Research Integration Into Undergraduate Classrooms.

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Abstract

Some engineering and technology faculty members have expressed many times an idea that most of the limited time existing for formal undergraduate engineering education is used to solve problems in a creative and unique way. In the same way, same would maintain that in this process where exists a surplus of emphasis on solving only simple, limited, unreal and classic textbook problems. In an attempt to increase student interest and ability in creative hands-on problem solving skills, an application of research and teaching program by inquiry in the undergraduate level classes is introduced. In this program, an open-ended project vehicle is used in which problems to be solved are intended to be realistic and complex, state-of-the-art and challenging, to generate and intensify the enthusiasm of the students and to more substantially prepare them for the “outside” world.

This paper addresses the issue of how research and creative approach to problem solving can be effectively integrated into different level classrooms from introductory classes to senior classes, where the students need to understand their participation in the discovery process where they are required to be active participants, not only passive receivers. In such process, faculty members and students are both learners and investigators, whose communications support a more effective learning process and generates many benefits for both sides. Further, in this paper, many examples of such open-ended projects and results will be given and addressed.

Introduction

One of the key issues, which significantly determines our tools and approach to any problem, is the determination of a process character, if it has a random or deterministic nature, or more realistic, the determination of the composition grade of both components and their significance in the phenomenon composition. Probably the following citation of Heinz Pagel, gives us an important clarification “The randomness at the foundation of the material world does not mean that knowledge is impossible or that physics has failed. To the contrary, the discovery of the indeterminate universe is a triumph of modern physics and opens a new vision of nature.” In this matter one may argue successfully about a factual basis of a hypothesis that such general classification of processes for random or deterministic or predictable or unpredictable are rather
a matter of perception, level of analytical depth, adequacy of the model applied, accuracy and completeness of observations used, the level of involved errors and verification process and/or other subjective correlation between dependant and independent variables or a combination of all the above mentioned components, rather than the character of the process itself. In other words, a purely random process, classified as a blackbox phenomenon from ones perception, could be fully deterministic from the perception of another person who may already know a deterministic model and is fully predictable, based on the known correlations. In addition to this controversy, this fact requires development of a list of challenging problems that need to be solved. In this sense a challenging problem is defined as a problem that is not yet solved satisfactorily and results could not be predicted with required accuracy (e.g. not ready-off-shelf instrument/system/solution is available and a solution is not known not only to the students but also to the professor).

One example of such problem is a process of flow pattern recognition in two-phase flow, which nowadays is consider widely as a random (unpredictable) process and it’s continuously challenging the academic community since the 1940s. This problem is generating a group of very challenging subjects for open-ended projects for both graduate and undergraduate classes. The other example is the problem of wear in a tribo system, which is not described by any theoretical model. The applied models and predictions are drawn based on phenomenological models or results using a pin-on-disc test. In this case, like in any experimental approach, the importance of use of such parameters like uncertainty, error analysis, data verification and identification can ever be overestimated.

Also, due to the broad agreement in the academic community that the learning process is recognized as a lifelong perpetual procedure where subjects and tools are changing constantly, it is important to expose students to all possible scenarios in approaching a deterministic or random process and probably more in general a process with superposition of both deterministic and random components. Also, it is necessary to teach the student how to approach such unknown problems and learn how to study such cases, including the interpretation and validation of the obtained results and models.

Teaching by Inquires

In an attempt to increase student interest and ability in creative hands-on problem solving skills, an application of research and teaching by inquiry approach is introduced in the undergraduate level classes. In these classes, an open-ended project vehicle is used in which problems to be solved are intended to be realistic and complex, state-of-the-art and challenging, to generate and intensify the enthusiasm of the students and to more substantially prepare them for the “outside” world. It is crucial that the students need to understand their participation in the discovery process where they need to be active participants, not only passive receivers. In such process, faculty members and students are both learners and investigators, whose communications support a more effective learning process and generates many benefits for both.

One of the preliminary requirements for successful implementation is to make a good choice in references used to utilize such resources as: patents, refereed papers and reports, electronic
databases via library or the Internet. In the selection of resources for educational purposes the composition of two contradictive requirements are the key issues, which are objectivity and adequacy from one site and state-of-the-art information from the other site. Facts of limited knowledge on the subject (learning process) and a relatively easy access to scientific or pseudoscientific information on the Internet are especially generating an inevitable need for intense involvement of process knowledgeable faculty in the teaching. This includes defining rigorous criteria for evaluation of quality resources before use in a learning and application process. Due to the fact of easy availability and use of a broad spectrum of materials on the net, the other important issue is plagiarism. Regardless of the efficiency, the limitation of instructor time and resources determines the solution, which is firstly to define plagiarism well and secondly underline the ethical and judicial repercussions of it, this may guide students to a self-policing process.

The next step is to determine the subject and scope of an open-ended project, which allows accomplishing the following goals:

1. Introduction to creative thinking by finding a solution to solve challenging problems requires a creative approach in full cycle from finding creative alternate solutions, via design and creation of first prototype, feasibility study, to the prototype evaluation and its redesign, and finally a report writing and presentation process (life-long-learning process, not only learn a material but application, to solve a problem in a creative way).
2. Introduction and application of errors, uncertainty and error analysis including an error reduction process.
3. Use of computer-aided experimentation and research process (Matlab, CADAS, the Internet, LabVIEW, spreadsheets, graphics software, and other electronic data basis)
4. Prediction of the results from theory and application of phenomenological approach with a physical experimentation to verify the applied theory and assumptions.
5. Application of data analysis and verifications (bias and precision errors, literature, concomitancy and redundancy).
6. Background search for the closest solutions (the Web, refereed journals, patents, library), which partially or fully will be implemented in the process.
7. Computer-aided communication and dissemination of results (publication, reports, class and conference presentations)

A challenging problem, in this meaning, is defined as a problem which is not solved satisfactorily on the industrial level in mechanical engineering (e.g. not ready-off-shelf instrument/system/solution available not only on the student level but also for the professor) which needs are identified and a problem/solution is in the research phase using a phenomenological approach, which requires utilizing the literature search, computer applications in most phases of the problem solving process, application of a combination of random and deterministic process approach, full-cycle solution from a unique idea, throughout design and prototype development, to feasibility study/proof of the concept and with final report, presentation, and prototype improvement. It is important in this process of learning by inquiry to find an excellent, nonbiased source of information, which are refereed journal papers.
The open-ended project approach with a full-cycle solution from unique idea, through design and prototype development, to feasibility study/proof of the concept and with final report presentation, and finally the prototype improvement directions, is the solution for incorporation of a professor’s research into the teaching process for the student’s benefit, which was the vehicle used to fulfill these requirements. In this process of learning by inquiry it is very important to find an excellent, nonbiased source of information, to do what is required to develop a pattern for using refereed journal papers and patents in the class.

In the list of challenging problems suited well for teaching by inquiry from which subjects for open-ended projects may be generated, includes the following topics:

**Spatial and Temporal Distribution of Concentration**

**Flow Pattern Recognition**

**On-line Viscometer**

**Flowrate Measurement Systems for Two-Phase Flow**

**Wear in Machinery**

**MEMS**

The open-ended project process is started by introducing students, in the shortest possible way with hands-on experience, to the following subjects:

1. How to find quality resources on the net and in the library? (including patents, refereed journals and reports).
2. How to approach, design and build a unique system in full cycle?
3. Experiments and experimentations, including data collection and analysis, data validation using concomitant measurements and redundancy, error and uncertainty analysis and reduction, data analysis and presentation.
5. Demonstration of a complex open-ended project including experiment, report, paper and presentation.
6. Students are conducting a complex experiment with all of those elements including background search and presentation of results.
7. Report writing and presentation process. Evaluation criteria, which is included in the appendix.

In the next step, a request for proposal from students is issued and collected. An example is included in the appendix. After teams and proposals are accepted, teams consisting of one to three students begin to work on the topic, doing a background literature search and analyses. Based on the search and analysis, teams design a first prototype with a feasibility study program, and definition and measure the final product success. This is the subject of the first part of each team’s report submission. If the report is accepted, it is graded and returned to students with
feedback. If a report is not accepted it is also returned to students with listed deficiencies to be addressed. The final step is to build a first prototype, conduct feasibility study, analyze data, write a final report, and make a presentation. The following results were generated in two open-ended projects in which the first is related to flow pattern recognition in two-phase flow and the second to determine the material composition based on abrasive wear criterion.

Flow Pattern Recognition in Two-Phase Flow

In a two-phase flow, the flow depends on various dynamic parameters. It shows different patterns for every imperceptible change. If a flow is passed through vertical round tube, a bubbly flow regime is found at low gas fraction and as the gas fraction increases, the flow coalesces into slug, churn and so on till the annular flow appears. All these different observations of mixture components in the time and space constitute the flow patterns.

The flow patterns of two-phase flow when observed by many researchers employing different methods came up with different results for the same type of flow. The reason for the different flow patterns is methods of flow pattern detections. The results obtained by use of various methods, undefined calibration procedures and the validation process make it extremely difficult to analyze and compare those results.

The experimental apparatus consisted of a vertical transparent column that is 35 mm in diameter, with a cluster of four flow pattern measurement systems [Fig. 1]. The apparatus supported closed-loop water, and open-loop air flows. A mixing chamber positioned at the bottom of the vertical channel allowed a mixture flow to enter the column. The sensors from each of the four measurement systems were positioned in a cluster, approximately 0.5 m from the mixing chamber.

In the report, only one run of the three major regimes is presented for each of the nominal values of spatial concentration. In order to assess the abilities of each system, optical, pressure, resistive, and capacitive, eight different flow patterns were arbitrarily chosen for comparison. The arbitrary distinction between these eight flow patterns was based on visual observation of differences. At each of the eight flow conditions, signals from the four different systems arranged in the cluster were collected simultaneously and over the same time duration.
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a closed-loop mode. A schematic representation of the experimental system used in this study is shown in figure 1.

![Flow Pattern 1](image1)

![Flow Pattern 4](image2)

![Flow Pattern 8](image3)

Figure 2. Concentration Signals for Capacitive Method; Time Domain (A: top row), Amplitude Domain (B: middle row), and Frequency Domain (C:bottom row).

The data collected at flow numbers 1, 4, and 8 is shown in figures 2. For each of the figures, show the time traces in row A for each of the measurements and three of eight flow patterns are chosen. Flow 1 was bubble flow, 4 was slug flow, and 8 was churn flow. However, the name of the pattern is chosen on visual observation of the naked eye and only to be used as a rough approximation. In row B, the data collected from each system at flows 1, 4, and 8 are shown in the amplitude domain as a function of the frequency of occurrences. In row B of these figures the shape and range of distribution of the frequency of occurrences is important in the evaluation process. Differences in the range of distribution of a method's signal from one flow pattern to another can help to distinguish between flow patterns and
generate differences in the CPDF from flow to flow, which are also important in the discrimination process. Row C is the plot of the PSD for each system at each of the flows, which is used to analyze the frequency structure of the primary signal.

![Diagram](image.png)

Figure 3. Comparison of RMS values of each signal obtained from four systems (capacitive, resistive, pressure, optical arranged in the cluster) vs. in-situ spatial concentration of two-phase flow.

The results of RMS values vs. in-situ spatial concentration for all four implemented systems at each flow condition (1-8) are shown in figure 3, in which the RMS values are plotted against the average concentration for each respective flow condition. For an overall view of each method's RMS characteristics with respect to average concentration, a “best fit” curve has been drawn in to represent the most likely characteristics. One possible approach to compare the ability of each method is by using criteria that determines the sensitivity of each method. This sensitivity can be directly related to the
absolute value of the RMS and the slope of the curve over a particular range. This means that a steeper curve relative to a more shallow curve would relate to a greater range of RMS values achievable by a particular system, and thus a better ability to determine a flow pattern.

**Abrasive Wear**

In the design process, one of the most important issues is to minimize the amount of wear being generated in an operation of any mechanical systems. One of the most effective solutions is to determine an optimal material composition of the cooperating parts based on the results of investigation on the amount of wear for different material compositions and configurations. Such investigation has a phenomenological nature and a final decision is made based on minimization of wear measured in experimental test systems.

The research results are verified by using two concomitant systems to determine the wear, and were compared with results reported by J. F. Archard and W. Hirst. In the research, a developed pin-on-disk test system was utilized to generate an abrasive wear on pins.

![Figure 4. Details of the pin-on-disk wear test system with hydraulic control.](image)

The pin on disk system consisted of a pin positioned perpendicular to a flat circular disk with the abrasive surface made up of metal sandpaper. The pin specimen revolves about the disk with the sliding path a circle on the disk surface. The plane of the disk is horizontal. The pin is pressed against the disk at a specified load by means of an arm and attached weights. Immediately prior to testing and measuring,
cleaning and drying of all pins were required\textsuperscript{7}. Care was taken to remove all foreign particles from pins. More information on pin-on-disk systems and tests are available in wear publications and patents\textsuperscript{5, 6, 7, 8, 9}. For measurement of wear, a concept of concomitant methods was implemented by length using a micrometer [\(\pm 0.0001\) in.] and by weight using a digital scale [\(\pm 0.1\) g].

A variable speed hydraulic system with a motor capable of maintaining constant speed under load, mounted where as that the pins vibration does not affect the test. The stationary pin holder is attached to a lever arm that has a pivot. Adding weights, as an option of loading, produces a test force proportional to the mass of the weights applied.

By using concomitant measurement systems, wear versus sliding distance for aluminum, brass, zinc-plated steel, and steel were determined. Example of experimental results of cumulative wear versus sliding distance for used materials determined by length is shown in Figure 4.

![Figure 4. Nondimensional cumulative wear of aluminum vs. wear distance from experiments in comparison with theory.](image)

![Figure 5. Relative errors by length of wears versus wear distance for different materials.](image)
By comparison the experimental results and theoretical results in Fig. 4, and excellent conformity is observed, which is determined by small differences between respective characteristics. Plotting error versus sliding distance, which is illustrated in Fig. 5, could perform more detailed analysis by using a criterion of defined error values, which are acceptable.

References

8. www.uspto.gov

JERRY K. KESKA

Dr. Keska, a mechanical engineer, currently serves as an Associate Professor of Fluid Power and Mechanical Systems in the Industrial Technology Department at the University of Louisiana at Lafayette. His research interests are in the areas of Microelectromechanical Systems (MEMS), fluid dynamics of complex heterogeneous mixtures (multiphase, slurries), tribology, microheatexchangers, computer-aided measurement systems and instrumentation, electromagnetic sensors, turbulence and flow pattern phenomena in mixtures, and deterministic and random signal analysis including validation process.
Appendix

Design Project and Feasibility Study (Open-ended Project)
(Select one of the three following options for DPAFS)

1. Submit a project proposal on the following subject:

Wear, defined as unwanted material removal, is a subject, which is known and experienced by everyone. It impacts strongly on the national economy and on the life styles of most people. Very often wear is accepted as the natural consequence of use; that is, a certain level of wear is accepted as normal and no attempt is made to improve the situation. For some applications this judgment may be correct; however, for others there may be significant cost penalties. From a national point of view, wear is very costly to the economy. At a recent workshop by the Office of Technology Assessment, U.S. Congress wear costs were documented in various equipment categories. Some examples (in 1975 dollars) were as follows: Naval aircraft, $243.87/flight hr; Navy aircraft tires, $1,853,200/year; Navy ships, $38.92/ship hr; cutting tool wear, $900 million/year. Automotive maintenance and repair costs were estimated to be $40 billion per year, a large portion of which could be attributed to wear. In a recent report by the National Bureau of Standards, $70 billion was estimated for corrosion, and $20 billion for wear. Peterson estimates, using two examples (fighter aircraft and ships), that the cost of wear per year is approximately two-thirds the fuel cost. These figures indicated that the cost of wear is large and national efforts should be made to reduce it.

Wear is not only a failure mode but also a prime cause of secondary failures. Worn parts lead to increased vibration and fatigue, shock loading, and misalignment, all of which increase the probability of equipment failure. In addition, wear debris can cause seizure of spalling failures in other components. Even if failure does not occur, wear causes a deterioration in performance. Energy is lost by the wear and loss of compression in internal combustion engines. Pumps and compressors become less efficient as wear occurs in the pumping elements and seals. This loss of efficient operation may well be the major cost of wear.

In design and operation of mechanical equipment, the engineer is faced with a number of problems, which relate to wear. Here the wear limit must be known and is usually supplied by the manufacturer when critical. In addition, some means must be available to ascertain the present level of wear. The simplest approach is to disassemble the equipment and measure the wear. This may not always be possible and is usually an expensive process. For many applications (e.g., brakes), it is possible to install wear gages, which give a continuous measurement of the dimensional change. Very often indirect methods are used, such as oil analysis, ferrography, or changes in operating parameters such as pressure, temperature, motions, or noise. Where direct or indirect measurements cannot be used, then some predictive scheme must be used to estimate the dimensional change.

Learn more about this subject and device as well as a method of wear measurement, direct or indirect (Literature study, professional discussion, etc.). Submit a short project proposal describing your idea of wear measurement, and failure prediction and detection.

GENERAL NOTE: You are encouraged to work in teams (up to three students) and hand in a single formal report per team. For your DPAFS submit a proposal describing your idea with time, references and realization plan for my approval. For report requirements and evaluation procedures see guidelines in Laboratory Manual.
# FEASIBILITY STUDY PROJECT

**FINAL EVALUATION**

Date: 

Project Team: _______________________________ Project Leader: ______________________________

Project Title: ________________________________________ Difficulty Factor ______

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<td>2.</td>
<td>Literature and patent search (documentation, discussion and analysis)</td>
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<td>3.</td>
<td>Deadlines (late penalty - minus 10 points per day)</td>
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<td>4.</td>
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<td>5.</td>
<td>LAB WORK: Data base, test matrix, accuracy, procedures, documentation of experimental activities, and analysis and interpretation of data</td>
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**TOTAL** 100