Introduction to the Pedagogic Research Tool Kit

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Acknowledgements:
The engCETL and the Engineering Subject Centre have collaborated on developing a programme of support for engineering academics in the area of Pedagogic Research. Following a number of successful introductory workshops attracting over 75 delegates from across the UK, this tool kit has been written to capture the resources and key lessons learnt. We would like to thank Professor George Brown, University of Nottingham, and Professor Mike Bramhall, Sheffield Hallam University, for their valuable contributions to the workshops and consequently this publication. Thank you also to the workshop participants who have helped us to identify the resources most useful to engineering academics wanting to get started in pedagogic research.

We are grateful to the Higher Education Academy for providing funding for the development and publication of this tool kit as part of their programme to support collaboration between Centres for Excellence in Teaching and Learning and Subject Centres.

Alternative Formats:
This publication can be downloaded from the Engineering Subject Centre website www.engsc.ac.uk
Please call 01509 227170 for alternative format versions.

Contact details:
The Higher Education Academy Engineering Subject Centre, www.engsc.ac.uk
The engCETL, www.engCETL.ac.uk

Published by the Higher Education Academy Engineering Subject Centre


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Overview
Over a two year period the engCETL and the Engineering Subject Centre collaborated to develop a programme of support for engineering academics in the area of pedagogic research. Using expertise within the two Centres, we ran a number of successful two-day introductory workshops and have now published this tool kit in order to extend and provide wider access to resources created for the workshops.

The tool kit comprises a series of briefing papers linked to examples of pedagogic research and evaluation from the engineering disciplines:

- **What is pedagogic research?**
  This paper explains key terminology and the different levels of engagement that may take place.

- **Writing for publication**
  This paper draws from the top tips collected from engineering academics who attended the workshops. It refers to the refereeing and submission guidelines for both engineering education and general higher education publications and suggests a number of possible outlets for pedagogic research writing.

- **Bibliography**
  This paper is a beginner’s guide to finding pedagogic research literature, accessible educational research-methods books and writing handbooks.

- **Research methods in practice**
  This paper showcases pedagogic research and evaluation examples from engineering education, with a particular emphasis on the appropriate use of qualitative research methods.

- **Learning and teaching theory - Education theories on learning: an informal guide for the engineering education scholar**
  This paper provides a guide to some of the theories used when talking about education and what these mean for engineers. It is a starting point for developing teaching practice and understanding students.
What is pedagogic research?
What is pedagogic research?

Defining our terms – pedagogy
Pedagogy is a word that many people appear to find difficult (Cannon, 2001). Essentially it is about teaching and who is taught (Walker, 2006) or “the processes and relationships of learning and teaching” (Stierer and Antoniou, 2004, p. 277).

Booth uses pedagogy “to signify particular sorts of meetings between students, teachers and knowledge, where there is an intention to learn, [… and she intends it] to be less encompassing than ‘education’ which can include institutions, political and professional regulations, and the needs and demands of society, as well as pedagogy” (2004, p. 22).

Defining our terms – research
Research is “systematic, critical and self-critical inquiry which aims to contribute to the advancement of knowledge” (Bassey, 1989, p. 35).

“Research is finding out something and making it public. Research provides the means of generating, testing and validating knowledge. Research is a systematic process of investigation, the general purpose of which is to contribute to the body of knowledge that shapes and guides academic and/or practice disciplines. Research is about advancing knowledge and understanding” (Brew, 2001, p. 21).

Research is NOT ‘intelligence gathering’ (i.e. just finding out something you don’t know). It “goes beyond description and requires analysis. It looks for explanations, relationships, comparisons, predictions, generalisations and theories” (Phillips and Pugh, 2000, pp. 47-48).

Pedagogic research
“Evaluation studies are fundamentally about asking questions, and then designing ways to try to find useful answers.” (Harvey, 1998).

Pedagogic or educational research “is systematic and sustained enquiry, planned and self-critical, which is subjected to public criticism and to empirical tests where these are appropriate. […] Research is educational to the extent that it can be related to the practice of education” (Stenhouse, 1985, pp. 18-19).

Pedagogic research is NOT “reports of studies providing descriptive and anecdotal accounts of teaching developments and evaluations … Pedagogic research is firmly situated in its relevant literature and high quality pedagogic research makes a substantial contribution to that literature” (RAE generic statement, HEFCE, HEFCW, SFC and DfEL, 2006).

Some people write and talk in terms of education rather than pedagogy and educational research instead of pedagogic research (for example Cohen, Manion and Morrison, 2000; Opie, 2004; Stenhouse, 1975). This should not be problematic as it is difficult to separate pedagogy or teaching and learning from the context in which it takes place. Our work takes place within particular institutions, influenced by accreditation bodies and the needs of employers, for example. It is considered good practice in educational research to make the context of any teaching and learning and any investigation or evaluation of teaching and learning explicit.

It is possible to engage in different levels of investigation or scholarship in order to enhance our understanding of the student experience and our own practice. Table 1 shows the hierarchical relationship between research and other forms of investigation offered by Ashwin and Trigwell and Table 2 highlights forms or evidence-informed scholarship as offered by Prosser. However, it is important to be aware that only that which is rigorous with respect to research design, which “enhances our theoretical and/or conceptual understanding of teaching and learning, is firmly situated in its relevant
literature and makes a substantial contribution to that literature and/or field” (Prosser, 2005, p. 8), is considered research. To help inform the type of study you carry out and the way in which you present the information, you need to decide where you want to start and how much you want to contribute.

### Table 1: The hierarchical relationship between research and other forms of investigation (Ashwin and Trigwell, 2004, p. 122)

<table>
<thead>
<tr>
<th>Level</th>
<th>Purpose of investigation:</th>
<th>Evidence gathering methods and conclusions will be:</th>
<th>Investigation results in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>To inform oneself</td>
<td>Verified by self</td>
<td>Personal knowledge</td>
</tr>
<tr>
<td>2.</td>
<td>To inform a group within a shared context</td>
<td>Verified by those within the same context</td>
<td>Local knowledge</td>
</tr>
<tr>
<td>3.</td>
<td>To inform a wider audience</td>
<td>Verified by those outside of that context</td>
<td>Public knowledge</td>
</tr>
</tbody>
</table>

### Table 2: Forms of evidence-informed scholarship other than research (Prosser, 2005, p. 8)

<table>
<thead>
<tr>
<th>Investigations and evaluations</th>
<th>enhance our understanding of a local problem or issue, providing recommendations for policy and/or action firmly situated in the relevant literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature reviews</td>
<td>collection and analysis of literature aimed at describing the various ways in which the object of the review is thought about and recommendations for practice</td>
</tr>
<tr>
<td>Scholarship of teaching and learning</td>
<td>evidence-based critical reflection on practice aimed at improving practice</td>
</tr>
<tr>
<td>Surveys of academic staff and student experiences of teaching and learning</td>
<td>collection and analysis of current experiences of teaching and learning</td>
</tr>
</tbody>
</table>

**Engaging in pedagogic research**

Those of us who engage in pedagogic research are in a position to understand the best way to meet our students’ needs and to add to pedagogic knowledge from the context of our own subject area. Attendees at pedagogic research workshops, run for engineering academics by the Engineering Subject Centre and the engCETL, were asked “How might engineering students benefit if their lecturers know about and do some pedagogical research?” They responded that this would enable them to:

- make informed judgements about the best ways to present material to encourage student learning;
- respond appropriately if students have problems in learning;
- teach more effectively;
- evaluate and adopt, where appropriate, new teaching methods.

Doing pedagogic research means using various research methods to understand and investigate our teaching practice and how best to enhance students’ learning. It means being aware of the teaching and learning literature, relating what occurs to what is understood by good practice and what is suitable in a particular context. It is not necessary to agree with that literature and it is of course possible to critically comment with reference to particular experiences. The research methods used can collect qualitative data (e.g. interviews, focus groups) or quantitative (e.g. questionnaires) or a mixture of both. It is possible to draw on different methodologies in designing research and analysing data (take a look at Cohen et al., 2000; Wellington, 2000) and the methods you choose will reflect the data needed to answer your research question. There are also numerous tools and inventories already available to answer some questions, for example the Course Experience Questionnaire (Ramsden, 1991) the Approaches to Teaching Inventory (Prosser and Trigwell, 1999; Trigwell and Prosser, 2004) and the Assessment Experience Questionnaire (Gibbs and Simpson, 2003).
**Ethical considerations**

Pedagogic research involves the study of people, which means it can get messy and is not easy to measure. Being a study of people and their experiences it also means that “ethical concerns should be at the forefront of any research project” (Wellington, 2000, p. 3), paying attention, for example, to any bias or manipulation in the research or any potentially negative impact on participants (see BERA, 2004; Cohen et al., 2000; De Vita and Smallbone, 2005; Oliver, 2003 for more information). All staff wishing to conduct an investigation involving human participants should consult their university’s ethical guidelines for research projects. Many provide a checklist to help you determine if ethical clearance is needed for your work.

Some people find the use of qualitative data challenging, feeling that it is somehow less rigorous or valid in its use of subjective opinion and perceptions, but data that best answers or sheds light on a particular problem is often qualitative in nature. Consider the case of students not understanding a particular concept: a conversation (or interview) with several students, perhaps of differing abilities, that takes them through a relevant problem will shed more light than a tick box survey based on your assumptions of their misunderstandings. A focus group of students who have used a particular system will allow you to understand their experiences and the processes involved in use. This may even highlight some peripheral element that you had not considered that is a real issue for students, or something as simple as a misunderstanding of purpose which impacts on use.

Any data collection and analysis, be it quantitative or qualitative in nature, does need thorough planning and careful interpretation and contextualisation. As has been explained above it is important to explain the context of any study. For example, in investigating how your students perform a particular task, you may wish to include reference to laboratory or workshop availability and other constraints that could affect their ability to complete a piece of work and thus impact on their results. Class sizes may have caused you to adopt a particular teaching strategy or you may want to comment about teaching and learning in the context of professional regulations.

**And finally…**

Although this may change over time, it is worth taking into consideration the Research Assessment Exercise (RAE) guidance for pedagogic research, submission of which was allowed under each subject panel. The guidance is very clear that “Pedagogic research in HE will be assessed where it meets the definition of research for the RAE. It is research which enhances theoretical and/or conceptual understanding of:

- teaching and learning processes in HE
- teacher and learner experiences in HE
- the environment or contexts in which teaching and learning in HE take place
- teaching and learning outcomes in HE
- the relationships between these processes, outcomes and contexts.

Reports of studies providing descriptive and anecdotal accounts of teaching developments and evaluations do not constitute pedagogic research. Pedagogic research is firmly situated in its relevant literature, and high quality pedagogic research makes a substantial contribution to that literature.” (HEFCE et al., 2006, p. 14).
References


Writing for publication

One of the criteria of pedagogic research is that it should inform and be scrutinised by a wider audience (Ashwin and Trigwell, 2004; Stenhouse, 1975) and certainly if you are researching or evaluating something you believe will be of interest to your colleagues you will want to share your ideas and findings. This paper suggests some ways you could do this and provides tips to help you get published.

The most highly regarded way of sharing knowledge and disseminating in academia is, of course, through peer reviewed academic journals, but a good way to try out your ideas or early drafts is at a conference; this is a valuable way to gain feedback and see what others in the field are working on. It is perfectly ethical to redraft a conference paper for submission to a journal (Price and Maushak, 2000), although this should be acknowledged.

The following advice comes from those who have been regular contributors and includes a summary of the tips suggested by engineering academics who attended pedagogic research workshops offered by the Engineering Subject Centre and the engCETL.

Top tips

When planning, writing and submitting your paper think about the focus and how the paper might get written and accepted.

• Collaborate with colleagues, especially those who are strong in your weak areas (e.g. the use of statistics or in collecting data through interviews or focus groups). Don’t forget to think outside your discipline area and across institutions.
• Base any research on the literature with a strong theoretical underpinning, making sure you reference the education literature in the chosen area (don’t forget international references if the audience is international).
• Explain how the research has been conducted, including the institutional context and the data collected – others may want to try the strategy so think about generic application.
• Be honest! Admit when it doesn’t work but explain why if it is relevant to the discussion. Remember that research is rarely the linear process it is often portrayed as!
• Write with a purpose, get into the habit.
• Have something to say, identify what is original or new about what is being presented.
• Devise an interesting question (with a teaching and learning focus).
• Avoid information overload.
• Ensure the research is accessible to the chosen audience.
• Pay attention to your purpose, structure and presentation.
• Consider including data that is both quantitative (any numbers you have) and qualitative (any relevant quotes) and highlight your evidence.

All journals provide detailed guidelines and submission advice, and it is worthwhile reading these carefully, not only to check you are sending your work to the correct journal, but also to make sure you follow style and formatting requirements. When you are writing a paper you should do some background research. Look at other papers which a journal has published. Consider whether the style suits your work and if your research is accessible to its audience before targeting a journal for publication. If you are still unsure about the suitability of your article for a particular journal, approach the editor for advice.

Just go for it! Lack of confidence and fear is what paralyses most of us. “Feel the fear”!
Types of submission
Different journals accept different types of contributions, from literature reviews and theoretical pedagogic research papers to examples of practice derived from action research and those presented as case studies, as shown below.

Action research
Action research is defined as “a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out” (Carr and Kemmis, 1986, p. 162). The main difference between traditional research and action research is that action research is done by practitioners who “investigate their own practice, observe, describe and explain what they are doing in company with one another, and produce their own explanations for what they are doing and why they are doing it” (Whitehead and McNiff, 2006, p. 13), rather than adopting the stance of spectator or outsider.

This type of research and/or evaluation is one way many first time pedagogic researchers start out, for example, they spot a particular problem their students have in understanding a concept and start exploring what it is the students find difficult, try out different strategies to help students understand this concept and investigate which strategy is most effective. Their exploration and any findings are then written up with reference to relevant literature in the field.

This type of research is sometimes criticised as being less rigorous and more anecdotal than ‘real’, empirical research, but this is not the case if the research problem and design are clearly articulated and the investigation and its outcomes are situated in the wider teaching and learning literature. This type of research may also be more widely accepted by your peers if there has been more than one pass at a particular problem, for example, a problem is identified, an intervention tried, the resulting outcomes investigated and the same intervention tried on another group of students to make a comparison with outcomes or another intervention is tried on the same group of students. For more information about this approach take a look at Whitehead and McNiff, among others.

Case studies
The guidelines for the journal Innovations in Education and Teaching International suggest how an in depth investigation into one aspect of your teaching or your students’ learning may be written up as a case study. They state that any case study “should include the following:

• a background scenario;
• a clear statement of the purpose of the work;
• a relationship to past or current work;
• who was involved;
• what happened;
• what deductions can be made;
• a critical review of the work;
• how the case study has implications for others.”

(see guidelines for the journal Innovations in Education and Teaching International at www.tandf.co.uk/journals/authors/riieauth.asp).

Pedagogic research papers
Full papers should be original works of a pedagogic research or developmental nature which are firmly situated in relevant literature and which will make a contribution to that literature. Education journals are looking beyond student satisfaction and looking for evidence of the impact on or improvements in student learning. It is not adequate to
say that students enjoyed something; it is crucial to show evidence of evaluation and the way in which the student learning experience has been enhanced. For example, how has student performance or conceptual understanding been affected?

References are also an important part of the paper. They list material which situates the work within a wider context and help explain why it is important or interesting to a potential audience.

References demonstrate “that the author is aware of and has read the work of other researchers/teachers in this particular area. References also provide the reader with materials that they can read to reach the same conclusions that the author has reached.” (Batchman and Reilly, 2004)

**Guidelines**

Journal referees are asked to consider the following types of questions when making a judgement about the suitability of a paper for publication:

- Does the paper tackle a topic of genuine interest for the audience of this journal?
- Does the paper contribute to the literature of learning and teaching within the field of engineering or across the disciplines?
- Does the paper build upon relevant references and bodies of knowledge?
- Is the paper likely to be of interest beyond the UK?
- Is the paper clear, concise and accurate?

**Opportunities to publish**

There are numerous options for the publication of learning and teaching research both within Europe and internationally. These include discipline specific options in the field of engineering education as well as those focusing on various aspects of education and concerned with the use of learning technology. Conferences provide an opportunity to try out ideas before submitting a paper to a journal.

In the engineering education field there are a number of well established conferences such as the annual UK based Engineering Education conference and those run by the American Society for Engineering Education, the Australasian Association for Engineering Education and European Society for Engineering Education (SEFI). Examples of teaching and learning conferences would be the annual Higher Education Academy conference, the Improving Student Learning symposium run by Oxford Brookes and the Society for the Research of Higher Education (SRHE) conference as well as the bi-annual Pedagogic Research in Higher Education conference run by Liverpool Hope. The Association for Learning Technology has an annual conference and Networked Learning (run by Lancaster University) occurs bi-annually.

Offered below is a selection of journals. Further listings are available from publishers’ websites, university libraries and the Engineering Subject Centre website at www.engsc.ac.uk/er/journals/, including details of Engineering Education: Journal of the Higher Education Academy Engineering Subject Centre. The short descriptions under each entry below are taken from the publications’ websites.

**Engineering Education - the Journal of the Higher Education Academy Engineering Subject Centre**

*Engineering Education* is a peer-reviewed, international journal and is freely available via the website of the Engineering Subject Centre and distributed in paper format to all UK university libraries and Engineering departments. *Engineering Education* is published twice a year. See www.engsc.ac.uk/journal
Journal of Engineering Education (JEE)
The Journal of Engineering Education is a scholarly professional journal published quarterly by the American Society for Engineering Education. Papers submitted are reviewed by an Editorial Review Board and external referees for their contribution to engineering and technology education, development of new ideas and appeal to a broad readership of engineering educators and others. See http://www.asee.org/publications/jee/

European Journal of Engineering Education (EJEE)
Published quarterly by SEFI, it examines the economic, cultural and social factors which influence the education of engineers in different societies and provides a forum in which teachers in engineering schools, institutions and industry can share accounts of good practice and discuss methodology. See http://www.tandf.co.uk/journals/titles/03043797.asp

Active Learning in Higher Education
Active Learning in Higher Education is an international, refereed publication for all those who teach and support learning in higher education and those who undertake or use research into effective learning, teaching and assessment in universities and colleges. Non-discipline specific in nature, it comprises accounts of research by those engaged in the field of learning and teaching across all areas of the curriculum in higher education. The journal is published by SAGE Publications www.sagepub.com/journalsProdAims. nav?prodId=Journal201469

ALT-J
The Association for Learning Technology publishes its journal three times a year. It “aims to promote good practice in the use of learning technologies in education and industry and facilitate collaboration between practitioners, researchers, and policy makers.” See www.tandf.co.uk/journals/titles/09687769.asp

Assessment and Evaluation in Higher Education
This journal publishes papers and reports on all aspects of assessment and evaluation within the various disciplines representative of higher education. The purpose of the journal is to help advance understanding of assessment and evaluation practices and processes, particularly in the contribution they make to student learning and staff and institutional development. See www.tandf.co.uk/journals/titles/02602938.asp

Australian Journal of Engineering Education (AJEE)
AJEE is an online journal which aims to generate interest in engineering education among academics and industry leaders within Australia, Asia and the Pacific Region. It also aims to provide an international forum for discussion, and to enhance the opportunity to exchange information on engineering education and industrial training at tertiary level, including the need for systematic and comprehensive research on methodology and curriculum development. To submit a paper see www.aae.com.au/journal/submitpaper. htm

BJET
The British Journal for Educational Technology is published six times a year and accepts articles that “cover the whole range of education and training, concentrating on the theory, applications and development of educational technology and communications. The Colloquium section publishes shorter contributions, summarising work in progress, raising queries, and questioning received wisdom.” See www.blackwellpublishing.com/journal. asp?ref=0007-1013
Studies in Higher Education
Studies in Higher Education is published six times a year and “welcomes empirically based, reflective and synoptic articles dealing with any aspect of higher education, approached from any perspective or discipline. A key criterion for publication is that articles should be written in an accessible, but rigorous, style that is likely to engage those without a specialist interest in the topic being discussed.” See www.tandf.co.uk/journals/titles/03075079.asp

Innovations in Education and Teaching International (IETI)
Published four times a year, IETI is for all practitioners and decision makers who want to stay informed about developments in education and training. It is the official journal of the Staff and Educational Development Association (www.seda.ac.uk). The content includes a range of perspectives and important contributions on new developments in educational technology. For instructions for authors see www.tandf.co.uk/journals/authors/riieauth.asp

Teaching in Higher Education
Teaching in Higher Education is an international, interdisciplinary, peer-reviewed journal addressing “the roles of teaching, learning and the curriculum in higher education.” It is published six times a year “and aims to open up discussion across subject areas by involving all those who share an enthusiasm for learning and teaching.” See www.tandf.co.uk/journals/titles/13562517.asp

References
**Tool kit bibliography: a starting point**

This bibliography is meant as a starting point rather than a comprehensive list of key texts. The aim is to provide advice for those designing research projects, looking for guides to understanding issues in learning and teaching or wanting help publishing their work. You may have your own favourites and you will find more extensive bibliographies elsewhere (some are included in this list).

**Basic research methods literature – choosing your methods, understanding methodological approaches**

  *This book aims to provide a guide for first time researchers in the fields of education and social sciences. It is a good general book on how to devise and develop a research idea.*

  *This book may be particularly useful in explaining the difference between research and evaluation and how to conduct evaluations.*

  *Another good general research guide, which goes through all the stages of conducting education based research.*

  *This book provides details of methods and methodologies which could be used. Although its primary focus is for those investigating school level education rather than higher education it is a good source book.*

  *This book provides a guide to basic research methods and methodology for small scale pieces of research offering practical and pragmatic guidance.*

  *Outlines the steps which should be taken when conducting good research.*

  *This publication provides more in depth support for conducting focus groups.*

  *This is a practical “how to” guide which uses examples and case studies to show the use of methods and techniques.*

  *In depth information for those unfamiliar and uncomfortable with qualitative research.*

  *Good general guide on how to design and conduct qualitative research, including a useful section on validity and reliability in qualitative research.*

  *Readable, general introductory text.*

**Understanding your teaching and your students’ learning**

  *Edited book about innovative and reflective practices in engineering education; a potential source of inspiration.*
Pedagogic Research Tool Kit


No nonsense classic about teaching and learning and the theories behind the practice.


General “how to” book, moving from the general to the disciplinary with subject specific chapters.


Classic text for those interested in how students learn and in e-learning. This is where the “Conversational Framework” is explained and applied to different media.


Edited book presenting accounts and case studies of first-hand experiences in developing, implementing or evaluating learning technologies.


Thought provoking writing about the art of teaching.


Edited book looking at approaches to e-learning and the emergence of new pedagogies.

Working on your writing

Very readable book giving insight into the way social scientists write. May help if writer’s block visits.


Good step by step guide on how to get writing and get published, aiming to inculcate productive behaviour.


This book offers practical advice on how to integrate writing into your working life.


Useful for those unfamiliar with writing about qualitative research. Looks at types of writing and ways of writing including collaboratively.

Some useful organisations, websites and online resources
The following are offered to inform, inspire and engage.

The Higher Education Academy (www.heacademy.ac.uk) publishes many resources both centrally and through the subject centre network (for information on the Engineering Subject Centre please see www.engsc.ac.uk).

The Academy Exchange magazine provides case studies and reports on hot topics such as employability, internationalisation and excellence. See www.exchange.ac.uk/default.asp for issues prior to 2005 and www.heacademy.ac.uk/resources/publications/exchange for issues from Summer 2005.

Bibliographies and guides from other subject centres and CETLs:
- Centre for Active Learning in Geography, Environment and Related Disciplines (CeAL) available at www.glos.ac.uk/ceal/resources/litreview.cfm
- Getting Started in Computer Science Education Research www.ics.heacademy.ac.uk/resources/pedagogical/cs_research/
- Getting Started in Pedagogical Research in the Physical Sciences and annotated bibliography available at www.physsci.ltsn.ac.uk/AB/AB-html/AB-html.html
Take a look at some of the numerous guides and briefings prepared by institutions both here and abroad. Some examples are:

**The Oxford Centre for Staff and Learning Development at Oxford Brookes**, see www.brookes.ac.uk/services/ocsd/2_learntch/2_learnt.html

**The Coventry University Centre for the Study of Higher Education**, see www.corporate.coventry.ac.uk/cms/jsp/polopoly.jsp?d=2929 for advice on research methods and “Designing an education research project” by Adrian Bromage, www.corporate.coventry.ac.uk/cms/jsp/polopoly.jsp?d=3163

**University of Brighton, Centre for Learning and Teaching**
Practitioner research in Higher Education – an annotated bibliography http://staffcentral.brighton.ac.uk/clt/research/annotated_biblio.htm

Australian universities are particularly strong in the study of teaching and learning. The **Carrick Institute for Learning and Teaching in Higher Education** was launched in August 2004. The Institute’s mission is to promote and advance learning and teaching in Australian higher education, see www.carrickinstitute.edu.au

**The Higher Education Research and Development Society of Australasia** (HERDSA) is a scholarly society for people committed to the improvement of teaching and learning in higher and tertiary education in Australia, see www.herdsa.org.au/

Organisations such as the **Carnegie Foundation for the Advancement of Teaching** (www.carnegiefoundation.org/index.asp) and the **International Society for the Scholarship of Teaching and Learning** (ISSOTL) (www.issotl.org/) are valuable sources of information and good starting places for finding further information.

Also of potential use is an article archived online which, although intended for an audience of primary and secondary teacher-researchers, offers a useful guide to the purposes of research, planning research and the weaknesses and strengths of various methods: Rickinson, M. (2005) Tool-kit 1: planning your research project. *Topic* (34), pp 4-11 (www.thegrid.org.uk/goodpractice/publications/documents/toolkit_planning_projects.pdf).

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Engineering Education organisations around the world are also useful sources of information, although you may have to pay a membership fee to gain access.

**The Australasian Association for Engineering Education** (A2E2) is a professional association committed to fostering excellence and innovation in engineering education. Established in 1989, the Association brings together academics, support staff, librarians, professional engineers and employers across Australia and New Zealand who have an interest in engineering education, see www.aaee.com.au/

**The American Society for Engineering Education** (ASEE) aims to further education in engineering and engineering technology by promoting excellence in instruction, research, public service and practice, fostering the technological education of society and providing quality products and services to members. The Society seeks to encourage local, national and international communication and collaboration, influence corporate and government policies and involvement and promote professional interaction and lifelong learning, see www.asee.org/

**Journals**
Access to journals can be dependant on the subscriptions which your university pays. It is however possible to freely access many of the online journals publishing peer reviewed articles on the scholarship of teaching and learning:
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- **Practice and Evidence of the Scholarship of Teaching and Learning in Higher Education** – online journal available at www.pestlhe.org.uk
- **International Journal of Teaching and Learning in Higher Education (IJTLHE)** – online peer reviewed journal available at www.isetl.org/ijtlhe/
- **International Journal for the Scholarship of Teaching and Learning** available at www.georgiasouthern.edu/ijsotl/
- **Mountain Rise** available at http://mountainrise.wcu.edu/issue.html
- **Journal of Asynchronous Learning Networks** available at www.sloan-c.org/publications/jaln/ (requires a free sign up for full access).

Last, but not least, do not forget to make use of your library, especially the expertise of your academic librarians. Take a look at ‘Engineers: what can your academic library do for you?’ (available at www.engsc.ac.uk/er/snas/library.asp).

Academic libraries provide vibrant study environments, employing the latest technologies and methods to meet your needs as a busy engineering teacher and researcher. Services they can offer include inter-library loans allowing you to access publications which your library has neither a print or electronic copy of.

In addition to finding information for you, libraries can usually assist you with storing and citing it. Most libraries support one or more bibliographic software package (e.g. Endnote or Refworks) which allow you to store, sort, and create automatic bibliographies from your references – a real time saver when trying to get that article finished.
Research methods in practice
Research methods in practice

Here are three examples of small scale pedagogic research and evaluation projects which were developed through discussion between a pedagogic researcher and individual engineering academics. The aim is to illustrate processes you may find useful in developing your own projects – please note that there is no one ‘correct’ way of conducting the research and evaluation or collecting the data. However it is important to develop a good research design and make sure the focus is about improving teaching and enhancing student learning. For this reason it may be helpful to discuss your ideas with someone more experienced in researching teaching and learning.

Research into your own practice tends to be part of an iterative, reflective process, often using an action research model (see the Writing for Publication paper, McNiff, Lomax, and Whitehead, 2003; Wellington, 2000). Figure 1 illustrates the process and shows the role of pedagogic research (highlighted by the labelled central arrows) in helping to identify, refine and inform your research and evaluation, with the ultimate goal of making a contribution to the field.

The first step in conducting pedagogic research and evaluation is the identification of an activity or issue that interests or concerns you, something about your teaching or your students’ learning. The objective is to explain what is currently happening and to identify the issue(s) you wish to investigate; the aim will be the enhancement or improvement of the situation and to do this you will want to think about any evidence you already have that things are not working, in the teaching and learning situation, as you would like. All of the cases described here involved an exploratory conversation to enable the pedagogic researcher to understand the context of the evaluation or investigation and ultimately helped to focus the investigations on particular teaching and learning issues. It

Figure 1: Researching your practice: the role of pedagogic research
is important to spend some time doing this, either on your own or with the help of a colleague, to clearly identify the focus of the investigation and ensure the focus is on teaching and learning. Clarifying the focus and domain that will be investigated is step two and is an important stage in helping to develop your research questions.

The third step is the selection of suitable methods to obtain the data that will help you understand the problem posed. While you might feel more comfortable using a questionnaire it is important to consider the way in which this may restrict the information you gather; open-ended survey questions, focus groups and interviews can allow participants more freedom to respond, including raising issues that may not have occurred to you. The data elicited in this way may provide a useful basis on which to construct a questionnaire later on, if appropriate and time allows, or for a further stage of the investigation.

You will need to think about the need for ethical clearance as part of this planning and research design stage, particularly in relation to the way you wish to gather information and disseminate any findings: generally participants should give informed consent for the use of any data they provide (they should understand what the data they provide will be used for and who will see it and use it) and they should be informed that they have the opportunity to withdraw at any stage as well as the right to have their responses made anonymous. Ethical clearance is a necessity if you wish to write about your investigation for a wider audience, so check your institutional guidelines.

The worked examples below illustrate how general queries were refined in order to focus on particular issues by exploring original intentions, aims and objectives with the academics wishing to conduct research and evaluation. Pedagogic research informed the design of these investigations and the selection of methods, but they would need situating within the wider literature relating to design-based learning (exemplar 1), assessment (exemplar 2) and project-based learning (exemplar 3) and to suggest areas for further investigation or likely innovations arising from what was found to be considered more than evaluation studies or ‘one turn’ action research (that is “one turn of the planning, acting, observing and reflecting cycle.” See Cain, Holmes, Larrett, and Mattock, 2007).
Exemplar 1:

**Issue:** How do I evaluate my Design and Make activity?

**Context:** Aeronautical Engineering – Design and Make Block

The Design and Make Block is a ten day activity that takes place outside term time between the end of Part A (first year) and Part B (second year) of the Aeronautical Engineering programme. This timing is due to the fact that many students leave for work placements following Part B. It is assessed, students are awarded a pass or a fail, and completion is required for admission into Part C of the programme to satisfy accreditation requirements. The student outputs are a model aeroplane that can glide and also fly using a small onboard motor, a team presentation of the design and a team report including individual reflective pieces about the process.

The lecturer had been granted an institutional mini project award to provide the small onboard motors, thus complicating and extending the activity. An evaluation of the activity was a condition of the funding. While this implies an evaluation of the different experience offered by the addition of powered flight there were no previous evaluations to afford a comparison. The researcher helped to refocus the evaluation to consider the student experience of taking part in the Block. The evaluation focused on whether students were making use of prior learning and whether their learning experience met their expectations and those set by the lecturer.

An additional focus for the evaluation emerged from conversations between the lecturer and the researcher: one of the programme review suggestions had been the incorporation of the Block into the formal teaching timetable and curriculum. Therefore a question was added to the evaluation to gather information from students which could inform the incorporation, due to take place in the 2008/09 academic year.

**Question(s) used to focus the evaluation:**
1. What previously acquired knowledge and skills from the course did students think they used?
2. What did students think they learnt from taking part in the Block? (benefits and challenges)
3. What lessons can be learnt from running the activity that might inform the development of a semester-based project activity for aeronautical students?

**Methods:**
1. **Observation**
   The researcher observed the conduct of the Block, sitting in on briefing sessions, consultations, presentations, visiting the workshops and viewing the flight challenge in order to evaluate the level of student engagement and understanding in respect of the Block aims. This was reinforced by the survey data collection – see 2 below – and aimed to inform the answer to Question 3 above.

2. **Collection of student feedback**
   The researcher drew up a survey, using six open ended questions designed to make students reflect on their experience of the Block and to test whether or not they felt they had used the knowledge the lecturer hoped they would and practised the skills he intended:
   i. Which completed modules do you think were helpful in enabling you to complete the Block? In what way do you think you have benefited from the Block?
   ii. What did you hope to learn from taking part in the Design and Make Block?
   iii. In what way do you think you have benefited from the Block?
   iv. What was the most difficult element of the Block?
   v. What aspects of the Block have you found rewarding?
   vi. How might the Block be improved to provide a better student experience?
This data was analysed by the researcher and primarily used to answer questions 1 and 2 above, but also informed the answer to question 3.

**Ethical clearance:**
In this institutional context it is considered acceptable for lecturers to conduct research and evaluation with a view to informing their teaching as long as it does not affect students adversely, i.e. impact on their marks. However we considered ethical implications and followed good practice: all returns were anonymous and returned to the researcher not the lecturer. The students were fully briefed, in a face-to-face session, about the purpose of the short survey and a summary of the data collected was prepared for them. This report was made available to the staff-student committee and other students were able to contact the researcher if they wanted to see a copy.

**Outcomes:**
The students claimed to be using previously acquired knowledge and skills from the course broadly as expected by the lecturer (information which was outlined during researcher/lecturer conversations), although with less understanding of the relevance of two modules identified by the lecturer: fluid mechanics and mechanics of materials.

The students thought they had been able to apply previously learnt knowledge and theory and practice teamwork, time management and communication, so in effect had done as expected by the lecturer. However, one of his aims had been to enable them to get to know their peers more, but only two people mentioned this as an explicit outcome (although it could be inferred as an implicit gain from comments about teamwork).

An evaluation report was drawn up for the lecturer, including student comments elicited from the survey data. This was discussed with the lecturer who responded to the comments; the response was then incorporated into the report. The report and the discussions around the evaluation informed the re-development of the design and make activity as part of the curriculum.

Student survey data was analysed and written up in two formats: a full report for the lecturer and a synopsis for the students on the course.

The lecturer reported that he found the process helpful in thinking through the changes to the activity and its incorporation into the main curriculum, for example student criticisms regarding the lack of time to complete design work (from having very little knowledge about aircraft design, to researching designs, creating a design template and then presenting their design for critique) was one of the issues taken on board. There were aspects such as the link to accreditation which students did not seem to have picked up that were then emphasised in the subsequent iteration of the course.

The lecturer used the evaluation experience to inform peer presentations about the conduct and outcomes of the Design and Make Block.
Exemplar 2:

Issue: Why are my students leaving their assignments to the last minute when they have an electronic submission system that can be used at any time?

Context: Electrical Engineering – the submission of laboratory exercises on one undergraduate module

The academic concerned had originally introduced electronic assignment submission to help with increasing workload (typically over 100 students submitting the same exercises) while at the same time revising the laboratory work and data collection procedure in order to better support learning and encourage good practice (particularly to encourage students to keep better laboratory notebooks). He also said that handling assignments in this way provided flexibility for the students, helped him to handle the marking load and provided tailored feedback for the students – the system he had built included automated assignment marking and the production of correct solutions.

The academic had access to data about conventional (hard copy) and electronic submission which showed that students were unlikely to submit assignments until the deadline, although some seemed to improve over time. He wanted to understand why students seemed to leave things to the last minute, in essence what was affecting their submission of assignments and what might be helping them to improve over time.

We refocused the question to look at the ways students deal with deadlines, whether or not they appreciated the flexibility of electronic submission and whether they thought the feedback they received was adequate – picking up some of the reasons the lecturer had given for the introduction of the system and trying to concentrate on the educational value of introducing such a system.

Questions to investigate
What do students think about the flexibility offered by the electronic submission of assignments?
What affects students’ submission decisions?
In what way does the feedback provided meet the students’ needs?

Methods
The lecturer analysed the systems data (information about hand-in dates and times) to see what this might suggest about student behaviour. Issues the lecturer thought were highlighted by this analysis were discussed with the researcher who drew up a series of open-ended questions to put to students. The aim of the questions was to investigate student experiences of electronic submission and the factors that impact on their use of the system and the time of submission. The questions were trialled with a couple of face-to-face interviews, changes were made and then it was circulated as a survey via email to the students who had used this electronic submission system (issues around the use of online or e-surveys are discussed in articles such as Glover and Bush, 2005 and Nulty, 2008). Data collection was done in this way in order to capture student perspectives before the end of term (that is, in response to tight deadlines). A focus group would have been the preferred method but not enough students were able to meet at the same time for this to take place. The researcher spoke with the students and collected the survey data in order to provide a degree of anonymity.

Survey questions asked:
1. Do you prefer paper-based or electronic submission for your assignments?
2. What are the benefits of electronic submission for you?
3. What are the disadvantages?
4. What affects the time and date you submit your work generally?
5. Do you tend to submit as soon as you have finished an assignment or do you wait? If so, why?
6. Do you prefer a late deadline, so you can manage your own workload, or a short deadline, say completion of the labs plus 2 weeks?
7. Have you become better or worse at dealing with deadlines during your time as a student?
8. What has affected this?
9. What feedback do you receive after electronic submission?
10. Is this adequate for you? If not, how could it be improved?

Ethical clearance
Students were alerted to the investigation and its purpose by the lecturer who also told them the researcher would be contacting them.

Students were invited to take part in a focus group on one of two times and dates. As only two students were able to make the suggested dates and it was not possible to find any other mutually convenient dates it was decided to treat these as pilot interviews and a way to develop the survey instrument. The students were informed about the purpose of the research and given informed consent forms to sign before participating in the interviews.

With respect to the email survey, the purpose of the research was explained in a covering email to which was attached the survey form in MSWord document format. Responses were made anonymous and coded to protect student identity and sent to the researcher.

Outcomes
The analysis of the electronic submissions system data seemed to indicate that:

i. students use submission deadlines to control what coursework is done and when.
ii. a long deadline increases the number of late submissions.
iii. time management gets better as students progress through their programme.

The interviews and survey data indicated that students value the flexibility offered by an electronic submission system as well as the opportunity, afforded by long deadlines, to discuss assessment strategies and solutions with their peers. However some would like more timely and detailed feedback and a few said they had concerns about the correct formatting of electronic submissions. They admitted to becoming far more strategic in the completion and handling of multiple assignments over their time at university, often learning from hard mistakes, including forgetting deadlines.

The outcomes of this investigation caused the lecturer to think about the timing of assignment deadlines with respect to other academic tasks, such as major projects and examinations, and the way in which the assessment process may be made more meaningful for the students with respect to the feedback received on the assignment submitted. There were also plans to implement a one or two week ‘deadline is approaching’ warning email and a clearer response from the system that submissions had been received.

This investigation has been written up for journal submission.
Exemplar 3:

Issue: How do I find out whether the project allocation system is working for the students involved?

Context: Mechanical Engineering – allocation of final year projects

Students have to do a project in the third year of their taught course. There are many students and a variety of supervisors. The project allocation software was created to help this process: lecturers who will be supervising projects put project descriptions on the system and students can browse these descriptions and make an appointment to discuss a project with a supervisor. The intention is that projects are allocated only following discussion between interested students and lecturers proposing projects. The lecturer selects their chosen student, from a system generated cohort list, following the discussion period.

The Project Co-ordinator, who is also a lecturer involved in this process, wanted to evaluate the success of the project allocation system with the intention of modifying and updating the system. The interesting aspect from an educational perspective was the underlying rationale for the use of the technology: to harmonise advice, guidance and access to information for students looking for projects and supervisors for their third year individual projects. The Co-ordinator was particularly keen to promote discussion between lecturers and students and encourage equal access to projects for all students involved; that is, the possibility of negotiation, especially for those students who might not have been a natural first choice for a project.

We concentrated on student perceptions because the process had been changed with the intention of making it more equitable and the system introduced to help alleviate what students thought was quite a stressful process by making projects visible to all.

Questions to investigate
In what way can we improve the project allocation process for students?
Is the project allocation process, as currently constituted, facilitating fruitful discussions and adequate support?
What barriers to successful project allocation do students identify?

Methods
A focus group was used to capture student experience. The questions were focused on the process rather than the system. Careful consideration should be given to who facilitates the focus group. It often works better if the facilitator (the person asking the questions) can be someone neutral who nevertheless has a good grasp of what information is required (perhaps after interviewing the person who wants the information). There should also be a scribe who can provide an immediate summary of salient points for participants which can be checked before they leave. Questions and prompts for the facilitator (these were used as a guide or structure for the discussion) follow:

1. Contextualisation - find out where students are from and what type of project they have undertaken.
2. Was the process that the system supported generally a positive or negative experience?
3. Run students through the process, as supported by the system, stage by stage:
   i. What do you think about the range of projects available on the system?
   ii. How useful was the discussion period?
   iii. Are face-to-face or online meetings preferable in this context?
   iv. How appropriate was the length of time allowed for discussion?
   v. How many staff did you try and meet?
vi. How many staff were you able to meet?
vii. What sort of things prevented you from meeting up with staff?
viii. How important is the supervisor to you in selecting your project?
ix. What do you look for in a good supervisor?
x. How did you prepare for the meetings with staff?
xi. In what way did these meetings help you decide on a project?

xii. In what way did these meetings help you secure a project?
xiii. How many submissions/requests did you have to make before you secured a project?
xiv. How would you feel about having to make a written submission about why you’re the best person for the project?
xv. How long did it take you to secure a project?

4. Which parts of the project allocation process did the system support best?
5. Which parts of the project allocation process did it not support and why?
6. What were the most challenging parts of the project selection process for you?
7. How would you improve the system?
8. How would you improve the process?

Ethical clearance
Students were informed about the purpose of the research and given informed consent forms to sign before participating in the focus group. They were assured of anonymity in any written reports, told that they could withdraw at any point and provided with a summary of the points raised.

Outcomes
The focus group data indicated that the opportunity to find out more about projects and supervisors was a very important part of the process for the students who were on the whole quite strategic in their actions. While the project allocation system helped manage the process and provided basic information, it was only as good as the information input and the time potential supervisors were prepared to spend with students prior to allocation. Some of the project descriptions were not thought to be helpful and the system could not replace the face-to-face contact that students said they found indispensable in trying to make sense of what was on offer.

The student comments provided evidence for the Co-ordinator of the importance of the discussion period, as well as suggesting ways in which the information available could be improved, for example short PowerPoint presentations or videos describing the project and/or the ‘rigs’ used and a listing of useful pre-requisite modules or skills. It was also suggested that former project students from Part D could be asked to share their tips for dealing with the process and the project, as one student said “I forgot I was teaching myself, went for an interesting project instead of something I could do in the time”.

There was a great variety in the way potential supervisors dealt with the face-to-face sessions, with some being inundated at office hour sessions, others being conspicuous by their absence and still others holding small explanatory sessions to enable interested students to ask for clarification. Selection criteria appeared, to the students, to be equally varied, from “if no one else comes by the end of the day it’s yours” to “prepare a page of ideas for the project and why you would be the best person”. Students wanted clearer guidelines on how to pitch themselves and their ideas and better feedback on why they were not successful.

The issues raised were used to review the allocation process and make modifications to the system.
References:
Education Theories on Learning: an informal guide for the engineering education scholar

an Engineering Subject Centre guide by Jenni Case
Author’s biography

Jenni Case is Associate Professor in the Department of Chemical Engineering at the University of Cape Town, South Africa, and a former director of the Centre for Research in Engineering Education (CREE), University of Cape Town. Researching students’ experiences of learning in order to improve the quality of student learning in science and engineering programmes has been a key focus of Jenni’s work to date.
Overview
This guide has been produced to complement and develop the Engineering Subject Centre’s existing range of resources about learning and teaching theory. It is aimed at newcomers to the field, such as:

- engineering teachers who want to be able to use education theory and research findings to inform their teaching; and
- aspiring engineering education researchers who want to launch their own projects.

Using a view of a theory as a set of ‘thinking tools’, the guide offers a selection for building up a tool kit. Six ‘tools’ have been identified. The selection is the author’s personal choice and the tools were chosen for their usefulness in engineering education research. Tools 1-3 broadly cover learning as acquisition, tools 3-6 look at learning as participation:

Tool 1: Concepts
Tool 2: Ways of experiencing
Tool 3: Approaches to learning
Tool 4: Community of practice
Tool 5: Identity
Tool 6: Discourse.

The guide has an informal tone to make it as accessible as possible for those who are new to education research. Each section provides a brief introduction to the tool, including a case study example and further reading. Wherever possible, references and further notes on terminology are in the footnotes. A detailed reference section is provided at the end of the guide. This structure enables the reader to engage with the text on either an introductory or more theoretical level, depending on their needs.
A view on theory in education

In the world of engineering there are theories that can be used for building a bridge, designing a chemical reactor or improving the aerodynamics of an aeroplane. It is probably then quite reasonable to assume that education theory will deliver some straight answers on how to conduct teaching or how to improve learning. If this were possible then this guide would offer you a set of rules to apply to your teaching and you could head off happy and secure. However, if you have spent any time working with students, for example giving a lecture and then seeing what students write in a test, you will already have that nagging feeling that improving teaching might in some odd way be more complex than designing an aeroplane.

In the field of social science where education finds itself there are indeed some who would claim to have formulated universal and general rules. The problem is not that these aren’t true, but that when you are working in this mode you tend not to come up with particularly interesting or useful insights. For example, it has been shown that schools with students from poorer socio-economic backgrounds have, on average, poorer academic outputs compared to those with students from wealthier backgrounds. Most teachers already know this. But how can we start to understand what is happening here so that we might be able to subvert the inevitability of such outcomes? Here we need to make different demands of theory.

There can be considered to be two types of theory in the social sciences. Firstly, there is the kind of theory that we are familiar with in the natural sciences and engineering: a set of general statements about the world that we can either prove or disprove empirically. As noted above, this kind of theory is often not terribly helpful in education. The second kind of theory is described as a set of ‘thinking tools’, concepts or heuristics that one can use to offer new ways of looking at the world, to suggest new lines of enquiry or action. Here we do not have a set of right answers waiting for passive transfer to new contexts; each new user of this thinking tool will have to put it to use in solving their own problems. You need to consider your own situation, look into the guide and choose the tool that seems best suited to your needs. On the one hand this can be daunting; on the other hand anything less than an academic engagement would be an unlikely way to go about your work as an engineering academic.

Further insight as to why the ‘engineering model’ of theory is not necessarily applicable to teaching can be found in the observation that teaching is ‘practical’ rather than ‘technical’ in nature: ‘it is a matter of making judgements rather than following rules’. There might be some educational problems that are amenable to technical solutions but most are not. It has been suggested that ‘enlightenment’ rather than ‘engineering’ could work as a model for how we should think productively about education theory.

\[1\] For a detailed meta-analysis of these studies see White (1982).
\[2\] (Mouzelis, 1995)
\[3\] (Hammersley, 1997, p. 147)
\[4\] It is also acknowledged here that many of the traditional ways of thinking about science and engineering knowledge have been contested in recent times, and it can certainly be argued that good engineering solutions are highly contextual and not simple transfers of theoretical knowledge from one domain to the other.
Building on the assertion that teaching is about making insightful judgements rather than applying technical solutions, this guide focuses primarily on learning theory. It is student learning that is at the heart of our enterprise, and any starting point for improving teaching needs, therefore, to focus on learning. This is not to discount the value of theorising teaching, curriculum, institutions, etc., but merely to assert that thinking about learning is a good starting point, especially if you are aiming to develop new insights into what is happening in your classroom and course.

So we now have an invitation to engage with education theory, to find those thinking tools that seem most applicable to our context and to use these to develop our teaching practice, to understand our students and to design our educational systems. ‘There is nothing so practical as a good theory’ was stated by the social scientist Kurt Lewin and this will be a useful mantra for the journey.

Who is this guide intended for?
This guide is intended for newcomers to the field:

- for engineering teachers who want to be able to use education theory and research findings to inform their teaching; and
- for aspiring engineering education researchers who want to launch their own projects.

It is worth noting that much current published literature in engineering education does not proceed from an explicit theoretical basis. This I feel is a great pity and a real limitation to what can be achieved in this area. The intention is that this guide will go some way towards encouraging more scholars to utilise education theory in guiding their work.

If you are planning to conduct your own research, once you have made the theoretical choices that this guide is focused on, you will also have to select or design an appropriate research methodology. There are many helpful texts on this topic.

A note on writing style
I have endeavoured to make this guide as accessible as possible for those who are new to educational research. From my own experience and those of colleagues, I know that it can be difficult to find your way into educational literature. This guide therefore uses a very informal style and is deliberately different to what you will find in the average journal article. Wherever possible, references and further notes on terminology are in the footnotes. For a first read through you can simply ignore the footnotes and stick with the main text. For a first excursion into this area it was judged most important to get to grips with the new ideas and how one might use them, rather than having an exhaustive treatment on the theoretical provenance of these tools. If you are enticed to go further you will need to read further, so bear in mind that what you have here is simply a starting point. In selecting articles to illustrate the tools, as well as offering further reading, I have kept to journal articles which are easily accessible. In many areas you will need to get to the source books if you want to go deeper and in engineering education you will also find that many research studies are only presented at conferences, especially in the USA.

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5 (Ramsden, 2003)

6 (Lewin, 1951)

7 A classic text here is Cohen, Manion and Morrison’s Research Methods in Education (2000). There is also a useful Higher Education Academy guide to conducting education research in the physical sciences which is very relevant for those starting out in engineering education research. Go to http://www.heacademy.ac.uk/resources/detail/SNAS/snas_708.
The structure of this guide

Using a view of a theory as a set of ‘thinking tools’, this guide offers a selection for building up your tool kit. Six ‘tools’ have been identified. The selection is obviously personal and I have picked out those tools that I have found particularly useful in my own research in engineering education. However, these also do follow general trends in education thinking and can be separated into two general groups. Sfard (1998) identifies two broad metaphors which underpin thinking about learning. The first metaphor centres on a notion of learning as acquisition, and the first three tools fit broadly under this heading. The second metaphor is about learning as participation and this describes the next three tools.

Learning as acquisition…

If I had to reduce all of educational psychology to just one principle I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly. (Ausubel, 1968, p. vi)

In working with tools 1-3 we will be focusing in different ways on ‘what the learner knows’. These tools will help us develop a range of different explanations for student success or failure that go beyond simply labelling some students as able and others as not. We will look at ‘concepts’ and ‘ways of experiencing’ in order to analyse conceptual understanding. With approaches to learning we will develop a theory which explains why some students are developing conceptual understanding and others not. Although these tools have different theoretical underpinnings they all basically build on a perspective which sees learning as the acquisition of something, be it conceptual understanding or a way of experiencing. They offer us a means to get to know our students in order to be able to improve teaching and learning.

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* If you want to go further you might need to get to grips with the key theoretical differences amongst the three theories in this group, especially between conceptual change theory (tool 1) which rests on a dualist constructivist epistemology and phenomenography (tool 2) which espouses a non-dualist position.
TOOL 1: CONCEPTS

What are we talking about here?
In thinking about the learner’s existing knowledge in terms of concepts we are putting forward an idea of mental structures in someone’s head. The aim of teaching and learning is to change these mental structures, hence the term ‘conceptual change’.

One thing that has been demonstrated repeatedly in research studies is that students’ prior conceptions are surprisingly resistant to instruction. Even after scoring high marks in formal assessment, when faced with conceptual type questions successful students, even at the tertiary level, can display concepts that are not in agreement with science.

An important idea which has recently emerged in higher education research is that of a ‘threshold concept’: those key ideas in a discipline which need to be mastered in order to see the world in a different way.

What does this mean for engineering education?
Most of the research on concepts and conceptual change has been in the natural science disciplines of physics and chemistry; some of this work with university students. Given that these are the disciplines which form part of the foundation for engineering studies, there is much here that can be applied directly to engineering education. For example, the Force Concept Inventory (FCI) is a test which can be administered to students both before and after instruction to determine to what extent conceptual change has taken place.

There is considerable scope to extend this work into the foundational concepts in the engineering sciences. For example, a concept inventory has now been established in the area of fluid dynamics.

In what ways might this be a useful thinking tool?
The focus on students’ concepts both before and after instruction was a major step forward in education theory – rather than simply stating that a student ‘got it wrong’, one started to take an active interest in the wrong answers. This has proved to be a very productive angle both for research and also for teaching. Teaching which elicits students’ prior conceptions means that instruction can be focused directly on what students are struggling with.

More recently, teachers are using the idea of ‘threshold concepts’ to unpack overloaded curricula and decide what are the really key ideas that students need to focus on.

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9 This perspective comes from cognitive science. Much science education research in this area builds on the studies of Piaget, and this is sometimes referred to as a ‘constructivist’ theory of learning (cf. Matthews, 1998).
10 Other terms which have been used instead of ‘concept’ include conceptual structures, phenomenological primitives, conceptual ecology and mental models (Leach and Scott, 2003).
11 An extensive bibliography by Pfundt and Duit (1994) details the literally thousands of science education studies which describe ‘alternative conceptions’ across a wide range of topics. A popular demonstration of this idea can be seen in the film ‘A Private Universe’ in which Harvard University graduates gave their answers to two simple questions about the causes of the seasons and the phases of the moon (Scheps and Sadler, 1988).
12 A very helpful overview by Glynis Cousin on threshold concepts can be found at http://www.gees.ac.uk/planet/p17/gc.pdf, published by the Geographical, Earth and Environmental Sciences (GEES) Subject Centre of the Higher Education Academy.
13 See Saivinainen and Scott (2002) for a useful overview of the FCI.
14 (Martin, Mitchell, and Newell, 2003)
Show me an example...


In the context of new requirements for engineers to ‘understand’ sustainability, Anna Carew and Cynthia Mitchell set out to investigate the understanding of a group of third year engineering students who had just completed a module on sustainable development. To do this they chose to use the SOLO Taxonomy: a scheme for characterising students’ conceptual development. This scheme proposes that conceptual development can be analysed according to five stages of increasing conceptual sophistication. At the bottom of the scheme is the ‘prestructural’ stage which essentially involves no real understanding. This is followed by ‘unistructural’ and ‘multistructural’ stages in which the student displays knowledge of one or more items of content knowledge, but with no interrelations. In the ‘relational’ phase the student interrelates different items and in ‘extended abstract’ the student is able to use critical reflection to generate new ideas.

Carew and Mitchell asked students to provide written responses to the question ‘in your own words, what is sustainability?’ They then classified these responses into the five different SOLO levels. What was notable was that 65% of these students displayed responses at the pre- or unistructural stages, despite having just completed a module on this very topic!

Based on these findings, Carew and Mitchell suggest that we need to move beyond general statements advocating students’ understanding in this area and we need to give more detailed guidance on what levels of understanding we should be expecting from our undergraduates. We may also need to rethink our teaching methods if we wish to develop conceptual understanding in our classes.

Where can I read further to learn more about this tool?


As noted above, research into students’ conceptions and conceptual change has been very prominent in science education research. John Leach and Phil Scott represent the research group at the University of Leeds which led much of this research. In this 2003 paper they provide a very helpful mapping out of the territory, summarising the work of key scholars in the area. This paper covers both ‘individual’ perspectives on learning, which focus on the theory outlined in this ‘thinking tool’, and ‘sociocultural’ perspectives which will be dealt with in tools 4-6. Because the aim of their paper is to argue for the necessity of combining these perspectives they include critiques of work that focus only on individual conceptual change. However they also point out salient theoretical positions in this area and they do argue for the value of this work.

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15 This was based on the latest accreditation requirements from the Institution of Engineers in Australia, in particular a requirement similar to statement E-3 in UK-SPEC.

16 (Biggs and Collis, 1982)
education theories on learning: an informal guide for the engineering education scholar

A very influential theory on conceptual change suggests that learners will only adopt new conceptions if they become dissatisfied with their existing conceptions and find the new conceptions to be intelligible, plausible, and fruitful. Leach and Scott caution against a purely ‘rational’ view on learning which sees students checking new ideas against their sensory perceptions. Adopting a new idea has a lot to do with the social context in which this takes place and teachers play a key role in persuading the learners of the viability of new ideas.

Leach and Scott have a strong interest in using the results of education research for designing teaching which can foster conceptual change. They review a number of studies which suggest that teaching methods which take no more time than conventional methods can have the desired effect. They do however note that improved research methodologies are needed to properly justify these claims.

17 (Posner, Strike, Hewson, and Gertzog, 1982)
TOOL 2: WAYS OF EXPERIENCING

What are we talking about here?
From this perspective learning involves a new ‘way of experiencing’, something which might sound quite similar to concepts and conceptual change. We are again interested in what learners know both before and after instruction – but there is one key difference that we need to note. With the term ‘ways of experiencing a phenomenon’ 18 we are not saying that students have concepts in their head, but rather that learning is a relationship between a person and a phenomenon 19.

If you want to uncover the different ways students are experiencing a phenomenon (a topic) then you need to conduct open-ended interviews with them and get them to talk about the phenomenon. You can then analyse the interview data using standard qualitative techniques 20 to sort it into different categories. These categories are then considered to represent the full set of possible different ‘ways of experiencing’. It has been found from many such studies that there are always a limited number of such categories. Strictly speaking, one can’t assign a ‘way of experiencing’ to a particular individual since the categories are arrived at often by using fragments of interview data from various individuals. It is better to think of the set of categories as representing the full range of ways of experiencing in a group of individuals.

What does this mean for engineering education?
Although the purists would perhaps not agree, it is possible at this stage to see many links between this tool (ways of experiencing) and tool 1 (concepts). The underlying theory is different, but in both cases one is able to investigate a range of different ‘prior ideas’ as well as unpack ‘wrong answers’. One practical point is that where concepts and conceptual change have been very prominent in school level science education research, phenomenographic research which focuses on ways of experiencing has been widely used in research in higher education, especially in the UK, Australia and Sweden. At the very least you will come across papers which use these latter terms and so it is useful to know at least something of what they are talking about.

In what ways might this be a useful thinking tool?
A focus on ‘ways of experiencing’ does open up new perspectives on teaching and learning. It is especially useful in the ways in which it links an understanding of student learning to acts of teaching. In recent work the awareness of a range of different ways of experiencing a phenomenon has led to a strong focus on variation. Here there is a claim that variation in experience is a necessary condition for all learning 21. When designing teaching one aims then to include variation, especially in what have been termed ‘educationally critical aspects’ of the object of study 22.

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18 This comes from a field termed ‘phenomenography’ (Marton and Booth, 1997). In the text here for readability I have chosen to use the term ‘ways of experiencing’ wherever possible.
19 This is termed a ‘relational’ perspective. Compared to constructivist learning theory, which implies a dualism between mind and body, this is a non-dualist perspective; concepts do not reside in a separate mind.
20 For example, see Strauss (1987).
21 See, for example, Pang (2003)
22 See, for example, Linder, Fraser and Pang (2006).
Show me an example...


In this study Delia Marshall and colleagues focused on engineering students’ ways of experiencing learning itself, also termed ‘conceptions of learning’. The assumption is that the ways that students experience or conceptualise learning is an important determinant of their ‘approach to learning’ (see tool 3) in a given context. Most previous studies of conceptions of learning had focused on social science or humanities contexts and it was expected that things might be slightly different in engineering, as indeed they were.

The students that were interviewed were on an engineering foundation programme at a UK university. Five conceptions of learning were identified in this study. Compared to other studies of conceptions of learning they did not find a simplistic conception of ‘increasing one’s knowledge’. This could be taken to mean something positive about the engineering course context. The least sophisticated conception of learning which was identified focused on memorising definitions, equations and procedures, so at least the students directed their learning with some purpose. This was followed by a slightly more active conception which involved applying equations and procedures. A substantial shift was seen in the third conception of learning which focused on making sense of physical concepts and procedures. Here there is an introduction of a reflective dimension. Going further, a small group of students conceptualised learning as ‘seeing phenomena in the world in a new way’, and a final small group displayed the most sophisticated conception of learning which centred on ‘change as a person’.

In considering the implications of these findings, Marshall et al. suggest that educators need to explicitly design curricula which foster these higher conceptions of learning. This, they suggest, will require a stronger focus on reflection, on the broader context for application of learning and more peer-level discussion.

Where can I read further to learn more about this tool?


Shirley Booth has played a key role in the area of phenomenographic research, starting with her PhD on students who were learning to program in a computer science and engineering course23. She then co-authored a key text, *Learning and Awareness*24, and has continued to be involved, especially in the application of this thinking in science and engineering education. In this paper she lays out a very practical argument for shifting from a ‘transmissive’ to a broadly ‘constructivist’ pedagogy. She argues that rather than depending on ‘folk pedagogy’, which is anecdotally derived, we need to ground our thinking in educational theory. In this paper she lays out and illustrates what it means to take a phenomenographic perspective.

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23 (Booth, 1992).
24 (Marton and Booth, 1997).
The context for this paper is a Computer Science and Engineering programme which underwent reform, prompted particularly by the low participation rates by women. The reform approach argued that improving the programme for women would also improve it for all students. This paper focuses on the introductory course for this programme which aimed to provide students with a particular orientation, termed a ‘relevance structure’, for the forthcoming programme. Building on phenomenographic theory, group work was implemented throughout the course to ensure a variation of perspectives.

The evaluation of this course was also conducted using a phenomenographic approach. The aim was to identify the different ways in which students experienced the course. This was firstly with regard to the intended ‘relevance structure’ and here it was found that many students had ways of experiencing that were at odds with the planned course direction. Secondly, given the importance of group work in the course design, they sought to identify students’ ways of experiencing group work. This was also quite surprising. Only a small group of students adopted the collaborative perspective that was intended. These evaluation findings were then used to modify the way in which the course was delivered, and in subsequent years it was found that a greater proportion of students (and tutors) were experiencing the course in the manner in which it had been intended.
TOOL 3: APPROACHES TO LEARNING

What are we talking about here?
Approaches to learning describe what students do when they go about learning and why they do it. The basic distinction is between a deep approach to learning, where students are aiming towards understanding, and a surface approach to learning, where they are aiming to reproduce material in a test or exam rather than actually understand it. A critical assumption here is that approaches to learning are strongly determined by students’ perceptions of the educational context and not only determined by students’ backgrounds. There is therefore no such thing as a ‘deep learner’ or a ‘surface learner’ – the same student can take different approaches depending on the educational context.

What does this mean for engineering education?
If approaches to learning are determined by the student’s response to an educational context then the challenge for educators is to create environments which foster deep approaches to learning. This is not as straightforward as one might guess, especially in engineering programmes which have high workloads and ‘high stakes’ assessment. Research with engineering students has also uncovered a more detailed range of approaches to learning, with ‘procedural approaches’ in between the classic deep and surface approaches. Procedural approaches involve students focusing on solving problems, and this can be with either ‘surface’ or ‘deep’ intentions. This suggests that we need to think about the traditional advice given to engineering students to ‘do loads of problems and understanding will come later’. From marking examination scripts and design reports most teachers know what happens when students have focused on learning problem solving procedures at the expense of understanding what they are doing.

In what ways might this be a useful thinking tool?
Context is everything in approaches to learning theory. You can’t simply ‘blame the student’ – you have to try and understand how the educational environment is being perceived. This is not as difficult as it might sound. Many people like to use inventories to identify students’ approaches to learning (for example, Ellis et al., 2008) but it has also been argued that simple qualitative studies using student interviews can generate useful contextual results.

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25 This original research is described in the book The Experience of Learning, now in its second edition (Marton, Hounsell, and Entwistle, 1997). Although out of print this book is available free online at http://www.tla.ed.ac.uk/resources/EoL.html. The field of phenomenography (described in Tool 2) developed from the original study which identified approaches to learning (Marton and Säljö, 1976).

26 (Ramsden, 2003)

27 This is a crucial difference between approaches to learning and learning styles (for an overview of learning styles in engineering education, see Felder and Silverman, 1988).

28 Biggs calls this ‘constructive alignment’ (Biggs, 1999).

29 See, for example, Case (2004).

30 (Case and Marshall, 2004)

31 (Case and Marshall, in press).
Show me an example...


Robert Ellis and colleagues conducted their investigation with third year engineering students at an Australian university. They focused their study on conceptions of learning (see tool 2) and approaches to learning, building on the assumption that conceptions of learning are likely to influence approaches to learning. They were interested to see how these ideas might apply in the context of an innovative course which used both face-to-face and online discussions.

They conducted both a qualitative study using a phenomenographic approach (see tool 2) and a quantitative analysis using student learning inventories. They obtained similar results from both analyses, showing relatively strong correlations between ‘cohesive’ conceptions of learning and deep approaches to learning. They concluded that it is important for lecturers to help students develop approaches to learning in which discussions (both face-to-face and online) are seen as important sites for building understanding.

Where can I read further to learn more about this tool?


John Biggs is one of the key scholars in this area of research. His early results with his ‘Study Process Questionnaire’ were surprisingly similar to those arising independently from the work by Marton, Entwistle and colleagues mentioned earlier. His writing is practical and highly accessible and a good starting point for anyone wanting to explore this area further.

In this paper, Biggs responds to concerns currently raised about how to meet the needs of the diverse range of students now entering higher education. In describing two hypothetical students, Susan and Robert, he provides a useful illustration of what deep and surface approaches mean in a particular course. He then puts forward his idea of ‘constructive alignment’ which involves creating educational environments where teaching and assessment are aligned with desired educational outcomes, such that more students will be likely to adopt deep approaches.

Biggs then backtracks a little to provide a very useful history on approaches to learning research. He uses these ideas together with the ideas of conceptual change (see tool 1) to formulate an approach to teaching which focuses on ‘what the student does’. This, he argues, is more effective than trying to cater to individual students’ varying requirements. To achieve constructive alignment one needs to ensure that learning objectives, teaching methods, and assessment are all focused towards the same thing. In discussing learning objectives he uses the SOLO taxonomy described under tool 1. He also provides a useful range of teaching methods for consideration, as well as assessment tools. This paper is really a helpful overview of a progressive and practical way to rethinking teaching in higher education.

32  (Biggs, 1978)
Learning as participation...

Learning is not merely a matter of acquiring knowledge, it is a matter of deciding what kind of person you are and want to be and engaging in those activities that make one a part of the relevant communities.

(Brickhouse, 2001, p. 286)

In working with Tools 4-6 we will draw on a very different perspective on what it is to learn. Here we focus on learning as participation. This is not any sort of activity: students are learning to do the activities associated with the professional community of engineers.

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33 This can be termed a sociocultural perspective on learning (Cobb and Bowers, 1999).
TOOL 4: COMMUNITY OF PRACTICE

What are we talking about here?
Community. Just another buzzword? Here is a thinking tool that invites you to consider the educational context as a ‘community of practice’. A community of practice is defined by the joint activities in which its members are engaged. Students are ‘newcomers’ to the community and they get inducted by participating in these joint activities. Even though the newcomers are at the margins of the community they do need to be involved in ‘legitimate’ (i.e. meaningful) activities. The teachers (and more experienced peers) are the ‘oldtimers’ in the community and they interact with the newcomers and also model the activities in the community. As students advance in their ability to carry out the relevant activities they become full members of the community of practice.

This perspective might sound more appropriate to an apprenticeship context than a formal educational setting, but many education scholars have now started to apply these ideas to what can be termed a ‘knowledge community’. The activities of the knowledge community comprise specialised ways of thinking, writing, talking, problem solving and so on.

What does this mean for engineering education?
This view on learning with a focus on ‘communities of practice’ has in fact always been implicitly present in engineering education. Our students spend periods in industry, they do practical investigations that get them to work with small scale versions of engineering equipment and our final year assessment is often in a design project which is supposed to model engineering practice. Taking on board ‘community of practice’ as an explicit thinking tool might help us to run these activities more effectively as learning experiences. In many engineering schools the practical and design courses receive less attention than the lecture-based theoretical courses, perhaps at least in part because these are not the courses that have high failure rates. We might be able to use these courses more effectively as key sites of learning which also energise and excite students.

But the ‘community of practice’ thinking tool can also be used to drive a more radical rethink of what we do. Perhaps we need to move ‘authentic’ activity to a more central place in our curriculum. This is what is being advocated by the Problem Based Learning (PBL) movement. This involves fully taking on board the central importance of students’ active participation to ensure effective learning.

More recently there are a number of scholars who have productively applied this thinking tool to designing and researching online communities of practice.

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34 The learning theory that encompasses this thinking tool is called ‘situated cognition’ (Brown, Collins, and Duguid, 1989) or ‘situated learning’ (Lave and Wenger, 1991)
35 (Wenger, 2000)
36 This is termed ‘legitimate peripheral participation’ (Lave and Wenger, 1991)
37 (Northedge, 2003b)
38 For a valuable review of the suitability of PBL to engineering education see Perrenet et al. (2000).
In what ways might this be a useful thinking tool?

What is the community of practice? Is it your classroom? Your department? The professional community of engineers? One can apply this thinking tool to communities at different levels. But if you consider your course or your programme then you need to think about what would be the appropriate activities that define your community of practice. You would also need to consider whether students are getting a chance to do meaningful activities and whether the classroom works as a community to support this learning.

Show me an example...


Jenni Case and Jeff Jawitz used the idea of ‘community of practice’ to explore engineering students’ experiences of industrial vacation work. They sought to investigate whether students experienced ‘legitimate peripheral participation’ (meaningful activity) or not. Engineering vacation students are traditionally in a difficult place, being only part way through their programme and on a short assignment, and it is generally considered difficult for managers to find useful things for them to do. Also considering issues of race and gender and the inherent conservatism of many engineering workplaces it was likely that access to the community of practice might be further complicated.

The study shows that access to meaningful activity is indeed a central determinant of whether the students have a productive learning experience or not. It was noted that the engineer assigned as mentor to the student played a key role in facilitating this access. In many cases the mentoring engineer was able to act as an advocate for the student’s status as a legitimate participant in the workplace.

Where can I read further to learn more about this tool?


This paper is focused generally on organisational contexts (and not directly on formal educational settings) but in it Etienne Wenger lays out very clearly how he sees the concept of ‘communities of practice’ which he originally devised together with Jean Lave. He helps us answer the question posed above – what makes for a community of practice? And all along the way he provides good examples to illustrate his concepts.

In this paper he suggests that we can have different forms of belonging to a community of practice: engagement (doing things together), imagination (constructing an image of ourselves) or alignment (making sure our activities are aligned with those of others). He goes on to make some interesting points about the importance of focusing on the boundaries of communities and looking at ways to broker knowledge between different communities. He also gives a good summary of his way of thinking about identity (see thinking tool 5).

This is a very practical paper for anyone wanting to apply the idea of ‘community of practice’ to their own context. He gives lots of questions and useful organisational matrices for structuring your investigation.
TOOL 5: IDENTITY

What are we talking about here?
Identity might seem to be a topic more suited to the clinical psychologist than the engineering educator: “I don’t need to know if my first years are well-adjusted 18 year olds, I just need to worry about whether they are learning any engineering!” It is therefore important to note that the view on identity that we wish to consider for inclusion in our guide does not focus on internal psychological makeup but is much more about how you present yourself to the world and how the world recognises you. In engineering education we are continually assessing whether our students are able to display engineering skills and knowledge with confidence. This is basically what we are talking about when we focus on identity.

There are a number of key assumptions that underpin this view of identity:

- **MULTIPLE**: we all hold multiple identities and deploy different identities depending on where we are and who we are interacting with at that time.

- **SHIFTING**: our ‘suite’ of identities changes over time: we take on new identities and we might sometimes choose to drop a particular identity. Some new identities might require us to do this and we might be in a dilemma if we don’t want to drop that identity.

- **PRODUCED**: there is nothing passive here. To be recognised as holding a particular identity, you need to talk and act in a way that others will recognise you as such.

What does this mean for engineering education?
Learning engineering is not simply a matter of ‘acquiring knowledge’; engaging with engineering is an act that has implications for how others will see you. Students come to engineering with some identities already in place that they use in the home, at school, with their friends. Taking on the new identity associated with learning engineering will either merge seamlessly with these other identities or else there might be a clash. A clash between these identities could result in academic failure or ultimately not choosing to follow a professional engineering career.

It is important to note here that we are not suggesting that undergraduate students are in a position to take on a full professional identity as an engineer. They are not yet able to behave in such a way that those in the engineering community would recognise them as an engineer. So we need maybe to call this the identity of being ‘an engineering student’. This is a broad concept that goes all the way from engaging in certain academic activities in class to a certain way of engaging with campus life. There may be a number of different identities available to your students that all, to some extent, can be used to successfully ‘pull off’ being an engineering student. But you can probably also think of some students who find themselves uncomfortable with or unable to take on these identities. Possibly more so than broad foundation degree programmes in the sciences or humanities, engineering as a ‘professional’ degree places strong demands on students around identity.40

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40 A useful exploration of the disciplinary identities on offer in engineering education is given in Matthew and Pritchard (2008). The edited book in which this chapter is found is also a useful resource on the topics of discipline, community, identity and discourse (Tools 4-6).
The engineering workplace involves a wide spread of practical engineering identities: some engineers focus on design, others on production, others on financial and managerial aspects of the business and so on. However, it seems that the tertiary institution offers a more narrowly defined range of identities and it is therefore possible that some students are not able to find an identity that ‘fits’ and thus either drop out or graduate without a productive identity to take into the workplace. This could be at the root of the failure of engineering programmes to deliver an acceptable number of successful graduates.

**In what ways might this be a useful thinking tool?**

Many engineering educators are concerned about the involvement of students from ‘non-traditional’ backgrounds in engineering education, for example women and ethnic minorities. These concerns centre on the choice to do engineering, success in engineering programmes and taking up engineering careers. Research in this area has often focused on trying to identify the ‘factors’ that underpin career choices and academic success. Some insights have been delivered, but we seem to still be very far from having productive insights as to how to widen access to engineering. Research guided by a focus on identity, as defined above in the sociological tradition, has the potential to generate important new understandings of this situation that can be used to guide future interventions. This might allow for a more dynamic approach than the sometimes overly general and static trio of ‘race, class and gender’. Engineering education research using identity as a theoretical tool has tended to focus mainly on gender issues (see below) and so there is productive future scope for exploring other aspects of diversity.

**Show me an example…**


In this paper Melanie Walker reports on a project which sought to understand the experiences of male and female students in a large Department of Electrical and Electronic Engineering at a pre-1992 university. She interviewed six men and nine women in in-depth individual interviews. The data was analysed using a framework focused on identity.

She found that women tended to adopt what could be termed a ‘resistance’ identity in which they asserted their difference from other females and ‘claimed to be “more like the boys”’ (p. 81). These identities offered a way of succeeding in engineering education but they did not challenge the dominant norms around ways in which one could be male or female in this environment. In fact, traditional ways of thinking resulted in women engineering students being stereotyped as more organised and hard working, something that the women didn’t actually welcome, especially in terms of the work that would get assigned to them in a group. Furthermore, for male students who did not identify with the views of maleness that predominated, there was also little room to move. Thus, the dominant culture ended up disadvantaging a subset of both women and men. While noting that there have been major changes in women’s opportunities in the world of engineering work, Walker notes that the engineering identities taken on by these students ‘both challenge and leave dominant gender relations in place’ (p. 86). Although she is reticent to prescribe practical solutions, her analysis suggests that we need to

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41 This argument is laid out in Allie et al. (2007).
42 See, for example, Seymour (1995).
43 See, for example, Woolnough et al. (1997).
44 Gee (2001, p. 99)
create spaces where both male and female engineering students can be free to create ‘project identities’ where they are able to build new identities that contribute towards a transformation of dominant gender relations in engineering.

Two further key studies on identity and gender in engineering education are:


**Where can I read further to learn more about this tool?**


James Gee is well known for his work in sociolinguistics and discourse analysis. In this paper he presents his take on ‘identity’ which is sociologically grounded with a particular focus on discourse (see tool 6). Gee’s writing is especially accessible for the non-specialist and this paper provides a useful mapping out of four different ‘sources’ of identity that we can recognise. This could provide a starting point for a research project into the engineering identities in your classroom. This paper is also a useful introduction to Gee’s notion of Discourse (as well as a quick crash course if you feel like it on modernism and postmodernism from a sociological perspective!). Towards the end of the paper he presents a brief illustrative study. It is set in a primary school classroom but it is not too hard to imagine how a similar kind of analysis could emerge from research in an engineering tutorial session. In his analysis of possible identities on offer to African American children in this classroom he provides a hard hitting analysis of how the institution might constrain possibilities for success depending on one’s social background.
TOOL 6: DISCOURSE

What are we talking about here?
With a focus on ‘discourse’ it might seem that we are focusing exclusively on written and spoken language – this might seem fine for the language teacher but only a part of what we are needing to think about in engineering education. In fact, the term discourse refers broadly to ways of using language, mathematical calculations, software, graphs, non-verbal gestures, artefacts and so on. It is the specialist discourse that characterises a particular community of practice (see tool 4). For example, the discourse of being an engineer will involve the practice of design to solve real world problems, and this includes collecting and analysing data, using empirical laws and correlations, doing mathematical calculations and modelling, as well as presenting one’s results to a range of different audiences. From this point of view, successful learning involves using a discourse in order to be able to participate in this community.

What does this mean for engineering education?
In engineering education we can therefore think of ourselves as working to produce ‘technologically literate’ graduates – with literacy used here in the broad sense of being able to use a particular specialist engineering discourse. What is worth noting is that discourse has been an especially useful thinking tool in mathematics education 45, which should be sufficient to persuade you that this is not simply the domain of the language teacher.

In what ways might this be a useful thinking tool?
So what’s the big deal? If we are focusing on ‘talking engineering’ how hard can it be… 46
In fact being able to use engineering discourse successfully, so as to be recognised as a competent graduate engineer by the professional community, is not so straightforward, as we all know. There is no simple ‘bluffer’s guide’ to see you through.

Discourse scholars have pointed out that learning a discourse is difficult precisely because so little is made explicit to the learner. Most of the key aspects of the discourse remain hidden. The task of the skilled teacher is to ‘make the tacit explicit’ 47. How to do this? Teaching can be conceptualised as:

- helping to create shared specialist meanings with students
- leading the journey from familiar discourse into the specialist discourse
- coaching students in using the new specialist discourse 48.

It is important to recognise that taking on a new discourse often involves both loss and gain. Students might be required to give up something of their familiar ways of communicating and relating to the world 49. Taking on the new discourse will need to seem worth it.

45 See Kieran et al. (2001).
46 Leach and Scott (2003, p 9) point out that this is a misconception.
49 Gee (2004).
Show me an example…


Julie Kittleson and Sherry Southerland research what happens in groups of mechanical engineering students who are doing their senior design project. What they had found was that, despite the lecturers attempting to promote collaborative work in student groups, there were very few instances of students grappling collaboratively with concepts. In trying to figure out why this was so they drew on discourse as a thinking tool.

They use a subtle distinction introduced by Gee which reserves the term discourse (with a little ‘d’) for students’ actual use of discourse in stretches of text or calculations. The term Discourse (with a capital ‘D’) refers more broadly to ways of thinking, valuing, etc. So the observation that students rarely engaged in any negotiation of concepts came from an analysis of their use of little ‘d’ discourse. To build an explanation as to why this was happening they turned to an analysis of the big ‘D’ Discourses that seemed to be operating in the situation. Here they uncovered engineering students’ views of group work which seemed to focus on using it for maximum efficiency and therefore dividing up work amongst the different group members and not working collaboratively. These Discourses were related to students’ views of what it was to be an engineer. They believed that different members of the group had different strengths and so should take on different parts of the task.

Where can I read further to learn more about this tool?

Sfard, A. (2001). There is more to discourse than meets the ears: looking at thinking as communicating to learn more about mathematical learning. *Educational Studies in Mathematics, 46* (1-3), 13-57.

Discourse analysis is surprisingly difficult to do for those of us who don’t have a background in linguistics, but the best way to learn about it, or even to see if you want to pursue it, is to look at real examples of how it has been used. This article is particularly useful in that it presents two examples of classroom discourse and then leads you conversationally through how one could analyse these using an acquisition perspective and then taking a discourse perspective. The setting is a school mathematics classroom, so one can certainly judge transferability to engineering education contexts.

In this paper, Anna Sfard uses her analysis of these two ‘episodes’ of mathematics learning to spell out key aspects of this perspective on learning. She defines a ‘communicational approach’ which sees thinking as nothing more than our internal (not necessarily verbal) conversations. By definition this is a process that embeds us in a social context. In helping to explain the meaning of ‘discourse’ beyond its everyday focus on reading and writing, Sfard provides a helpful description: discourse is ‘anything that goes into communication and influences its effectiveness’ (p 28). In considering mathematic discourse she notes that its ‘mediating tools’ are predominantly symbolic and that these are regulated by ‘meta-discursive rules’ which are often tacit.

This is a lengthy but very rich paper. It will take a long time to read through in one sitting (be warned!) but you will hopefully find it useful to return to various parts of it. It is really a complete manual for doing a relatively accessible and potentially very productive form of discourse analysis in engineering education.

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50 This derives from the work of the Russian psychologist Vygotsky (1962; 1978).
Concluding comments

In recent times the idea of the ‘scholarship of teaching and learning’ has come to the fore. Ernest Boyer, who coined the term (1990), put forward a compelling argument around what scholarship in the academy should entail. He suggested that academics might aim to be scholars, not only in the traditional sense of researching in their discipline (what he termed the ‘scholarship of discovery’), but also to engage in a ‘scholarship of teaching’51. A range of definitions have been offered on what it means to be a ‘scholar’ of one’s teaching52. These include being an excellent teacher, using the literature on teaching and learning to inform one’s teaching, conducting research on the teaching of one’s discipline, together with explicit reflection on and communication of one’s work to allow for peer review. A significant aspect of this work therefore demands an engagement with education theory. This guide has presented a kit of ‘thinking tools’ which the scholar can skilfully apply to complex contexts. This has been merely a starting point and of course this kind of journey does not have an end; there is a lifetime of interesting reading and thinking ahead. Enjoy the ride!

If you have any comments or suggestions or other ideas that you wish to share, please contact me at jenni.case@uct.ac.za.

51 Subsequently also termed the ‘scholarship of teaching and learning’ (SOTL). Note here that Boyer proposed a total of four types of scholarship, including the ‘scholarship of application’ and the ‘scholarship of integration’.
References


education theories on learning: an informal guide for the engineering education scholar


Sfard, A. (2001). There is more to discourse than meets the ears: looking at thinking as communicating to learn more about mathematical learning. Educational Studies in Mathematics, 46 (1-3), 13-57.


**Engineering Subject Centre Learning and Teaching Theory Resources**

This guide has been commissioned to complement and develop the Engineering Subject Centre’s existing range of resources about learning and teaching theory, available at http://www.engsc.ac.uk/er/theory/index.asp
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What happens next?

The feedback and discussion received will be reviewed by the Centre and author, and views and suggestions will be incorporated into new editions of the guide.

If you have any queries about this document or the process behind it, please contact us at enquiries@engsc.ac.uk
About the series:

This is one of a series of peer reviewed booklets looking at various aspects of teaching and learning aimed at all those involved in engineering education. The complete series is also available on our website.

This guide also forms part of the Engineering Subject Centre and engCetl’s Introduction to Pedagogic Research – a Tool kit for Engineering Academics.

About the centre:

The Engineering Subject Centre is one of the 24 subject centres that form the subject network of the Higher Education Academy. It provides subject based learning and teaching support for all engineering academics in the UK.

The Centre’s Mission is:

to work in partnership with the UK engineering community to provide the best possible higher education learning experience for all students and to contribute to the long term health of the engineering profession.

It achieves this through its strategic aims: sharing effective practice in teaching and learning amongst engineering academics; supporting curriculum change and innovation within their departments and informing and influencing policy in relation to engineering education.

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