The Benefits of the Undergraduate Research Experience

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I. The role of the University.

If the question was posed to me " What is the role of a University", I would respond by saying that the role of the University is to transform High School graduates into professionals after about four years of education; another way of saying it is that the role of the University is

transfer of knowledge
generation of knowledge
and to a lesser extent, application of knowledge

In trying to fulfill our educational objectives, my personal opinion is that our effort should be directed towards cultivating and increasing the ability of students to think. That the ability to think is more important than the simple transfer of knowledge is obvious: Even if a student learns everything by the time the B.S. degree is awarded, a short time after graduation that engineering professional

(a) will have to obtain new knowledge, probably on their own
(b) it is very probable that a few years after graduation, the young engineer will be the head of a group that involves persons from various disciplines; in that capacity simple, dry knowledge of facts will not be at all helpful; the ability to think, however, will be extremely valuable.

What means do we have in our disposal to accomplish this objective? The "traditional" or "classical" approach is what we call teaching consisting of

classroom instruction
exams & HW
special readings, discussion etc.

In this mode of operation, the students are for the most part passive participants, at various degrees, I admit, depending on the style of the instructor. It is my personal belief that the students' ability to think will increase if we incorporate research as an active component of teaching. Yes, to me, research is not an appendix of the book of teaching but an integral part of it. This is particularly true if one believes that the purpose of a university experience is education and not training. Differences between education and training presented in PRISM, the ASEE monthly, in Jan. '97, are shown in Table 1.

If we believe that we, as University teachers, are in the education and not the training business, we should tailor our teaching towards the left side of this table which means, in turn, that research should become a necessary element of the educational experience, not an afterthought.

Table 1. Education and training

Education	Training
To think (plan, integrate, design, discover etc.; to develop conceptual skills for thinking beyond the current paradigm)	To do (Implement, build, process etc; to develop contextual skills to enhance immediate performance)
To do right things	to do things right
Long-term impact	Immediate result
Broadly based	Narrowly focused

II. Advantages of undergraduate research participation

You all know how difficult it is to keep students, or any audience for that matter, interested for 50 min. Our students are the products of television upbringing which means that they expect every speaker to be as interesting and as competent as a TV performer. Since this is difficult, if not impossible, most of us fail to keep the class tuned to the lecture. Even if the students are awake, my experience has been that they keep the lecture as a one-way conversation: They do not participate in the lecture either by asking questions or by answering them; they just buy their time; they watch for buzzwords about HW and tests and other tasks that may improve their grade.

Research, on the other hand, is different. The critical point is to make the research topic relevant to their field, interesting, and exciting. Then, the students really participate in the process, they get excited, they work, and they learn without knowing it. Knowledge is transferred without the effort on the students' part being felt. That's the main advantage. Other advantages are that research ,

* gives them the opportunity to show initiative; assignment is given in a general sense; they have to provide the specifics.
* makes them create something that they feel is their own; that may be a computer algorithm; an equation; a mathematical model; an experimental setup, etc. Creation is followed by pride in their work
* makes them aware of the need to record data and keep accurate records.
* gives them the opportunity to evaluate data; keep some and throw others away.
* makes them organize their findings in a logical fashion for an oral presentation and/or a written report.
* makes them aware that life is not always a success in every try; failure is not a catastrophe; it's normal; one should just learn from a wrong turn, from a mistake, and move on with better planning.

All these items mentioned here cannot be present in the normal class lecture. Of course the instructor may provide examples of research projects, describe the process, the successes and the failures. But, we all know that describing some activity is not the same as actually doing it.

III. Connection between research and design

Everybody in engineering is talking about design these days. Students, we are told, should be exposed to the design tasks from day one. Well, the research experience is a perfect conduit, a perfect bridge leading to design. Let me remind you of some the words in the design description given by ABET . Design is,
* devising a system, component or a process
* decision making process
* iterative process
* basic sciences and mathematics are involved
* establishment of objectives and criteria
* synthesis
* analysis
* testing and evaluation
* development of student creativity
* open-ended problems
* use of modern design theory and methodology
* consideration of alternative solutions
* realistic constraints

I am sure all these items/concepts are familiar to those involved in research. True, the objective of design is to produce a process, a product, a machine with specific characteristics. Research, by contrast, may not be that specific; research may be the testing of an idea. And here lies a fundamental difference between research and design:
The result of testing an idea may prove the idea to be wrong; in research, such a outcome is not a failure. In design, by contrast, if the end product is not achieved (i.e. it does not satisfy all constraints or it does not perform as planned), the design is considered a failure.

IV. Examples of undergraduate projects

Since I teach in a Nuclear Engineering Department, the examples I will present come from that discipline. However, the process I used can be applied in any field. At the University of Missouri-Rolla (UMR), undergraduate research may start in two ways.
(a) The student may sign for a course entitled Special Problems with the campus-wide number XX300 (e.g. NE 300); the student may sign for 1-3 hours of credit.

(b) The student, in consultation with a faculty member submits a proposal to the campus requesting support through a UMR program called Opportunities for Undergraduate Research Experience (OURE). If the proposal is approved, it is funded in the range of $ 500-1000; the student is paid that amount (minus expenses, if there are any) , registers for XX300 for 2-3 hours, and performs the research, most frequently during the Summer after the end of the Junior year; in many cases, the research continues during the Fall semester of the senior year. It is required that the student submit a written report after the project is finished to the Vice Chancellor for Academic Affairs. In terms of curriculum type of credit, this XX300 is considered a Technical Elective.

After the student agrees to do the research, I have a meeting with him or her in which we set up the details and expectations from the project; a timetable is decided upon; the writing of the final report is also discussed. Although students may come and see me anytime, if I am in my office and I am not busy, I set up a weekly ½ hour meeting at a fixed time, specifically to discuss with the student the weekly progress of the research; I require an informal written statement describing the past week's effort, about one page of text. I explain to the student the importance of a literature search, of documenting references, of recording all the work being done, and generally of keeping written records of everything (in a notebook or in a computer file).

Project 1: " Dose rates for several organs in a human from contaminated soil and Hot particles using the QAD computer code".

This work was published in Health Physics. In doing the project, the student learned the general principles of the point kernel techniques, use of buildup factors, hot particles (radioactive tiny specs of matter encountered in power plants), human phantom modeling using combinatorial geometry, and the use of the code QAD[1] .

Project 2: " Calculation of neutron flux and neutron radiation dose in a human phantom".

The student used the S_N transport codes DOT[2] and TORT[3] , a 2-D and a 3-D code, respectively. In doing the work, the student learned about cross section libraries, cross section multigroup structure, general principles of the S_N method, and phantom modeling for a deterministic transport code. The results of this project were not impressive, but the student learned a lot and continued to graduate school.

Project 3: " A study of the semiempirical equations for the dose rate outside a shielded cylindrical volumetric gamma source".

The student used the code QAD as the basis of checking the accuracy of the semiempirical equations given in the Engineering Compendium for Radiation

Shielding [4] . He also checked the various formulae proposed for buildup factors for multilayer shields. The student learned about buildup factors, point kernel techniques, combinatorial geometry, and the use of the QAD code. This work was presented in an ANS student conference.

Project 4: " Gamma dose to a fetus from internal and external sources"

This project was done at the time we were going through the transition from the old to the new regulations of 10CFR20. The student used the code QAD [1] to model the human body and the fetus at different stages of the gestation period. She learned about the 10CFR20, modeling the human body, a fetus, and the point kernel techniques.

Project 5: " Modification of the code VARSKIN mod 2"

VARSKIN [5] is a NRC-approved code for the calculation of the dose received from beta particles emitted by hot particles lodged on the clothes or the skin of a radiation worker. Most of the hot particles emit both betas and gammas and most of the dose delivered to the worker, primarily on the skin, comes from betas. VARSKIN computes the beta dose accurately but it uses many approximations in the gamma dose calculation. The student improved the gamma dose calculation by changing the VARSKIN algorithm appropriately.

Project 6: " Sensitivity analysis of radiation dose calculations"

When a dose rate is calculated, particularly in environmental restoration efforts, many of the parameters are known with a considerable uncertainty attached to them. The objective of the project was to determine the effect of the uncertainty of a particular quantity that enters into the calculation on the final result. The student assumed a certain distribution of radioactivity in the soil, wrote the algorithm and calculated dose rates under different scenarios. The uncertainty part was handled by assuming a certain distribution for each parameter and then using Monte Carlo techniques for the estimation of the distribution and uncertainty of the final result.

V. Conclusions

I found nothing but benefits when undergraduates are involved in research. Personally, I believe that the students learn a great deal and understand the material better. This "learning" and "understanding" perhaps can be explained by the fact that the students see the immediate application of concepts learned in solving real problems. I can talk in class about cross-section libraries, kernel techniques, combinatorial geometry, buildup factors etc; for most students these concepts "do not register". But, if they appear in a research project, their usefulness becomes apparent and the need to understand them immediate. For this reason, I strongly advise and encourage undergraduates to do research and offer them the opportunity to work with me, if they so desire.

References

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