Industrial relevance in Engineering Education: Solving the accreditation faculty resource dilemma

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Abstract. *Universities throughout the world must increasingly demonstrate their ability to satisfy the conflicting needs of their faculty, students, the potential employers of those students and the criteria and requirements for programme accreditation. The attention of governments and employers has led to an increasing awareness of the vital importance of providing engineering students with an industrially relevant design experience. Unfortunately this provides a resource dilemma for time-constrained, research-oriented engineering faculty that can only be solved with validated design and analysis methodology already used by industry. This paper presents the globally recognised, validated ESDU data and software collection and discusses how that data are already used cost effectively by over 120 universities worldwide to help fulfil teaching and accreditation requirements with minimum faculty time.*

Author Profile

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Introduction

Universities throughout the world must increasingly demonstrate their ability to satisfy the conflicting needs of their faculty, students - and the potential employers of those students.

Todd et al (Reference 1) reported the results of a survey of engineering employers that summarises frequently cited industrial perceptions of the weaknesses of recent engineering graduates: lack of design capability or creativity, lack of understanding of manufacturing or quality processes, narrow view of engineering and related disciplines, weak communication skills or experience in teamwork.

Prados et al (Reference 2) note that "*by the late 1980's, engineering employers and visionary educational leaders were recognising that effective preparation of engineers for twenty-first century practice demanded fundamental changes in the dominant engineering science paradigm*" and that "*this emphasis had produced graduates with strong technical skills, but that these graduates were not nearly so well prepared in other skills necessary to develop and manage innovative technology*". This excellent paper concludes, "*in recognition of these needs, engineering universities and their relevant accreditation bodies developed more appropriate programmes that retain the strengths of the engineering science approach while compensating for its limitations*". Many of these models were "warmly received" by industry but not widely adopted by most institutions "*because of their faculty labour-intensive character and inconsistency with the academic research culture that dominate most large [U.S.] engineering schools".* Inevitably, this faculty resource dilemma extends beyond North America and is global in nature.

A European commission paper, presented in Bergen in May 2005 at a conference of European Higher Education Ministers entitled "Realising the European Higher Education Area – Achieving the Goals" (Reference 3), states "*our universities face bigger challenges and stronger competition than ever before"* and "*A quick look at the figures tells us that the situation is alarming".*

The conference stated that it was "*going to take decisions which will be decisive for the architecture of the European Higher Education area*" concerning quality assurance and the European qualifications network. In particular, it stated that the Commission were supporting sector-led projects to establish European Quality labels in Engineering (and Chemistry).

Accreditation

The EUR-ACE Accreditation of European Engineering Programmes and Graduates (see www.feani.org) issued Document A1-en (November 17th 2005) that provides "EUR_ACE Framework Standards for the Accreditation of Engineering Programmes" (Reference 4). The principal aim of this project is to develop a framework for the accreditation of engineering degree programs in the European Higher Education Area.

Reflecting recent changes in accreditation philosophy, the proposed framework describes the Program Outcomes of an accredited programme but do not prescribe how they are achieved. Thus universities retain the freedom to formulate their programmes with an individual emphasis and character and include new and innovative elements. It is emphasised, however, that there must still be a strong element of industrial relevance to properly prepare students for the practice of engineering design as well as understanding the elements of theoretical analysis.

For the Chair of every University Engineering department, this presents an inherent faculty time and resource dilemma. The strategy and needs of most faculty members striving for promotion, and eventually tenure, are not usually compatible with the teaching of the industrially relevant courses necessary for the accreditation of the department's degree programs. Most faculty members have a very strong research background but typically have relatively limited current practical industrial experience of the activities and practices relevant to the interests of their industry-bound students.

The EUR_ACE Framework Standards for the Accreditation of Engineering Programmes

The EUR_ACE framework lists six Programme Outcomes for accreditation:

- Knowledge and Understanding
- Engineering analysis
- Engineering design
- Investigations
- Engineering practice
- Transferable skills

and the

- Criteria and Requirements for Programme Assessment.

Six Programme Outcomes for accreditation

Knowledge and Understanding

The EUR_ACE framework states:

"The underpinning knowledge and understanding of science, mathematics and engineering fundamentals are essential to this outcome. Graduates must be able to demonstrate their understanding of their particular engineering specialisation and also that of the wider context of engineering."

For a Faculty member whose expertise is usually concentrated in the specific topics of their research specialisation, significant time will be required to prepare to properly teach a variety of topics "in the wider context of engineering".

Engineering Analysis

The EUR_ACE framework states:

“Graduates should be able to solve engineering problems consistent with their level of knowledge and understanding, and which may involve considerations from outside of their field of specialisation. Graduates should be able to use a variety of methods, including mathematical analysis, computational modelling or practical experiments and the ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods. Higher degree level programs also require that graduates should have the ability to formulate and solve problems in new and emerging areas of their specialisation and to apply innovative methods in problem solving.”

It is very hard to disagree with any of these outcomes. But does the research-driven Faculty member have the time to keep fully up-to-date with the areas outside of their subject specialisations or the new and innovative techniques emerging in industry? Would significant time spent on such commendable and interesting knowledge contribute to tenure? Sadly, it rarely does.

Engineering Design

The EUR_ACE framework states:

“Graduates should have the ability to apply their knowledge and understanding to develop and realise designs to meet defined and specified requirements, an understanding of design methodologies, and an ability to use them. Higher degree level programs also require that graduates should have an ability to use their knowledge and understanding to design solutions to unfamiliar problems, possibly involving other disciplines and to use their engineering judgement to work with complexity, technical uncertainty and incomplete information.”

Teaching design must therefore contrast the theoretical underpinning of design methodologies with their implications for the designed system operating in its actual environment. The research-oriented Faculty member must therefore spend significant time projecting (and possibly gaining) a practical understanding of the quite distinct thought processes and philosophy of engineering design – as practised in industry. Alternatively, he/she must have access to industrially relevant teaching tools (including software) that the student can easily use to rapidly assess the performance of numerous design alternatives and gain vital experience of the design process.

Investigations

The EUR_ACE framework states:

“Graduates should be able to use appropriate methods to pursue research or other detailed investigations of technical issues consistent with their level of knowledge and understanding. Investigations may involve literature searches, the design and execution of experiments, the interpretation of data and computer simulation. Higher degree level programs also require that graduates should have an ability to identify, locate and obtain required data and to design and conduct analytic, modelling and experimental investigations. Further, they should have the ability to critically evaluate data, draw conclusions and investigate the application of new and emerging technologies in their branch of engineering.”

To conduct these investigations, the student must have access to appropriate data, computer simulation software and the tools to conduct analysis and modelling investigations. To introduce new and emerging technologies into lectures, the faculty member can include their own research work - but must also have examples of the methods actually used in Industry if they are to satisfy the accreditation requirements.

Engineering Practice

The EUR_ACE framework states:

"Graduates should be able to apply their knowledge and understanding to develop practical skills for solving problems, conducting investigations and designing engineering devices and processes. These skills may include the knowledge, use and limitations of materials, computer modelling engineering processes, workshop practice and technical literature and information sources. They should have the ability to select and use appropriate equipment, tools and methods, the ability to combine theory and practice to solve engineering problems and understanding of applicable techniques and their limitations. Higher degree level programs require a comprehensive understanding of applicable techniques and their limitations."

This requires that a significant portion of the curriculum provides the opportunity for the student to use - then subsequently learn to judge the use of - appropriate (i.e. industrially-relevant, validated) engineering tools and methods. As noted previously, research-oriented Faculty members may not have relevant current experience of the practical application of engineering theory and will require time and/or resources to gain sufficient understanding to be able to effectively teach such courses.

Transferable Skills

The EUR_ACE framework states:

"The skills necessary for the practice of engineering should be developed within the programme. Graduates should be able to function effectively as an individual and as a member of a team"

Major portions of the objectives for the transferable skills outcome of the programme are inevitably achieved by a group design project where students work together on an open-ended project. This course is typically taken during the final semester/phase of the degree at the same time that many students are seeking employment. To provide an appropriate variety of projects for the students to be creative, the Faculty member must have the support of an extensive network of analysis and design tools available. Given the importance of demonstrating industrial relevance for accreditation, it is also logical to adopt a resource actually used by the very companies who will be interested in employing graduates capable of using them. When one also considers the huge amount of precious time it would otherwise require the faculty member to create these tools themselves, without significantly enhancing their path to gaining promotion/tenure, the argument for introducing existing tools becomes overwhelming!

Criteria and Requirements for Programme Assessment

Excerpts from The EUR_ACE framework also states that the needs, objectives and outcomes of the programme must identify and satisfy the needs of interested parties (students, industry, engineering associations etc.) and that the educational objectives of the programme must be proved to be consistent with the Higher Education Institution's mission and these interested parties.

The Institution must obviously ensure that the previously stated programme outcomes are achieved by the specified curriculum. Similarly, the resources must include computing facilities, libraries and associated equipment available to students.

The educational process is partially assessed based on whether its graduates enter an occupation corresponding to their qualification. Further, the 'stakeholders' (graduates, industrial employers etc.) confirm the achievement of the programme's educational objectives.

Clearly these criteria require the university to seriously consider the industrial relevance of their curriculum and its resources.

Industrial Tools used in University Education

The foregoing examination of the accreditation criteria, that [European] universities must satisfy, clearly demonstrates the need for industrially relevant, validated engineering design/analysis methodology that faculty members will have limited time and motivation to produce themselves. Consequently existing ‘industrial tools’ that might be easily and rapidly adapted for university education must be considered.

Many successful computer software (and hardware) companies invest in future customers by offering wide access to their products for universities by providing unlimited access with significant price discounts. There is a realistic expectation that the best graduates will progress rapidly in companies and subsequently manage significant project budgets that will require tools with which they are personally familiar. Indicative of this, one usually encounters graduates talking about commercial software such as Autocad (et al) and Excel rather than 'computer-aided drafting' and 'spreadsheet' software.

Increasingly, companies producing such software must address the question of user training by producing tutorial-type examples and interactive 'walk-through' demonstrations. These features are important attributes for both industrial users and the harassed Faculty member!

However, building courses around specific software can be hazardous. Software inevitably becomes obsolete or a better product may appear. More significantly, industry's expectations are not satisfied and the newly appointed graduate is usually sent on a training course to study the most recent version of the software actually used by that company. As noted, companies want experience and an understanding of engineering design that enables the student to understand the relevant theory, its application, its limitations and the practical/empirical significance of applying the actual techniques used to develop the company’s products. It is no coincidence that these are the very educational objectives for an accredited program noted in the six program outcomes above!

Even a superficial review of the various ‘design guides’ (entering, for example, the keywords “Engineering design guide” in one of the Internet search engines) provides a plethora of options. For an excellent in-depth review and facilities for access to such resources, the EEVL project (see http://www.eevl.ac.uk) is recommended.

However, in the many safety critical industries (aerospace & aeronautical, nuclear etc.), Engineers must use validated methods and material properties that are globally recognised in order for their products to be certified for use. In more ‘general’ industries, increased regulation (and the all too common threat of litigation if a design fails) is also forcing businesses to use engineering methods whose value and integrity are proven. A university seeking to attract students and gain accreditation will therefore wish to demonstrate that their curriculum includes such recognised methods. If, however, one reviews validated engineering design guides used in Industry then the choice of genuinely validated resources that will fulfil the accreditation requirements is greatly reduced. One of the few such resources is provided by ESDU.

ESDU Data

ESDU provide subscription-based validated and authoritative engineering design data, methods and software for the engineer. These are presented in over 1380 electronically-delivered documents with supporting software (with source code available) and are the result of more than 66 years experience of providing engineers with information, data and techniques for fundamental design and analysis. Endorsed by professional institutions, ESDU data and software form an important part of the design operation of companies large and small throughout the world and is globally accepted throughout the aerospace industry.

Significantly used by international aerospace companies (including Airbus, Boeing, Lockheed-Martin, BAE Systems, Saab, EADS etc.), it is widely considered to be the most accurate, up-to-date and comprehensive collection of validated data and methods. This represents a vast resource of design guides, analysis software and test methods that are also widely used by non-aerospace companies providing services or producing a wide variety of products.

Formerly the technical department of the British Royal Aeronautical Society, ESDU is the only collection of validated data of its kind in existence. ESDU provide design data and methods for aerospace, mechanical, chemical, civil, structural engineering with particular applications in the petrochemical, water re-use plus the crucial MMDH aerospace material database.

Within these engineering disciplines, the content is divided into 23 topics, known as "Data Series". Each "Data Series" is produced by ESDU's resident engineers and, crucially, validated by committees of independent, unpaid experts drawn from a broad range of industrial, academic and research backgrounds. Information is presented in a clear and concise format and is the result of careful distillation of large information sources. There is a strong emphasis on the use of unpublished information taken from sources only available to ESDU – a direct result of key communication links with industrial companies and academic institutions. Faculty, students and industrial subscribers have the opportunity to consult ESDU engineers and ask questions on published data or request information on related topics. ESDU is owned by IHS (Information Handling Services) of Englewood, Colorado, USA and operates from London, UK.

But, despite the depth and breadth of this type of data and its obvious benefits for the accreditation, can it be easily and readily adapted for educational uses to solve the engineering department chairperson's faculty member's time and resource dilemma?

Inclusion of ESDU data in the engineering curriculum

Currently, over 120 universities include ESDU data in their curriculum as a means to equip students with the necessary tools and knowledge used extensively in industry. There are three ways in which ESDU data are included in the university teaching curriculum:

(1) Data cut-and-pasted from documents (called Data Items) included in lecture notes, handouts, visual aids, etc.

(2) Coursework assignments that use ESDU data and its associated software

(3) Project or thesis work (usually final year undergraduate or postgraduate) utilising the definitive industrial methods described in ESDU data.

Mechanical engineering disciplines covered by ESDU include: engineering materials and plasticity; thermofluids; solid and structural mechanics; design for manufacture/advanced machinery design; design of machine elements and power transmission; fatigue and fracture mechanics; composites; mechanical vibrations and noise; heat transfer; tribology and mechanisms.

Aerospace engineering topics include: aircraft performance and aerodynamic design; aerospace structures and aeroelasticity; aircraft dynamics, stability and control; computational fluid dynamics.

Chemical engineering and environmental science material includes: process integration; heat exchanger design including crude oil fouling, internal flow; and physical data properties.

Civil engineering interests include: wind engineering; water re-use; building and structural responses.

The inclusion of the widely used Metallic Materials Data Handbook (MMDH), a database used widely in aerospace engineering work (European equivalent to MIL-HDBK-5E Handbook), is an important resource for material science and mechanical engineering faculty.

The contents and organisation of the ESDU Data service, including software, are described in Appendix A. See also the Web site at www.ihsesdu.com.

(i) Adaptation of course projects provided in the ESDU University Guide

To assist time-constrained faculty with course development, a constantly updated "ESDU University Guide" is provided. In addition to highlighting relevant data for each engineering discipline, it provides examples of teaching modules and course assignments that may be cut, pasted and subsequently adapted for the teacher's particular work.

For example, students taking a machine design course might be required to design a planar linkage mechanism capable of producing a specified output motion. Each student is given an individual set of design constraints and target output motion. Therefore students may usefully work together without fear of plagiarism and the teacher will receive a variety of projects improving his/her "enjoyment" of the grading process.

This type of project is only possible where the software is readily available, easy to use, validated and includes clear examples of its use. Enthusiastic, gifted students having access to theory, analysis and data dealing with associated topics can easily extend the scope of the project. In this example, kinematic and kineto-static analysis of the linkage is easily carried out using the OSMEC software while balancing and structural analysis software may be included in the project using methods fully described in the ESDU Mechanisms and Stress/Strength Series, respectively. Similarly, bearing design is carried out using data from the Tribology Series and link component life may be estimated via the Fatigue:Endurance Series etc.

(ii) Creation of course notes and handouts

In an experience common with many junior Faculty, I was given six days notice and 'an instruction to volunteer' to teach the Dynamics of Machinery course (the Professor normally responsible for the course had changed his plans!). Not having studied the subject for many years, let alone taught it, I spent many hours re-assessing the topic, creating course assignments, lecture notes, viewgraphs and handouts without a real sense of what the students would need from the course if they had to actually apply the course content. With access to the Data Items and software in the ESDU Dynamics Series, my preparation would have been quicker, easier and my eventual delivery of the course greatly enhanced. In particular, the software would have formed a significant part of the three course assignments and the theoretical principles would have been discussed in terms of the behaviour of aircraft rather than the abstract example of a pendulum!

Creating handouts is quick and easy when one can cut-and-paste sections of validated text from an ESDU document into the word processor where the teacher adds his/her own particular comments and enhancements. All documents contain representative sketches, figures and photographs that may be cut-and-pasted as bitmaps or easily converted to viewgraphs. <u>There are no significant copyright restrictions on the educational use of this data.</u>

(iii) Use of computer software source code (ESDUpacs)

There are approximately 160 computer programs available within the ESDU data collection. Source code is available for over 90% of these programs that may be adapted or extended by faculty and students for a variety of uses. This opportunity is particularly applicable to graduates working on a project or thesis as part of a Masters Degree or Doctorate.

(iv) Development of new courses

As University departments evolve and faculty members come and go, the need arises to develop new courses and degree programs. The availability of validated, industry-standard data and software significantly eases this process. The advantages of ESDU Data in the earlier example of a faculty member having to teach an unfamiliar subject at short notice are even greater in the case of a department looking to demonstrate resources when proposing a new program. It is relatively rapid and straightforward to compile an impressive document by cutting and pasting text from both the data and the "ESDU University Guide”!

(v) Enhancing teaching by providing greater variety and depth

Throughout this discussion, the benefits of ESDU data are presented as a solution to the faculty time and resource dilemma. Typically, this dilemma faces relatively junior Faculty yet to gain tenure. However, most faculty care deeply about their teaching and derive great personal and professional satisfaction from imparting knowledge and helping to guide their students toward a greater understanding and enthusiasm for the engineering profession.

Such professionals will not wish to give the same lectures that they were subjected to as students! With the breadth and depth of the ESDU Data Series, it is much easier to develop new and interesting assignments that change each year. Since faculty members are encouraged to consult the ESDU engineers, they are actively supported and kept informed of new Data Items and amendments to old Items (as obsolete or superseded analyses and design techniques are removed or updated).

One may also attempt more ambitious (computer-based) problem solving projects without needing to use lecture time to describe the underlying theory behind the software. This may be achieved by referencing (or requiring the students to study as course work) the theory and its application that is clearly presented in the associated Data Item. One may also set more open-ended projects where the students are given a task and have to search through databases (not just ESDU) and use their initiative – exactly the way that they will be expected to work if they progress to industry.

(vi) Research proposals

When submitting research proposals, the proposer must demonstrate the current knowledge of the topic that he or she intends to extend. Since ESDU data consists entirely of validated documents that describe the 'state of the art' in a particular specialised subject area, it is often very effective to cut-and-paste the relevant sections (typically the introduction/synopsis and the references) from the Data Item straight into the research proposal document.

(vii) 'Short Course' provision

As universities seek to broaden their links with Industry, enhance their reputation and income and maintain information resources with shrinking library budgets, the provision of short courses is emerging as a highly cost-effective activity.

Since ESDU Data Items are "intended to be bring a generally-educated engineer into an area of specialisation" then it is clear that an enormous variety of short courses may be easily created using a set of linked Data Items from one or more 'Series'. The material necessary to present such a course is drawn from the Items as easily and rapidly as the traditional teaching material described earlier.

Existing university clients have already demonstrated that they recovered their annual ESDU subscription by providing as few as two short courses!

ESDU are currently developing a sample short course to be included in the "ESDU University guide".

ESDU has three experienced former University faculty who provide short courses in Aerodynamics, Mechanisms, Fatigue, Mechanical joints design and Process Engineering Technology.

(viii) Meeting accreditation criteria

The implications of using validated data also play a significant part in meeting the programme's accreditation criteria. Considering the six programme outcomes for accreditation noted above.

All ESDU Data Items describe and assess the application of industry's current knowledge and understanding of science, mathematics and engineering fundamentals in the wider context of engineering.

Over 1000 ESDU Data Items consider the mathematical analysis and application or interpretation of experimental data and its relationship and use with relevant theory. These Items provide examples of the application of such theory and thereby illustrate the ability to identify, formulate and solve engineering problems. Indeed the very problems that the student will face when entering employment!

Over 200 ESDU Data Items form an essential part of the design activities of many major engineering companies, supported by all of the analysis Data Items. The further requirement that higher degree level programmes should provide experience of designing solutions to unfamiliar problems is ideally solved by ESDU – since providing this type of solution is their raison d'etre!

All Data Items concentrate on the accuracy, applicability and assumptions of the relevant engineering theory and its use in practice. Consequently most Items discuss complexity, technical uncertainty and how to deal with incomplete information or an ill-defined design specification.

The ESDU data collection is itself an important part of the industrial literature as well as providing validated tools for the design and execution of experiments, the interpretation of data and programs for computer simulation. Similarly, Data Items provide the ability to critically evaluate data, draw conclusions and investigate the application of new and emerging technologies in the many branches of engineering.

Since ESDU data is a significant part of the approved engineering practice and methods for over three hundred globally-recognised engineering companies, its contribution to the students' exposure to industrially-relevant engineering practice is clear to both employers and accreditation bodies!

As noted, the transferable skill of working as part of a design team is best gained by taking part in a group design project that requires the availability and selective use of industrially-relevant design and analysis tools. ESDU provides these tools for design teams working in industry – so what better way is there of providing students with a realistic transferable skill that they can talk about during their interviews with prospective employers!

Conclusions

This paper discusses a solution to the time and resource dilemma that faculty seeking promotion and tenure inherently face.

The ESDU data service is presented as a solution that can be cost effectively applied to numerous time-consuming educational activities.

The significant contribution of an ESDU subscription towards satisfying the crucial accreditation criteria has also been highlighted.

There can never be a total solution to the faculty time and resource dilemma but the ESDU data service provides a very significant contribution.

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3. EUROPEAN COMMISSION "Realising the European Higher Education Area – Achieving the Goals", **Conference of European Higher Education Ministers**, Bergen, 19/20 May 2005.

4. EUR-ACE "Document A1-en (FINAL)", ***EUR-ACE Framework Standards for the Accreditation of Engineering Programmes***, November 17th 2005.

Appendix A - The ESDU Basics

ESDU produces documents presenting engineering methodologies that are available from the www.ihsesdu.com Web site. Alternatively, they are available in both 'hard copy' form and on CD-ROM.

At the time of writing, ESDU Data is divided into 23 *Series* with more than 315 *Volumes* containing over 1380 *Data Item* documents with over 160 *ESDUpac* FORTRAN calculation source codes and over 100 *VIEWpac* PC executable codes.

ESDU divides the engineering information into Series, each covering a particular engineering discipline. The Series are organised into Volumes. Each Volume comprises a number of self-contained but related design and analysis methodologies (Data Items) covering a specific engineering component or topic with, in many cases, associated computer programs.

Data Items	A self-contained design and analysis guide covering a specific engineering component or problem with, in many cases, associated computer programs (*ESDUpacs* and/or *VIEWpacs*). Supplied as: Adobe Acrobat PDF files on the Web site or CD-ROM. Hard copy loose leaf documents within a *Volume*,
Volumes	A collection of related *Data Items*.
Series	A collection of related *Volumes*.
ESDUpac	A computer program to perform a specific engineering calculation associated with a specific *Data Item*. ESDUpacs are written in strict ANSI 77 FORTRAN and are supplied as source code. All ESDUpacs are file input/ file output originally designed for batch processing. Subject to the licence agreement subscribers are free to modify the ESDUpac source code and/or incorporate it into their own programs. Supplied as ASCII source: in colour-coded HTML on this site, in a ZIP file, downloadable from this site, on a PC format CD-ROM.
VIEWpac	An application program to allow one or more *ESDUpacs* to be run in a 'user friendly' manner. The VIEWpac contains all the information necessary to write the input file(s) for the associated ESDUpac(s) and, in some cases, to interpret the resulting ESDUpac output file(s). Note that not all ESDUpacs are accessible within VIEWpacs. Most VIEWpacs are available to run under MS-DOS running within the ESDUview program. Some are supplied as Microsoft Excel spreadsheets or as Windows programs. Supplied as PC executable codes: In a zip file, downloadable from the Web site, for the non-ESDUview codes (i.e. Excel spreadsheets and native Windows applications) On a PC format CD-ROM.