration devices in the classroom have been for the most part encouraging, while in some instances somewhat sobering. Lessons learned, included the importance of reliability and repeatability, as well as the desirability of action and movement, to help capture the interest and imagination of students seeing the devices for the first time. For the devices of inherently stationary nature, the use of suspense and rhetoric may be essential to exploit the devices' full educational potential.

An unanticipated result of the project to date has been the very positive experiences reported by the student team members with regard to the cross-disciplinary nature and the team dynamics of their working environment. Moreover, they have also expressed enthusiastic appreciation for the skills and knowledge gained during their time spent on the project.

One of these has been in the area of oral presentations. They have had the opportunity to present ongoing project results at several regional events via oral and poster presentations as well as device demonstrations. These have included the:

- AMP/WERC Undergraduate Student Research Conference (NMSU), Fall 2001
- Student Seminar of the NASA Space Grant Consortium (NMSU), Fall 2001
- AMP Undergraduate Research Assistants' Presentation Seminar, Fall 2001 Semester
- Tri-City, Tri-State, Bi-National Water Festival held in Las Cruces, 2001
- NMSU College of Engineering Open House, Fall 2001 Semester .

Summary of Results and Conclusions

Based upon a review of current classroom demonstration devices, essentially one-half of the planned total of fifteen devices has been chosen and fabricated. Most of these have been subjected to preliminary evaluation by the design team, in both classroom and prospective-student recruiting environments. The feedback gained will continue to be used to refine the functional effectiveness of the devices. Those judged ready will be incorporated, together with their lecture support notes, into at least two courses during the Spring 2002 semester for formal evaluation. Efforts will continue in the selection, fabrication, and preliminary evaluation of the remaining demonstration devices along with their accompanying lecture notes and simulations.

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References

1. Educational Materials Development Project Website: http://cagesun.nmsu.edu/~nkhandan/nsfproject.html

2. N. N. Khandan, 2002, *Developing Computer-Based Tutoring & Testing Materials for use by Undergraduate Engineering Students to Practice Problem-Solving Skills*, 4th Annual Science, Engineering, Technology, and Education Conference, New Mexico State University, Las Cruces, NM.

3. http://www.pira.nu/, PIRA (Physics Instructional Resource Association)

4. http://www.wfu.edu/physics/pira/pira200/pira200.htm

5. http://www.physics.ncsu.edu:8380/pira/, demonstration bibliography

6. White, F.M., 1999, *Fluid Mechanics*, 4th Ed., McGraw-Hill Publishing Co., New York.

7. Munson, B. R., D. F. Young, and T. H. Okiishi, 1999, *Fundamentals of Fluid Mechanics*, 3rd Edition Update, John Wiley & Sons Inc., New York.

8. Hwang, N. M. C., 1981, *Fundamentals of Hydraulic Engineering*, Prentice Hall, Inc., Englewood Cliffs, New Jersey.

9. Mott R. L., 2000, *Applied Fluid Mechanics*,
5th Ed., Prentice Hall, Inc., Upper Saddle River, New Jersey.

10. Daugherty, R. L. and J. B. Franzini, 1977, *Fluid Mechanics and Engineering Applications*,
McGraw-Hill Publishing Co., New York.

11. Granet, I., 1971, *Fluid Mechanics for Engineering Technology*,
Prentice Hall, Inc., Englewood Cliffs, New Jersey.

12. http://www.insight-media.com/IMHome.htm.