Math, Engineering, and Science: Applications for Grades 4-8

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Abstract:
We present what we believe is a novel outreach program providing grade 4-8 math teachers a "grade-appropriate" exposure to real-world engineering and science situations, and how the mathematics they teach has real, interesting, and fun applications. The project originated in the spring of 2004, and culminated in a week-long mid-summer workshop attended by some 25 grade 4-8 math teachers from several local SE Idaho school districts. We present our motivation for developing this program, an overview of the structure of the workshop and topics covered, a description of the resource materials developed for use by the workshop participants in their respective classrooms, and follow-up school visits by ISU College of Engineering student-faculty teams. We conclude the paper with our thoughts on future extensions and improvements in this program.

Motivation for the project:
It has been nationally recognized, and well documented, that the United States is facing a looming shortage of citizen engineers and scientists in the coming decades.[1] Since the Second World War, the US has relied on "technological innovation" in preserving our preeminent stand in the world economy, and in ensuring our own security. The basis for this technological superiority has been our ability to train and retain engineers and scientists. However, over the past decade (at the very least), more and more college bound students are opting for careers outside the realm of engineering and science. In recognition of this, the National Science Foundation has instituted programs meant to make the choice of engineering and science as a college major more attractive and financially affordable; e.g. the CSEMS Scholarship Program, available at many colleges and universities.[2]

In our opinion, waiting until a student is enrolled in college to entice him or her into engineering or science is too late. Without the proper high school math background, students deciding on engineering or science careers when arriving at college will often face one or more years of remedial work (mainly mathematics preparation for calculus). This clearly does not apply to all universities: highly selective institutions probably don't admit students without the necessary high school preparation. However, many state universities and colleges operate under a mandated "open-admissions" policy: any state resident student with a valid, in-state high school graduation diploma or certificate must be admitted (our university is one such institution).

A trend in recent years in high schools is to allow students more freedom in their course of study. This is in contrast to the situation prevalent 30 or more years ago, when "college-bound" students took a more or less fixed sequence of college preparatory courses leading up to, but not necessarily including calculus. Unless high school guidance counselors and their career planning materials stress a proper mathematics and science background training, students will opt for less strenuous and more "enjoyable" courses, arriving at college unprepared for a major in science or engineering. In Idaho public institutions of higher education, nearly 30% of freshmen and sophomores took remedial instruction in their first two years of college attendance.[3]

Hence, the added year or more of remediation may be a factor in dissuading undecided college students in pursuing careers in science and engineering.

In the local geographic region (SE Idaho), where our university (ISU) draws most of its students, we face another set of problems:

1. There is a lack of understanding as to the difference between careers in engineering, vs. technology. The local school district's career guidance handbook places engineering in the same category as electrician, welder, and automobile mechanic.[4]
2. There is no emphasis placed in the guidance handbook on pursuing a career in the sciences or in mathematics, in fact, no mention is made of careers in scientific research or mathematics in this handbook. Mathematics and science courses are recommended for students who do intend to pursue a medical degree.
3. There is a low cultural expectation placed on students to attend college and earn a degree. Our region has a mix of rural agricultural and small city "blue-collar" workforces. Pursuing a career similar to ones' parents is the norm. Only 12% of 18-25 yr. olds in SE Idaho are enrolled in college, and only 20% of the total state population has a college degree (BS or higher).[5]
4. The Federal "No Child Left Behind Act of 2001", and the State of Idaho's response to its mandates (instituting batteries of standardized tests for grades K-12, called ISAT), has forced many math teachers to devote more of their class time to test taking strategy, dry-run practice quizzes, etc. to the point where topics not on the state's official math guidelines for measurement by the ISAT are not covered. Standardized tests are typically short answer or computationally oriented. Being lost from the curriculum are the integrative and descriptive aspects of mathematics.
5. Teacher education, at ISU (Idaho's only public university offering teaching degrees), for those pursuing the mathematics emphasis or mathematics minor certification, requires a core of mathematics courses (calculus, abstract algebra, linear algebra, analysis, modern geometry), but no applied mathematics. Thus, our primary and secondary math teachers receive training in pure mathematics, but not its connections to the sciences or engineering. Likewise, the particular science emphasis/minor requires a core of science, but minimal mathematics. For students pursuing the teaching degree without a mathematics or science emphasis, there is no substantial mathematics or science component.[6] Our K-12 math teachers can't give compelling reasons why the math they are teaching is important, useful, or interesting, and our science teachers can't connect the science with the mathematics. It is not that they do not want to do so, but rather they have not been exposed to these connections in their training.

Our project attempts to address several of the above problems. We believe:

1. getting teachers excited about, and capable of, tying the mathematics they teach to real world science and engineering applications will spark the interest in, and awareness of, these fields in young students, hopefully resulting in early recruitment!
2. teachers need to get a true feel for how engineers and scientists think and approach their work (not the polished, rigid, "scientific method" all students are forced to memorize, and

which comes across as stilted and boring). Besides computational skills, students headed into the sciences or engineering need problem solving skills, pattern recognition abilities, estimation skills, validity checks, etc. These skills and habits are best introduced early, and integrated into their mathematics (and science) training.

3. the mathematics taught even in grades 4 through 8 has interesting applications. By presenting these applications, perhaps we can help ameliorate the onset of math phobia, and make mathematics a more relevant, and less dreaded subject; one that shouldn't be avoided in selecting high school plans of study.

Workshop overview:
In the winter and spring of 2004, a proposal was developed jointly with the ISU College of Education, and subsequently funded by the Idaho State Board of Education, to run a summer workshop entitled "Math Applications in Engineering and Science: Grades 4-8". The workshop was to carry 3 academic graduate credits, for teachers needing coursework towards post-baccalaureate degrees in the College of Education. We (the authors) were responsible for the structure and content of the workshop, and the co-PI from the College of Education was responsible for performing follow-up classroom visits in the fall of 2004 to assess how well the teachers were integrating the materials into their teaching plans. Enrollment was limited to 25 participants, selected from the local rural school districts, and was quickly booked to capacity.

The workshop was to carry 36 contact hours of instruction, over a one week period. Sessions were generally 1½ to 2 hours in duration, beginning at 8 AM and running to 4 PM daily, with coffee and lunch breaks separating them. Attendance at all sessions was required for successful completion of the course. Homework assignments relating to upcoming topics were assigned nightly. Some of the sessions were lecture-discussion periods, some were hands-on use of demonstration equipment or software, while others were "working group" experiment, data collection, and analysis sessions, followed by class discussions. All workshop lectures and class discussions were held in a local high school's computer laboratory, capable of multimedia presentations, and giving each participant a workstation to use if necessary.

The topics comprising the sessions, as they occurred in chronological order during the workshop, were:

1. The looming problem: a shortage of scientists and engineers.
2. What is engineering, and how is it different from science?
3. The engineering design process.
4. Calculations, significant figures, and scientific notation.
5. Collecting and reporting data. Accuracy vs. precision. Sources of error.
6. Physical units and dimensions. How can these guide you in solving a problem?
7. Estimation problems, and reasonableness/validity checks. Visualizing the magnitude of a result of a computation or estimation.
8. Displaying data and simple statistics. What they tell you about the data, and what can you deduce from them. Histograms and scatter-plots. Discovering trends in data.
9. Sorting and searching algorithms.
10. Physical experiments which supposedly can be modeled by linear relationships.
11. Linear algebraic equations, and applications to physics. Visualizing manipulations of linear equations using physics.

12. Linear Diophantine equations, and applications to chemistry.
13. Basic probability theory, randomness, and pseudo-randomness. Detecting trends.
14. Number theory, prime numbers, and random number generation. Random walks.
15. Fitting linear equations to scatter-plots. Outliers, and censoring data.
16. Physical experiments which are modeled by non-linear relationships.
17. How do we recognize a nonlinearity in messy data? What do we do about it?
18. Java applets for statistical visualization.
19. Finding different ways of measuring the "same" physical quantity. Assessing the quality of   the experiment.
20. Java applets for visualization of physical experiments.
21. Wrapping it all together, how to integrate the material from this workshop into your courses and teaching plans.

Several of the above sessions were actually split across days, and/or revisited throughout the week. In most cases, we were able to present grade-appropriate (grades 4-8) material in each of the sessions.

The workshop attendees were asked to break up into 3 static "working groups". Whenever a group experiment was to be performed, the group would work as a team on devising the experimental setup, determining the method(s) to be used for collecting the data, and interpreting and presenting the results of the experiment to the entire workshop. Groups were free to, and in fact, encouraged to "engineer" their own experimental design. When the groups presented their results and interpretations to the class as a whole, we would discuss not only their results, but their experimental design and their rationale behind it.

Details for some representative topics:
To give the reader a better feel for the flavor of the workshop sessions, we present in this section a more detailed description of several of the above numbered session topics.

In topic 3, the engineering design process was outlined and discussed. Here is an excerpt from our course manual:

"The process is as follows:

1. **Understand the problem.** What do we want to find? The area of a circle? The product of two numbers? Collecting data to find a suspected trend? In any case, drawing a picture of the problem often helps in understanding the problem.
2. **Collect facts.** Physical facts, time, size, weight, temperature, height, etc. must all be collected. Note the units for the information collected.
3. **Select the proper principle(s).** The problem may be to covert Fahrenheit temperature to Celsius temperature. You want to choose the correct formula. You may want to find the area of a circle, so you want the formula for a circle and not for a rectangle. You may need to make use of multiple principles in solving a single problem.
4. **Make (and note!) necessary assumptions.** To find the area of a circle, we need the value of Pi. How many decimal places will we use? Pi = 3.14 or 3.14159. It will make a difference in the final result. If information is missing, or must be guessed at, make note of that.

5. **Solve the problem.** Using the proper equation(s) identified above, solve the problem, showing the steps of the solution. Don't just write down an answer.
6. **Check the result.** Does the answer make sense? If you are finding the area of a rectangle with height = 5.75 ft. and width = 9.33 ft. and you get an answer of 536 $ft.^2$ you should realize the answer does not make sense based on the size of the numbers for height and width, and by performing a "ballpark estimate" of the expected result.
7. **If necessary, repeat the above,** starting at whatever point you identify as being the cause of an unacceptable error in your final result.

> We will use the engineering design process throughout this short course. We really can't help it, because that's the way we think! However, we tend to use the process almost subconsciously, so, we will try to point out in our work this week the above steps being applied."

To an experienced scientist or engineer, the above steps may seem trivial, especially for single step problems. However, the process is invaluable when attacking compound, ill-posed problems. This is the link that we wanted to make with our teachers, and in fact, practiced with them repeatedly throughout the short course. "Answers" to problems were never really allowed to be just that. We always questioned their validity.

In topic 7, estimation problems, the authors began by working through several simple estimation examples, illustrating the engineering design process being invoked step by step. The problems began quite simply, but grew in complexity and "ill-posedness". In one instance, both authors independently worked through and presented the same problem before the class (estimate the annual culinary water usage for the city of Pocatello). The estimates we ended up with were reasonably close (same order of magnitude), in spite of our distinct approaches.

An excerpt from the course manual on estimation follows:

> "For school children, the process of estimation, and the concomitant work with orders of magnitudes, will give them an appreciation for the "size" of numbers. They will learn the "bottom-up" approach, and be able to use it in other problem solving situations and in their daily lives. They will learn to put facts and information together from various sources. The process will stress and strengthen their abilities with unit consistency and unit conversion. They will learn to be able to pinpoint where their estimates may be weak, and needs more input or better information. Lastly, the estimation process gets them thinking about the complexity of today's world, and the technology most take for granted.
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> Here are some examples of estimation problems which you could use in your classrooms. Some of them will have "correct" or verifiable values, available from outside sources. Others will just have to remain untested as estimates. There often is more than one way to run through the estimate. Allow for this, and even encourage this, in your classes. So long as the estimates can be defended, and make dimensional and physical sense, you should accept them (maybe noting that they may be high/low by some order of magnitude, so that the final result can be adjusted accordingly). Many of these would be

suitable for group projects, with group reports and class presentations. We have noted the grade level at which such a problem would first be appropriate, in terms of required mathematical skill and knowledge base.

1. Estimate the total gals. of paint needed to paint a classroom's walls (g4).
2. Estimate the total gals. of paint needed to paint all the classrooms in the school (g5), or all the rooms in your home (g4).
3. Estimate the cost of painting the classrooms in the school (g5), or the rooms in your home (g5).

These previous 3 problems will need the coverage of paint (area /gal), the area involved, and, for the cost estimation, the hourly rate of a painter, the rate at which a painter can paint a wall's area (area/hr), and the rate at which he can "edge-in" or "cut-in" (length/hr), together with the total edging involved (length). Other factors can be thrown in as well: cost of rollers and brushes, time involved in laying tarps, moving furniture, setting up ladders, scaffolding, etc.

4. Estimate the daily household water use for one family (g4).
5. Estimate the annual household water use for a family (weekly and seasonal effects) (g5).
6. Estimate the total daily residential water use for your hometown (g5). You will need a population estimate and the estimate from the problem 4.
7. Estimate the total annual water use for a city or town (g6). Take into account residential, business, industry and other public arenas, governments, etc. (so parks, golf courses, churches, etc. would be included). Check your estimate against city usage figures available from the water dept.
8. Estimate the total volume of water delivered in a thunderstorm (g6). You will need the area, duration, and "inches of rain". (Typical for a summer thunder burst: ½ in. of rain.)
9. Estimate the total volume of water delivered in a typical snowstorm (g6). You will need the same information as in the previous problem, replacing inches of rain with snow, and the water equivalent of snow. (Typical values are 1 in. of snow = 1/12 in. rain, or less!)
10. Estimate the volume of water stored in a local reservoir, when full (g6). You will need the area of the reservoir and an average depth. It is fun to do this off of a topographic map, using the contours of the surrounding land surface to extrapolate to what is going on depthwise in the reservoir. Computing the area can be done by overlaying a grid, and counting squares.
11. Estimate the height of a flagpole, building, or tree (g5). How many different ways can you do this?
12. Estimate the number of bags of concrete mix needed to make a sidewalk (g5). You will need the vol. of an 80lb. bag of dry concrete: 19 in. x 16.5in. x 4.25 in. and that the water added to the dry mix barely increases its volume, as well as the size of the sidewalk, and its depth.

13. Estimate the number of bags of concrete mix needed to set a post in a post hole (g6). Draw a typical situation: a 6 x 6 in. post, in a hole, roughly circular, that is 4 ft. deep and 2 ft. in diameter.
14. Estimate the cubic yards of concrete in a section of highway: e.g., US 20 from Rigby to St. Anthony (g6). You will need the fact that it is a 4 lane divided highway in this section. You will need the width of the roadway, the depth, and the mileage. To get a feel for how large this number is, you can take the result and convert it into bags of concrete mix.
15. Estimate the annual energy savings that would be made by a family (g5), community (g5), US (g6) recycling aluminum cans that they use. You will need estimates of the number of cans used by each person each day, the population of the community, and the population of the US (about 300,000,000). You will also need the fact that the energy cost of producing one 12oz. aluminum can from raw materials is the equivalent to 6oz. of gasoline, whereas the energy cost to melt and reuse one aluminum can is the equivalent of 1/2 oz. of gasoline. You may want to express your answer in terms of total gallons of gasoline that would be saved per year, and then convert this to something more meaningful, like dollars saved, or potential miles that could be driven, etc.
16. Estimate the total number of gallons of gas used per year by your family (g5), community (g5), US (g6). You will need the mpg ratings for your family vehicles, and for an "average car". You will also need estimates the number of cars, and of miles driven per week per vehicle. Is this going to be the same for here in Idaho, as for other parts of the country?

The following estimation problems aren't as technical, but are meant to give an appreciation for the size of large numbers.

17. Estimate the number of seconds in a day (g4).
18. Estimate the number of seconds that a student has lived (g5).
19. Estimate the number of seconds in an average lifetime (g5).
20. Computers execute a whole lot of "instructions" per second (g6). Computers have an internal clock which "tics" at 10^9 cycles per second. (One Gigahertz is this rate: 10^9 cycles per second. One Megahertz is 10^6 cycles per second). Assume that a computer can perform one instruction per cycle, and it takes 5-10 instructions to do anything "useful" (like add two numbers, store the result, etc.). When you bring up a computer program, there is often a time delay. Estimate how many "useful" operations have been performed in executing that task. You will need the time needed for a program to start up, e.g., the time needed to boot your computer.
21. Estimate the number of human generations that have occurred since the American Revolution (1776 AD) (g4), the US Civil War (1861) (g5), the Magna Carta (1215)(g5), the death of Julius Caesar (44 BC) (g6), the building of the great pyramids at Cheops (g6), the migration of people to North America via the Bering Land bridge (15000 BC).
22. Estimate the number of blades of grass in 1 sq. ft. of yard (g4); in the school football field (g5).

23. Estimate the number of dry beans in 1 qt. container (g5). How many different estimation techniques can you come up with? Can you predict which techniques will be more accurate beforehand?

Many of these are fun, and instructive in subject matter other than mathematics. Sources of other problems arise everyday. We are sure you will begin to notice these, and realize their teaching potential, once you have worked a few of the above.
In class, we worked on several of these problems, some in conjunction with the subject of data collection and analysis, some just for the sake of estimation."

The estimation skills that are second nature to engineering professionals take a surprisingly good amount of conscious effort to develop. In fact, many of the workshop participants at first had a natural stubborn resistance to the process! When we first started stepping though some simple estimation problems, several of the participants looked uncomfortable, and at least one vocally stated so. Mathematics teachers at this level have been conditioned to think of there always being **an answer** to a math problem, not **an entire range** of potentially valid answers! Their discomfort in treating 7,343,551 as 7 x 10^6 or even 10^7 in an estimation process was noticeable. However, when we performed one estimate in several different ways, and ended up with the same order of magnitude for the result, they began to see the utility in the method. Also, when they began to realize that problems that need solving aren't always well posed at the beginning, they realized there must be room for multiple approaches, and different answers, depending on the assumptions made along the way.

As the estimation problems were worked on and discussed in class, an interesting interaction became evident. The participants in the workshop at first tried to mimic an earlier approach taken in performing an estimation process. Gradually, with some prompting and prodding, they actively began to seek out novel approaches. Often, one group would build off of the ideas gleaned from the presentation by a different group, but with novel modifications. One of the most successful problems in this aspect was problem 23 directly above. Approaches varied:

a) Take a subsample of known volume, directly count its numerical content of beans, and scale this value up appropriately.
b) Same as a), but use several subsamples to get an average number of beans per unit volume.
c) Use the elliptical volume formula to compute the volume of 1 bean. Assume a 75% packing density, scale the isolated bean volume by 4/3 to find the volume 1 bean uses, and divide the 1 qt. volume by this occupancy volume to obtain the number of beans.
d) Weigh the jar empty, weigh it full of beans, subtract to find the beans' mass, and then weigh a fixed number of beans. Scale this to find the total number.
e) Use a gridded dressmaker's cutting board to spill the beans onto, and rattle the board to get the beans settled into a single layer. Use a ruler to massage the layer of beans into a rectangular area. Count the number of beans in a small sub-area. Scale this result accordingly.
f) Fill the jar with beans with water. Drain off the water, measuring it to find out how much volume the beans actually had. Take a small (¼ cup) sample of beans, and compute the average volume of a bean, by the same technique (here counting the actual number of

beans in the small sample). Divide the larger bean volume by the average volume per bean to obtain the count.

All of these techniques ended up yielding counts in the same order of magnitude, and several of these actually agreed to 1 or 2 significant places! It was encouraging to find that the participants began to integrate other mathematical/statistical concepts into their problem solving skills.

While working on the process of estimation, we included a group of problems which were meant to give students a feel for the magnitude of numbers. For example, visualizing a small city's annual culinary water usage of 3.65×10^8 gal/yr (an estimate done in class for Pocatello, ID.) can be done by converting this volume to acre-feet, and then using the reasonable approximation that one acre is roughly a football field sized area. The equivalent volume works out to 1.12×10^3 acre ft./yr. So, imagine a tower of water, roughly a quarter mile high, rising vertically above a football field!

The segments of the workshop stressing mathematical models that occur in physical situations were laid out as follows: first, the relevant physical model was explained. The basic equations from physics were, whenever appropriate, derived from first principles (Newton's Laws, Conservation of Energy, Conservation of Momentum, etc.), and manipulated into the desired mathematical relationship. Then, an experiment is described which would, if our modeling is correct, be able to provide us with empirical data verifying the assumptions of the model. The course participants were then provided with the essential ingredients for the experiment, and asked to perform it under as many variations in the independent variable as possible. Data were collected, scatter-plots or histograms produced, and trends deduced. Discussions of the groups' findings were then carried out in class.

The physical experiments ranged from the very simplest, to some that were quite challenging. A sampling of the experiments we actually performed follows:

1. Determining the expansion coefficient of water, as it freezes from liquid into solid ice.
2. Verifying the moment equations for a balanced beam.
3. Hooke's law verification for springs, deducing the linear relationship between force and displacement.
4. Torricelli's Law verification for liquids, deducing that the flow rate of liquid exiting a spigot at the bottom of the container is independent of the shape of the vessel, and that the exit velocity depends only on the height of the liquid above the exit pipe.
5. Torricelli's Law verification for liquids, deducing the nonlinear (square root) dependence of exit velocity on the height of the liquid.
6. Period of oscillation for a spring-mass system. Deducing the nonlinear (square root) dependence of the period of oscillation on the mass attached to the spring.
7. Conservation of energy, relating time of flight of a water balloon shot vertically, to the potential energy of a launch slingshot, as quantified by the amount the slingshot's elastic bands are stretched prior to launch.

The messier the experiment, the more the teachers enjoyed the process of collecting data, trying to determine the best way to get reliable measurements, and in actually seeing the predicted trend show up in their actual data. It is no surprise, for example, that a volume of water will expand in fixed proportion as it freezes. It is reassuring that plots of change in volume vs. original volume ended up falling along a straight line, with slope approximately 1/9. It is much more surprising to learn that the exit velocity of water from a vessel depends only on the square root of the height of the water above the exit, and that the data actually shows this convincingly! (At first, we had the groups plot the exit velocity vs. the height, and this showed an upward trend, which was nonetheless recognizably not linear, as it was concave downward. Then, we had them plot the square of the velocity vs. height, and the result was clearly linear.)

We won't describe in any detail the remaining topics in the workshop, but they followed the general flavor of the above cited estimation and physical modeling problems. All were constructed to contain material at a level appropriate to students somewhere in grades 4 - 8. For example, several of the Computer Science applications stressed manipulations with integer division, modular arithmetic, prime numbers, and factoring. Such material would be appropriate to grades 5-8. The material on linear Diophantine equations in Chemistry would probably be restricted to grades 7-8. However, the data collection and histogram construction, and devising sorting algorithms, could easily be presented at grade 4. The simple probability models (using coin tosses to drive a random walk) could be presented at any grade as well, whereas computing theoretical probabilities would be restricted to grades 7-8. The statistical and physical demonstration Java applets would best be reserved for the upper grade levels as well. As most of the workshop participants came from smaller, rural, schools, they often taught several grade levels, and could make use of the material somewhere in their course plan; or knew their colleagues well enough to relate the workshop ideas to the appropriate grade level instructor.

Workshop materials that were provided to the participants included:

1. The workshop manual. This was provided in rough paper format during the workshop, and later was edited, expanded to include workshop data and analysis, and burned onto a resource CD-ROM.
2. A collection of Java Applets, all of them open source, for performing a variety of statistical analyses and data display and manipulation operations, and for performing virtual, idealized, physical experiments. These applets were also burned onto the resource CD-ROM, along with web links to their authors.
3. A collection of small executable computer scripts, for performing a variety of simulations. These were written by the authors in C++, are open source, and were included on the resource CD-ROM.
4. Open source computer software that may be useful to math teachers, but not directly related to the course content was also included on the CD-ROM. This included a C++ GUI -based development tool, the octave numerical analysis software, a simple spreadsheet program, etc.
5. A collection of easily obtainable objects from which we constructed many of our experiments. This included wooden yardsticks, double sided masking tape, an assortment of fishing weights of known mass, monofilament line, coiled springs of various stiffnesses, an inexpensive stopwatch, surgical tubing and a cloth cradle (for the slingshot experiments), water balloons, various shaped plastic containers with fixed diameter spigots and height gradations (for the Torricelli experiments).

The total cost of all the materials worked out to less than $30 per participant. We felt that we should provide them with the actual experiment equipment (all of it home-brewed) used in the workshop, mainly to show them how easy it is to improvise. Only a reasonably accurate scale for weighing would be needed in addition to the materials we provided, and this should be available from their local school's science lab.

At the conclusion of the workshop, we indicated that we would be willing to visit the participants classroom's if invited, and bring along a group of engineering students from ISU to run any variety of desired experiments or demonstrations. We also indicated that we would gladly serve to consult and advise on any new ideas the participants may come up with after the workshop for in-class projects, and check on their scientific or mathematical validity and appropriateness.

Follow-up visits:
In the fall of 2004, we received numerous calls requesting classroom visits, not only from our workshop participants but also from some of their colleagues who had heard by word of mouth that our demonstrations would be of interest to their classes. We would put together a team of engineering students ranging in number from 3 to 5, recruited from the local student engineering professional societies, assemble the desired experiment(s) and demonstration(s), and visit the classroom for typically several class periods, engaging the students in the demonstrations. It should be noted that the Society of Women Engineers (SWE), formed the majority of the volunteers. We feel this is important to show that engineering can very well be a genderless profession. We also brought along our College of Engineering Student Services Representative, who would give a short presentation on careers in engineering, and the kind of classes students would need to take in school to get into college, prepared for engineering. Admittedly, this career presentation was pitched at an elementary level, but many students had never heard of "engineering" as a profession beforehand! Now, they had an inkling of what kinds of things engineers do. Reports received back from the respective teachers indicated that the visits were a success, and that we could expect future requests for visits.

Concluding remarks:
The workshop teaching evaluations we received consistently applauded our approach, and our enthusiasm in presenting the workshop material. The hands-on experiments and data collection activities were the highlights of the workshop. Many of the participants indicated that even though they would not be able to incorporate our material in a large scale into their teaching plans, they nonetheless had their eyes opened and gained an appreciation for the engineering thought process, and what connections their math has to real world situations. Many stated that the material we showed them gave them confidence in explaining the usefulness of the mathematics to their students. However, many indicated that much of the material would be better appreciated, and more easily integrated into the curricula, at the upper range of grade levels (6-12). Nearly all participants commented on how much they wish they could integrate our material into their class plans, but their hands are tied largely by the realities of getting their students prepared for the ISAT's. We agree wholeheartedly with the observations in these evaluations. Statistics on how many of the participants integrated the short course material into class plans, and at what grade levels, will be collected in the spring of 2005, and should be available at the 2005 ASEE Annual Conference. This data is being collected by the ISU College of Education as part of the State Board of Education grant agreement's project assessment.

To improve the workshop for the benefit of the lower grades, we would recommend separating the participants into two levels: grades 4 & 5, and grades 6-8.   The material for the lower group would be able to concentrate more on the material relating to arithmetic, pattern recognition, and basic geometry skills, and the upper level group would receive more emphasis on the data visualization, estimation, modeling, and experimental design skills.

We also agree with the observation that a similar workshop with grade appropriate mathematics and applications should be developed for use in high school grades 9-12. To this end, we have proposed such a project to the Idaho State Board of Education, for possible implementation in the summer of 2005. The high school program could consist of demonstrations which integrate the natural, physical science, and mathematical coursework at the appropriate grade level. It is not known at this time whether a repeat of the workshop will again be offered, or if the above suggestion for a high school workshop be adopted. Again, this will be known by the time of the 2005 Annual Conference.

The course resource CD-ROM is available from the authors, and is distributed free of charge to educators, under the license and copyright agreements stated therein. To obtain a copy, send an email request to boswkenn@isu.edu , requesting the CD. Please indicate the intended purpose for your request.

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1. “Science and Engineering Indicators”, National Science Foundation, accessed at: http://www.nsf.gov/sbe/srs/seind04/start.htm , 1/1/05.
2. “CSEMS Awards by State and Territory”, National Science Foundation, Division of Undergraduate Education, accessed at: http://www.ehr.nsf.gov/ehr/due/awards/csems_by_state.asp , 1/1/05.
3. “Supporting Higher Education in Idaho”, Western Interstate Commission for Higher Education, accessed at: http://www.wiche.edu/Policy/Fact_Book/index.asp and the link: http://www.wiche.edu/Policy/Fact_Book/PDF/id.pdf , p.7, 1/1/04.
4. “Pocatello-Chubbuck School District High School Handbook and Curriculum Guide”, Pocatello-Chubbuck, Id, School District 25, accessed at: http://www.d25.k12.id.us/students/hshv24.pdf, p. 96, 7/7/04.
5. “Idaho Educational Attainment”, Social Science Data Analysis Network, University of Minnesota, accessed at: http://www.censusscope.org/us/s16/chart_education.html , 1/1/05.
6. “Idaho State University Undergraduate Catalog, 2003-2004”, Idaho State University, pp. 147-150, 2004.

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