Life with Experiments

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As a mechanical engineer specializing in fluid and thermal sciences, circumstances eased me into experiments for my doctoral research. Ever since, I have invested more than a fair share of my time setting up apparatus, developing instruments, generating data and analyzing results. It has been a remarkable journey with a promise of unending excitement.

Working in an academic environment, I have had a chance to set up experiments essentially from scratch. I could pick the geometry of my choice, the probes to use and appropriate measurement systems. I could debate on the use of mechanical gauges such as inclined tube manometers versus digital, single channel versus multi-channel, multiplexing, and instantaneous versus time-averaged records. I found myself developing a broad perspective on how specific decisions could be arrived at, in the process, getting grounded in the engineering profession itself.

When I saw myself building a laboratory, it occurred to me that I was following the historical evolution of the subject itself, though on a compressed timescale. I could do simple experiments on formation of a boundary-layer over a flat plate and flow-induced oscillations. I could reproduce Moody's diagram. I saw alternate vortex shedding from a circular cylinder and, indeed, could perform Reynolds' laminar-turbulent transition experiment using dyes. Practically all kinds of flows could be visualized using kerosene smoke. I realized that my understanding of the subject had greatly matured. I utilized this opportunity to setup undergraduate experiments that would accompany the main course on fluid mechanics.

Modern era is replete with examples where technology has been decisive in the way we live and work. Doctors give examples of medicine and surgery conquering disease. In experiments, several such developments have fundamentally altered the way data is collected - regarding questions we may ask and devices we can build.

I will narrate three examples here. First, the ability of computers to position and traverse probes, collect data, start and stop experiments, coordinate measurement systems and analyze numbers has taken the subjective element out of research. What started as a replacement of drudgery has led to creative experiments being performed, and very profound issues addressed. Data analysis and graphics capability of a computer now makes it an oscilloscope, spectrum analyzer, voltmeter, temperature recorder, correlator and many more rolled into one. Smaller and faster computers are now being embedded inside other instruments such as microscopes. Of course, computers are getting integrated with the human body and the consequence of this development is no doubt, curiosity, nonetheless, alarm.

The second is the invention of lasers that can now “see” everything as images that in turn are recorded by cameras and sent to large computers. Lasers now measure anything from particle velocity, to temperature, species concentration, and flames spreading in furnaces and engines. They do it in three dimensional space and in real time. I find that the appreciation of what lasers can do is poor among the engineering community. I wish the issue is addressed.

Distinct from computers but connected to it is the virtual world of internet and experiments that can be thus conducted. Internet brings in the possibility of collaboration among individuals and Institutes that are physically separated. Doing experiments in a laboratory elsewhere by sending commands over internet is the simplest (but very useful) possibility. Of real value is when expertise from multiple sources are pooled together to conduct a joint experiment. Called synergy in the management context, cooperation has been a weak link in research, limiting us in many ways from hitting breakthroughs more often. This development awaits exploitation on a grand scale but has a transformative power of a paradigm shift.

Working in a laboratory environment forced me to ponder on the nature of research that engineers need to carry out. I had been struggling all along with the central purpose of my experiments, beyond niceties such as better understanding of the phenomena and significance of higher order effects. The obvious struck me later that the purpose was to examine cause-effect relationships in the framework of forces, fluxes, potentials, and energy. The goal was not to see things as they were. The purpose was to check what made a system work. This awareness led to several questions, for one, could pre-defined flow patterns be created? When I discussed the subject with my colleagues, I was told that creating new reality was a design perspective. Since then I have come to view the goal of analysis, experiments, characterization and indeed all of research as steps that yield a new process, or a device, or a system possessing certain desirable properties.

With computers, lasers and cameras at our service, experimentalists now experience a new problem of plenty. Data is time-dependent and three dimensional. Special devices now store the measurement records. Since the goal continues to be improving new processes or building new ones, the experimentalist is required to mine mountains of data to extract information of value. Fortunately, the subject of data analysis with large but ‘gappy’ information is gaining ground and we can identify patterns (or the lack of them) through numbers that exist purely in the virtual world. The mathematics needed for such studies is very sophisticated. Experimentalists had better not leave their analytical skills behind.

Historically, experiments have been way ahead of theory in driving human progress. Much of present day knowledge stems from controlled experiments, and in turn,reconciled with a newer theory or principle. The situation has turned topsy-turvy, ever since computers and numerical simulation have emerged on the scene. Computational experts now claim that their simulator can replace experiments. This claim is heavily discussed, but within the domain of fluid and thermal sciences, experts see it differently. There are strengths in each approach and the greatest gain is to be seen when the two work in tandem. A mathematical model getting triggers from an experiment running in parallel can simulate extremely complex phenomena. Conversely, an experiment may run with boundary conditions or geometry determined from a model running alongside.

My association with real functioning devices has had an unexpected benefit. I have been able to conceive of simple but new gadgets and configure new measurement systems that I feel are of use. The acquired wisdom is a pay-off that all experimentalists deserve.

There can be no two opinions that theory, experiment, and simulation constitute the three pillars of the modern thought process. What could be debatable is the perception that experiments carry the greatest load of them all.

The term *experiment* is very broad, context-specific and takes on unique meaning to each group of professionals. Science experiments are highly focused with the primary aim to prove or disprove a theory. Engineers pursue a much broader goal, such as performance enhancement of a device. It may entail application of a collection of techniques and methodology to accomplish the overall purpose. Biologists record, characterize and analyze species populations as a part of their experiments. Sociologists work with human populations and statistics to improve understanding of human behavior. There are great differences, division and points of departure, depending on the subject matter. Yet, the importance of experiments is a common refrain, universally emphasized across disciplines;I am glad to be living in this world.

If experimentalists from various disciplines were to function together, they better develop a common language. Thematically they may discuss interplay of experiments and theory, measurement on multiple length scales, and measurement on multiple timescales. Abstract communication will enhance cross-talk and lead to fruitful inter-disciplinary research.

I think my interest in experiments has rubbed off on students who have worked with me. Many who have graduated think experiments are important, can be done, and worth their time and effort.