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Striking the balance: Research in the undergraduate curriculum

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Abstract

Competitive current research in engineering is an expensive, often economically chancy undertaking. University colleges, facing strong competition from the established universities for research grants, short residence times for both academic staff and students, and with a historical pedagogical bias mean that under these circumstances promoting research is a challenging task. This paper explores the unique facets of this situation, tries to characterise what are likely to be profitable research topics, hints at ways to exploit the capital of the university, and finally reminds the disservice of pushing research into the undergraduate curriculum as well as the worthwhile.

Keywords: Research, education, engineering

1 Universal goals and private motivations

Karlstad University in central Sweden is a young university that has grown originally in the 1970s from a teacher training school. Karlstad University is similar to a number of other institutions in Sweden that are currently undergoing a change in emphasis from primarily an undergraduate teaching to a balance between research and an undergraduate education. All this happening in a country of falling student applicants and in the background, a political will that is driving towards the most cost effective education possible. The European Union requires that a professional engineer's qualification include 3 years post gymnasium training. But three years (or 120 working weeks) is a short time to include all the necessary components of a profession. Educationalists push for the degree to be lengthened, while the market (employers) and the funders (governments) push for a shorter, more concentrated degree. Finding space in the already over crowded curriculum requires that we simultaneously consider multiple goals in any course. The issue then is how to strive for a balance between a strong research program that may only involve small numbers of academic staff and postgraduates, and stimulating, relevant, succinct and enthusiastic undergraduate education.

The electrical engineering degree at Karlstad University, as do most engineering degrees, requires a 10 or 20-week diploma work usually carried out in a local company. This involves the execution of a small research project to be documented in a report by the student. For the purposes of the following argument, this particular research experience is not considered. What is instead considered is the value of research that finds its way into the normal undergraduate courses, and if this is a good thing. The term research applies not only to recent discoveries, state-of-the-art methodologies, but also to an appreciation of the classical philosophy of doing science, mining the literature and competently criticising the results, developing and executing a project plan.

In cases the output is insufficient to keep the investors happy[1]. How then can we as a University college with teams consisting of young graduates com-

[1] *The Chemical Engineer*, Hans von Doesburg, 9th Dec 1999

pete? If we do assemble the pre-requisities, how can we keep them in place? The university is, by nature, an institution with a very short half-life. The undergrads spend only 3 years, post-graduates only another 4.

Proposing to change the research component in a university college raises two fundamental questions: what is the goal of a university and what motivates the academic personnel? The statutes for a university in New Zealand are clear: "Besides developing intellectual independence, being critic and conscience of society and meeting research standards, universities are also charged with being a repository of knowledge and expertise and employing teaching staff who are active in research to advance knowledge."[2] These statutes are probably globally applicable to many universities, so it is interesting to note that there is little explicit mention of education of the undergraduate students. What motivates academics is more subtle, but publication in peer-reviewed journals, recognition and subsequent promotion will likely feature in many cases. Note that salary is not considered to feature highly, at least by Ramsden, (p251).

But the eliteness of the ivory tower mentality is long outdated, particularly in the technical fields. This is made explicit by the grant awarding authorities (such as the KK foundation in Sweden, ARC in Australia and European 5th Framework) where they require a 50% financial match from industry.[3] In some peoples minds this is an unacceptable compromise to academic unbiasness and integrity, perhaps even academic prostitution.[4] Whatever the merits of this argument, these people are ineligible for these grants. These grant-giving bodies stress applied research, with a relevance to stimulate local industry and with clear economic goals. This is a conscious departure from the purely theoretical pursuits of the "big science" traditionally carried out in places such as CERN, which have until recently, consumed large fractions of European research funds.

It is pleasing to note that the chairman of the United Kingdom's countrywide Research Assessment Exercise (RAE) criticises the present ranking criteria for being "too biased towards academic publications."[5] He continues, "This in turn drives researchers to pursue projects that will result in more journal papers." He argues that the assessors should take into account 5 points: encompassing strategy, creation of new knowledge, knowledge created in the context of application, independent scholarship, and vitality and sustainability of the research group.

Our experience at Karlstad University in the technical sciences (particularly the Forest Industry Center) has been that one or more of the following need to be in place:

1. Marketing services such as a particular piece of specialised equipment (electron microscope or microwave network analyser) or using specialised software (Matlab/Finite element studies)
2. Joint trouble-shooting of a novel nature that may require skills and analysis outside the company's internal resources.

There are two problems associated with this approach. One is that running specialised equipment is costly, and many of the larger concerns can afford this, (e.g. BTG have a network analyser, FEM software, Volvo have stress analysis software, Stora Enso have a STFI Fibre analyser etc), so the market is then restricted to the smaller to medium sized local companies that would typically use Inova or Tipps Wermland. But in many cases, this can hardly be considered research. Martin Sundqvist, from Tipps Wermland, estimates that almost none of the consulting jobs that pass through Tipps Wermland could be considered research, and only 1 resulted in a research publication. Clearly the incentive here is to

[2] *New Zealand Hearld*, Jade Reidy 2000

[3] *The Current Swedish Model of University Governance: Background and Description*, Ann Fritzell, Högskoleverket, 1998

[4] *Le Monde*, January 5th & 6th, Benoit Hopquin (Argument that the environmental agency Cedre was biased in its assessment of the Erika oil spill disaster since it used Elf and Totalfina resources and accepted funding)

[5] *Paper weighs down the RAE*, Phillip Ruffles, The Chemical Engineer, p4, 20th January 2000

use the consulting jobs to obtain financing to fund other projects, or to build and strengthen contacts.

The other problem associated with the second approach is that the research can get too focussed, too specific for the particular company, and consequently lack global appeal and run into confidentiality problems.

Engineers can't count. Franklin, NWT, 1999 (?)

2 The gap between the final-year undergraduate and publication

The single biggest hindrance to research in our institution at present is the gap between the ability of the final year student ready for a PhD study, and the expectations of the international research community for this level of study. Two components are needed to close this gap. One is simply more knowledge, techniques and practice in the immediate discipline. We estimate that to critique competently relevant literature requires at least another 2 to 3 years of focussed study. The other is the level of maturity and the broad base necessitated for interdisciplinary collaborative research. Granted not all the participants need to be versed in all the fields, but once again, academic research is essentially a lone pursuit, and academia has so far been extremely reluctant to view otherwise.

Our experience in the electrical engineering department is perhaps typical. We have two, perhaps three plausible fields of research: automatic control, antenna theory, and VLSI. We have just initiated D-level courses in the two former fields, but only in automatic control have we published. The problem is the lag time from the level of proficiency expected in an undergraduate degree, and the leading edge of research, particularly in theoretical matters. Obviously theoretical research is much cheaper and faster than that with a substantial experimental component, so consequently has been the favoured route of universities. In fields such as signal processing, algorithms, and automatic control, the concepts are often first developed in a university, and then ported over to industry. The common denominator here is a strong underlying use of mathematical algorithms. Such training of the new graduate, even for those concentrating primarily on mathematics, is generally considered insufficient. This is not limited to engineering since discussions with colleagues in economics, uncovered similar observations[6], as do experiences from Germany.[7] At Karlstad University lack of mathematical prowess has been recognised as a source of concern , although the trend is probably similar in many Swedish University colleges.

If that rules out theoretical research, one option left is applied research. Quite apart from the insidious academic bigotry that surrounds anything applied, the immediate drawbacks are the expense involved in carrying out experiments, particularly at industrial scale, and the time required to design, fabricate and setup the necessary equipment, and analyse the results. This leaves the researcher with precious little time to make science. Of course lip service has been paid to the importance of this type of research, and many conferences and meetings have as titles things such as 'Closing the theory/practice gap'. Even the prestigious International Federation of Automatic Control have started a new journal, Journal of Control Engineering Practice, but this does little to address the imbalance. One telling review of applications in LQG, a powerful control scheme, showed only 10 industrial applications over almost a decade. This is at best pitiful compared with the tens of thousands of articles published over the same time in theory or simulated studies. Our hope is to close the theory/academic gap, but this does demand different skills such as an appreciation of the art of engineering, and a close proximity to industry with real practical problems and people willing to get their hands dirty.

[6] Berndt Andersson, Finance, Karlstad University

[7] Prof. Helmut Neunzert, Kaiserslauten, Germany. Public lecture *Mathematics as a technology: Challenges for the Future* 30 Nov 1999.

3 Does doing research make better teachers?

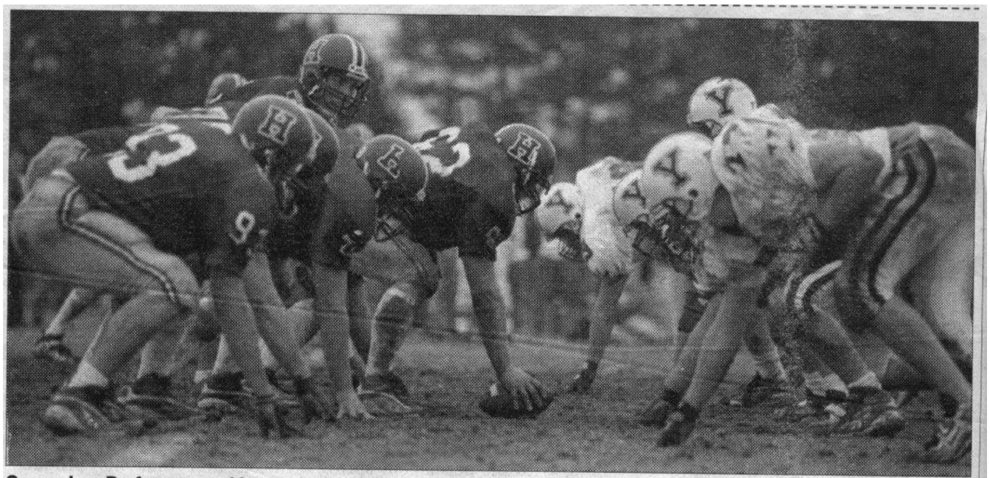
From my perspective, one of the unique characteristics of this debate is that it is a point worthy of consideration at all. In many of the established universities, the hiring of academic lecturers is biased towards past research publications, and the ability to attract future research grants. For this reason, it is common in UK, Australia and NZ universities to provide compulsory introductory courses in teaching for all staff. The realisation being that the staff are by default motivated, independent researchers used to setting their own goals, but perhaps have little idea about what motivates others to learn. Our problem at Karlstad University which until recently was best described as an almost exclusively teaching-only institution is quite the reverse. We did however start life as a teacher training school, and now perhaps we are in the adolescence time moving towards a mature university.

The immediate problem with establishing the value of research in teaching is that a quantitative assessment of teaching becomes inevitable. The difficulty is how to undertake this assessment reliably. Paul Trout, professor of English at Montana State University argues in *The Guardian Weekly* that students are inappropriate to assess academic staff.[8] His analysis of the average student is considerably damming, and he regards the student numerically based evaluation scores of teacher merit forces academic staff to become less demanding, create workloads less taxing and lower grading standards. Trout, even in his capacity as a columnist in National Forum does not however offer any solutions, only the recommendation that the present system be dismantled. Finally, it is interesting to see how *The Guardian Weekly* views American university students, at least as far as their accompanying illustration (reproduced in Fig. 1) tells us anything.

Naturally not all agree with this pessimistic view of undergraduates. This attitude is in direct opposition to findings such as Ramsden who argues that students are mature enough to distinguish between the popular and the competent, and with the proper controls, "using student ratings like this also happens to be potentially fairer and less threatening to individual members of staff, particularly junior ones." So how do the students at our institution rate? The small informal survey I carried out that asked who was to be preferred between a competent pedagogue delivering a 'standard level' course and a top-notch researcher giving a technically advanced course. I observed that the students tended to gravitate to the pedagogue. We do see a swing in this attitude towards the researcher and the challenging course in the third year, but this is not exclusive. A concrete example of this is in our 3rd year of the electrical engineering program where we have 38 choosing the VHDL course while only 8 take the considerably more difficult digital signal processing course. Similar numbers take analogue electronics in favour of the technically advanced antenna course. This has interesting implications given that our local electronics industry is heavily invested in DSP, signal processing, design of efficient antennas for mobile phones, wireless communication etc. Have our students lost the gamble of a challenge?

The attention to detail, the cross checking, validation or simply 'pedanticness' valued by researchers while positive attributes, quickly turns sour if over done in the context of an undergraduate engineering education. Attention to detail is something my colleagues and I struggle with in the first few years of undergraduate teaching. This is particularly noticeable in the commenting and documentation of computer code, the completeness of specifications for design of experiments, following templates for laboratory reports for example, which are on average undervalued by the students and hence poorly executed. The detrimental effects of an enthusiastic slavish attention to detail is to stifle an innovative approach to problem solving, discourage changing the question if it turns out that it was inappropriate from the beginning, and perhaps most importantly, the loss of any overview of the problem. To paraphrase 'If it is not

[8] Paul Trout, *Spring Fervour*, Guardian Weekly, March 23-29 2000. (See accompanying article on page 8)



Game plan: Professors seeking perfect ratings should 'teach nothing and give 66% of students As' Photograph: Al Bello

Figure 1: Illustration accompanying Paul Trout's article on the student assessment of US college professors. The caption reads: "Game plan: Professors seeking perfect ratings should 'teach nothing and give 66% of students As' ".

worth doing, it is not worth doing well.'

It is not that our students have lost their imagination, innovation and inventiveness, but they do hide it well. My own teaching style could be described as mildly confrontational which demands that the student *stand and deliver*, something I understand is avoided in Swedish society. A typical lecture consists of 30 individuals trying to hide. But later, in the laboratory after hours, I find groups of students fabricating circuit boards, programming EEPROMs and micro-controllers, deciphering scant documentation (in English), some of whom I know have yet to pass the relevant embedded system courses, all without any supervision. To this day I have no idea what was produced, except that it supposedly interfaced between a parabolic antenna and a TV (to improve the reception, you understand).

4 Do research skills make better engineers?

If the generally accepted skills that are a necessary pre-requisite for an academic can both have positive and negative impacts on students, then this is probably true in the reciprocal case.

Research skills have the potential to address what I perceive as a loss of imagination that occurs somewhere in the Swedish education system. It is important to note that I do not believe that this loss is irrevocable, but that particularly the traditional large-scale anonymous lectures and examinations stifle a questioning lateral approach. It is just not efficient for the students in this environment to apply these characteristics. It appears that they conform for the duration and obtain their objective - a university diploma. Such behaviour has also been noted in the UK where Cowan notes that while civil engineering students could competently number-crunch, they lacked what he termed qualitative understanding. A research component could address this failing.

Once outside the lecture room where the questions are more varied, and results less quantifiable, these skills return. Students taking part in something that is new and industrially relevant generate considerable enthusiasm. One of the positive comments I've heard is when a young graduate student was asked by a senior member from industry if they were happy with the topic, their response was that if industry considered the problem important enough, then this was quite exciting.

It is important to remember that students are the university's capital. We use diploma students to assist in the PhD studies by pursuing a small subtopic. Often this topic may have limited chance of success, and for that reason we would be hesitant to put the graduate student on this work. However the demands for a successful outcome are less for an undergraduate, and one still is exposed to the educational aspects of research listed previously. For example in one project investigating the production of the cellulose derivative CMC, we needed to establish correlations, if any, between final product and incoming raw cellulose. We were not quite sure what to look for, and we anticipated some tedious laboratory analysis. It must be addressed, but should we gamble the time of our PhD graduate?

5 Inappropriate research topics

Clearly some research topics are not suitable for general digestion. These include topics that are flavour-of-the-month, but unfortunately perhaps last month. Sometimes it takes time to spot current new ideas for what they really are. In many cases they are variations on well established themes, that may have certain advantages, but only in specialised cases. Examples in the automatic control area, (the specific area of interest to the author) could be neural networks, expert systems, fuzzy control.

Other inappropriate topics include those that are not relevant to our locale or overly specific topics that cannot be generalised. These may be interesting relevant research topics, but not likely to be of interest to our students if they are to remain locally, something that our university should always consider. Some concrete examples of this nature in the automatic control and modelling area are the study of DAEs (differential and algebraic equations) when solving simulation systems involving large-scale distillation columns (we model pulp & paper production which has quite different characteristics), underwater welding (oil & gas platforms), and industrial crystallisation (of sugar/alumina). Environment issues are always interesting to Sweden, but topics such as estuary ecosystems, heavily polluted water systems such as in Eastern Europe are not relevant.

6 The role of research in the undergraduate education

The technical undergraduate education in many universities is well established and is often substantially the same as that of at least two decades ago. A quick survey of course literature from our department showed many texts from the 1980s and we still deliver most of the information using the classical lecture model with exercise hours and laboratories to classes of around 20 to 80 students. What is also revealing is that the general feeling of the teaching staff is that while this method may not be optimal, no one has very clear and convincing alternatives.

What has changed however is the nature of university research. One of the drawbacks with traditional academic research is that each researcher must ultimately work independently. The PhD is awarded to an individual who shows a capacity for a substantial individual intellectual contribution. This conflicts with commercial research and especially industrial engineering where teamwork is highly valued. However recently the funding bodies, (particularly EU 5th framework) are encouraging collaborative ventures, particularly across disciplines and even geographical locations. This is an encouraging sign since a single individual's capacity to make a significant contribution in the science and engineering areas is rapidly drawing to a close.

For Karlstad University and other similar young institutions of higher learning, I would recommend to choose carefully what areas to invest research effort in. The research should be relevant to our local situation, be organised in groups to obtain some critical mass and tightly focussed. Ideally the participants should exhibit a linear graduation of expertise and experience, and it is advantageous to combine many different backgrounds. This latter desire is one way a small, centralised university such as Karlstad can compete with older, larger and geographically separated institutions where academics have little need, and show even less desire to collaborate with those outside their corridor.

Final thought for the day: Somewhere along the way, perhaps we as adults have forgotten how to play? What do you think the accounting department said when they were presented with an invoice from the local toy store? It paid for this.

Figure 2: What do you think the accounting department said when they were presented with an invoice from the local toy store? It paid for this.

References

Paul Ramsden, *Learning to Teach in Higher Education*, (1992) Routledge, `www.sri.com/policy/stp/erc/contents.html`

John Cowan, *On Becoming an Innovative University Teacher: Reflection in Action.* The Society for Research into Higher Education & Open University Press, (1998)

Ronald Barnett *Higher Education: A Critical Business* The Society for Research into Higher Education & Open University Press, (1997)

Spring fervour: US college students have a big say in how lecturers are graded, and it affects standards, argues Paul Trout[9]

At the end of the spring semester, college students throughout the United States will rate their instructors on how well they knew the course material, showed "concern" for students, graded "fairly," etc. Administrators will then crunch the numbers and use them - with other material - to decide whether instructors deserve pay increases, retention, tenure and promotion. Procedures differ from campus to campus, but evaluation scores are almost always the primary way to assess teaching. The use of numerical forms to reward and punish instructors is supposed to improve teaching, but in reality it is doing more to dumb it down than any other policy or practice on campus. Here's how it works. Every year I compete with my colleagues for a share of merit-pay money. The amount I get depends on how a committee of colleagues evaluates the quality of my work in three areas: service, scholarship and teaching. If I "meet expectations," no bonus money, but if I "exceed expectations" in a category, I get a share. I do best, of course, if I "exceed" in all three. In my department, to "exceed" in teaching, I have to receive scores of at least 3.6 on a scale of 4. To get scores this high, I have to make a lot of students happy. There's the rub.

What makes many students happy nowadays? "Understanding" and "friendly" instructors, "comfortable" courses and "fair" grades. To translate: teachers who are not demanding, workloads that are not taxing and grading standards that are not high.

Studies have found that students give lower ratings to instructors who have high standards and requirements — two attributes closely associated with student learning. One study found that for every 10% increase in the amount of material students learned, the professor's rating decreased by a half-point. The researcher advised professors seeking a perfect rating "to teach nothing and give at least 66% of the class As." Many college students are unprepared for the rigors of higher education. Growing numbers cannot read, write or compute proficiently and have, at best, only a weak grasp of basic historical and cultural information. Students with these handicaps rarely appreciate being made to read, write and reason cogently.

Even worse, many students now coming to college have almost no desire to learn or understand things outside their narrow vocational interest. According to a UCLA survey, 40% of each freshman class is "disengaged" from educational values and pursuits. Students are inattentive, easily bored and unwilling to work hard, especially on difficult or abstract material outside their interests. Because of numerical evaluation forms, these students have a powerful say in how hard they are worked and graded. To get high scores, most instructors have to please them, or at least not upset them. Even a few students, angry about a demanding workload (or a C grade) can have a devastating effect on evaluation scores simply by giving an instructor "zeros". Untenured and part-time instructors are especially vulnerable, because low evaluation scores can threaten their jobs. A few years ago an untenured faculty member told me that after receiving low scores, he consciously made his course easier. "I watered it down," he said. "If I weren't afraid of these teaching evaluations, I would have done it differently. " Tenured professors — as reward-driven as anyone else outside a Trappist monastery — can also cave in to the perverse incentives of the reward system. If even Mark Edmundson, a six-figure full professor at the University of Virginia, complied with student demands for "comfortable, less challenging" classes - as he admitted doing - what sort of heroic resistance can be expected from those trying to reach a salary of $50,000 before retirement? No one can say precisely how many instructors have dumbed down their courses. But an extrapolation from one study would suggest that a third of the 900,000 instructors in higher education may have eased their requirements and standards. If this system is to be dismantled, it will be up to US taxpayers, parents, legislators, public-interest law firms and alumni to

[9]Paul Trout is a professor of English at Montana State University, Re-printed from The Washington Post Post and The Guardian Weekly 23-March-2000, page 24

bring about changes.