Chapter 2
Developments in Engineering Education and Engineering Education Research in Europe

Erik de Graaff

2.1 Introduction

Our civilisation is highly dependent on engineering. We need engineers to design and manage the tools that our lifestyle requires, from mechanised agriculture to electronic gadgets. Without exaggeration, we can say that engineering education is the key to future success. This chapter aims to present an overview of the development of engineering education in Europe. The cultural diversity of so many different nations results in a fragmented picture of the historical developments with examples from just a few countries. The original economic-driven initiative of the European Union (EU; The European Coal and Steel Community, ECSC) established in 1951 paved the way for a political union and a desire to extend the collaboration to other areas including higher education.

An important step in this development was the signing of the Bologna declaration by the ministers of education of 29 European countries on 19 June 1999. The Bologna declaration propositioned a European Higher Education Area in which students and graduates could move freely between countries, using prior qualifications in one country as acceptable entry requirements for further study in another. In the wake of the Bologna declaration, an ambitious tuning project was started aiming to equate the different systems of higher education while maintaining the rich diversity of European education and the independence of academic and subject specialisms. As a result, Europe is more and more able to set uniform goals and to develop a common policy in promoting Europe as a knowledge society.

Furthermore, this chapter presents an overview of the present situation of engineering education and the development of engineering education research (EER), which is subsequently analysed to provide a foundation for a vision of future developments.

E. de Graaff (✉)
UCPBL, Aalborg University, Aalborg, Denmark
e-mail: degraaff@plan.aau.dk

M. Abdulwahed et al. (eds.), *Advances in Engineering Education in the Middle East and North Africa,* DOI 10.1007/978-3-319-15323-0_2

2.2 A Historical Perspective on Engineering in Europe

2.2.1 Introduction

Engineers have built Europe. All over Europe, man-made structures dominate the landscape. Without engineers, half of the country of the Netherlands would disappear below the waves of the North Sea. Europe also played a major part in the development of engineering. After a few early engineering feats, like the pyramids in Egypt, the hanging gardens in Babylon or the great wall in China, the initiative moved to Greece and later Rome. The Greek contributions to mathematics greatly helped the development of engineering. In the sixth century B.C., with the application of geometry principles, the Greek engineer Eupalinos managed to dig a tunnel through Mount Kastro at Samos, starting from the two ends and meeting in the middle.

Engineering accomplishments are a hallmark of civilisation. However, besides grave monuments and temples, most practical engineering throughout the ages has been carried out in a military setting. For instance, the Roman army employed engineers to construct roads, bridges, fortified campsites and war machines. To intimidate the Germans, Julius Caesar made it a point to build a bridge across the river Rhine, just to show he could.

2.2.2 Emergence of Higher Engineering Education

In many Western countries today, engineering education still has a background in the military. For instance, in Holland the first engineering school was established in 1600 at Leiden University on the initiative of the military leader of the young Dutch republic Prins Maurits. Under the name *'Duytsche Mathematicque'*, the school aimed to train land surveyors and builders of fortifications.

In France, the Ecole Polytechnique was established in 1794, named *'Ecole Centrale des Travaux Publics'*. When Napoleon came into power, he adapted the regime at this engineering school, introducing military discipline. Since then, the Ecole Polytechnique developed as a place where the French military and policy elite received their schooling. Years later, the French engineer and mathematician Poincarė analysed the functionality of the French system of engineering education in order to explain the loss of the French in the war against Germany (Galison 2003). At the other side of the Atlantic, the third president of the USA, Thomas Jefferson, established the first engineering program in America at the military academy West Point in 1802.

The transfer to the civil environment and the establishment of an academic status took quite some time. The development of Delft University of Technology (TU Delft) in the Netherlands can serve as an example. On 8 January 1842, King Willem II founded the 'Royal Academy for the education of civilian engineers, for serving both nation and industry, and of apprentices for trade'. The academy also educated civil servants for the colonies and revenue officers of the Dutch East Indies. Just over 20 years later, the Royal Academy was transformed into a polytechnic school, bringing the school under the influence of the rules applying to secondary education. This school went on to educate architects and engineers in the fields of civil works, shipbuilding, mechanical engineering and mining during the rest of the nineteenth century. It was not before 22 May 1905 that an act was passed, acknowledging the academic level of the school's technical education—it became a Technische Hogeschool, or an institute of technology. The institute was granted corporate rights by an act passed on 7 June 1956. Recognition of the institute as a university of technology had to wait until 1986.

Engineering is foremost a practical profession. In the old days, the way to learn a craft was to start working as apprentice to an established craftsman. The master–apprentice system was formalised in medieval times. A student had to stay in the service of the master for a fixed period before he could prove his skills with a master-test and become a full member of the guild. This way, the guild protected the quality of their profession. Institutionalisation of engineering education in Europe dates back to the eighteenth century. Research and science were closely connected in the formation of technology and were the basis in engineering education. In the nineteenth century, when the most engineering schools were established, there was a clear pedagogical idea: to teach science and to present research.

2.3 The Current Status and Impact of Engineering Education Research

2.3.1 Introduction

Since the end of World War II, participation in higher education—including engineering education—increased substantially. As a consequence, higher education changed dramatically, from highly individualised personal study plans to programmes for mass education and lecture theatres with several hundred seats. Presently, engineering education in Europe is developing towards a common market. A specific goal of the Bologna declaration is to promote mobility among (engineering) students in Europe. As a consequence, universities are also engaging in an international competition to attract students. It is not surprising that presently we observe an increasing interest for improvement and innovation in engineering education. All over Europe, 'Centres of Expertise in Learning and Teaching' within universities are being established or, in case of older existing institutes, reinstated. The position of such institutes in the university organisation is by no means clear, and also the tasks and responsibilities vary widely from one university to the next.

In most cases, the position within the organisation is not stable and varies with every change in local university politics. For instance, at TU Delft in the Netherlands, originally an educational service centre was created in the central university staff bureau. In the mid-1980s, a scientific department was established, headed by a full professor on university teaching and educational development in higher education. When the professor left, just before the turn of the century, the department started to dwindle. Finally, the section was split up in a research group and a teacher-training centre (De Graaff and Sjoer 2006). A few years later, the research group was discontinued, and the last member of the original group left TU Delft at the end of 2011.

The conclusion of the cycle of events depicted above is twofold: First, a university of technology needs expertise on educational innovation in higher education, and second, it is not clear where this educational expertise should be positioned in the organisation. Below, different organisational positions of educational expertise centres at Dutch universities will be explored from a historical perspective (De Graaff and Sjoer 2006).

2.3.2 Research and Development Centres in the 1960s

Europe has a respectable tradition of social scientists researching engineering education (de Graaff and Borri 2006). During the 1960s, the number of students enrolling in higher education increased dramatically. As a consequence, universities had to adjust their teaching methods in order to deal with mass higher education (Wiegersma 1989). Innovation and improvement soon became keywords in dealing with this issue. In a scientific environment, it seems natural that research plays a major part in order to establish a solid foundation for quality improvement. However, in order to achieve that, a major gap needs to be bridged. As it was put by a reporter at the end of the first national convention on Research of Higher Education in the Netherlands, Eindhoven, 27–28 April 1966: 'If one wants to improve the quality of teaching in higher education, then, first of all it is necessary to establish contact between the following two groups of people: those who are concerned with the teaching of science and those who are engaged with the science of teaching' (Vroeijensteijn 1981).

At the beginning of the increase in interest for research on higher education, the Dutch schools of technology played a central part. The third national convention on Research of Higher Education was organised in Delft, 15–16 January 1976 (Vroeijensteijn and van Woerden 1976). At the opening of this conference, the minister of higher education addresses the position of the Research of Higher Education (in Dutch, Research van het Wetenschappelijke Onderwijs, RWO) centres. The minister points out that the position of the RWO institutes differs markedly from that of other research institutes because their finances are drawn directly from the university funds. Although the financial position of the RWO institutes is sound, the positioning of these institutes into the university organisation is difficult. The gap between research and application of the outcomes is one of the problems singled out by the minister. Since the average university professor does not have enough time

Table 2.1 Educational units in Dutch higher education during the mid-1980s

Scientific department in one of the faculties
Rotterdam
Maastricht
Scientific department with professional teacher training
Utrecht
Leiden
Research institute with an affiliation to the local university
Amsterdam
Nijmegen
Groningen
Educational centres as part of the administrative university staff
Amsterdam (free university)
Delft (technical university)
Enschede (technical university)
Eindhoven (technical university)
Tilburg
Wageningen

to study educational science along with his own profession, the minister states: 'it is not surprising that it is hard to implement new educational insights in the practice of higher education'.

One might say that Research on Higher Education became a booming business during the 1980s. The respective institutes were allowed to hire more and more researchers. The various educational centres joined forces in an informal network of Centres for Research on Higher Education (CRWO). The network includes both general universities and universities of technology. The CRWO network continued to organise study conferences (Bartelds et al. 1987). Also, a section Higher Education was established as a thematic group operating within the national framework of educational researchers. The CRWO has played a major part in the start of educational research in the Netherlands. More recently, the CRWO transformed into a society of professional educational consultants in higher education (EHON).

By the time of the fourth national convention on Research in Higher Education in 1981, research institutes were established at or in close relation to most universities. Although some of these institutes were strictly service oriented (notably the educational service at TU Delft), most were research departments with their own scientific staff, fitting to the trend in industry of establishing 'Research and Development Centres'. Table 2.1 lists the organisational positions of educational units in the mid-1980s.

The classification above is not beyond debate. In some cases, staff units style themselves as research group. The presence of a professor with an assignment of research in higher education is taken as primary criterion. Such professors were appointed at the scientific departments and at some of the research institutes, but not at a staff unit. However, starting with this grouping, in the next section, we can have a look at the changes taking place in the following years.

2.3.3 Emerging of Consultancy and Training Centres

Despite the initial optimism, the problem of a deficient connection between research outcomes and educational practice in higher education only became bigger. In part because the researchers tended to become more and more involved in their own theories and in part because the teachers did not apply the same sound scientific methods they used for their own professional field to their teaching tasks (van der Vleuten 1997). The logical consequence of this gap was a growing pressure on the RWO institutes from their financers to spend less time on scientific research and invest more in innovation projects with a concrete and measurable outcome. Gradually, the institutes drifted apart. Some institutes even adapted to the style of commercial consultancy firms and managed to continue the growth process. Others turned into research institutes drawing on research funds; the ones who were more dependent on the primary stream of university funding tended to lean more heavily on consultancy and training. In some cases, the research-oriented departments were curtailed and repositioned within the universities' administrative staff. An example of this development is Rotterdam where the Erasmus University first closed down its department of educational research completely. A few years later, a new institute was founded, focusing on consultancy rather than on research. As related in the introduction, something to the same effect happened in Delft. Also at Twente University, a successful educational unit was downgraded in size as well as in organisational position. In Eindhoven, the Educational Service Centre was finally closed down. It is interesting to note that a recent study could not find evidence supporting a relationship between satisfaction with the operation of the institute and particular positioning in the organisation. Apparently, each solution has its own benefits. Table 2.2 summarises the situation in 2006.

Educational research institutes that acquire their main funding out of research grants tend to operate rather independently of the host university. University management appears to be unhappy with this independent position; consequently, they prefer to organise the educational consultants as a staff unit with limited or no research tasks. As a consequence, scientific research in higher education is cut short. What started out as research-based institutes aiming to sustain innovation in higher education through scientific research ended up as consultancy units supporting existing practice. Yet, if you aim for the highest quality, educational innovation based on applied research of higher education is needed (de Graaff and Kolmos 2013).

2.3.4 Revival of Educational Research

In the past years, EER has been on the rise once more all around the world (Borrego and Bernhard 2011). Engineers more and more often carry out their own educational research. In the USA, the book *Scholarship Reconsidered* (Boyer 1990) had a big impact. Ernest Boyer argued that the intellectual rigor of scholarly activities should

Table 2.2 Educational units in Dutch higher education in 2006

Scientific department or institute
Utrecht
Leiden
Maastricht
Amsterdam (free university)
Groningen
Heerlen (open university)
Consultancy or research institute with affiliation to the local university
Amsterdam (UvA)
Nijmegen
Rotterdam
Enschede (technical university)
Educational centres as part of the administrative university staff
Tilburg
Eindhoven (technical university)
Wageningen
Delft (technical university)

be extended to encompass four interrelated activities: discovery, integration, application and *teaching*. The Scholarship of Teaching and Learning aims to improve student learning and is usually motivated by a teacher's interest in how students in their own classrooms are learning (Huber and Hutchings 2005).

In the USA, the National Science Foundation (NSF) makes substantial funds available for EER. Universities like Stanford, Purdue and Virginia Tech have fast-growing departments for research on engineering education. Also in Australia and Asia, the trend to strengthen engineering education through research and innovation is manifest. The contributions of the USA (and Australia) dominate the worldwide network on Research in Engineering Education (REES).

As we have seen, many universities in Europe have their own locally funded educational support centres. However, as most of these centres focus on consultancy and training, there is not much room for research. Altogether, it appears to be harder to raise funds for educational research in Europe than it is in the USA. Apparently, the financing system of the European projects does not favour the topic of EER. An explanation can be found in the EU system of applying for funding. Brussels provides ample funding for European projects aiming to improve research and education in Europe each year. However, research and education are administered by two different directorates: the Directorate General (DG) for Education and Culture and the DG for Research and Innovation. The topic of EER has the misfortune to fall between these two directorates. In the long run, this could mean Europe runs the risk of falling behind compared with the rest of the world in a research area where it once had the lead.

2.4 Methods of Engineering Education Research

2.4.1 Methodological Diversification

In the beginning, research on higher education was conducted by social scientists, employing their own set of research methods (see Sect. 3.1). As engineering education develops as a field of applied research in its own right, more and more teachers with a background in technology and the natural sciences are involved. A characteristic of a fully developed branch of science is an all-embracing research methodology. The following criteria define a scientific discipline:

- Well-established chairs
- A public debate on research methodology
- A coherent theory, distinct from other domains

Presently, engineering education fulfils the first criterion. There are chairs in engineering education established around the world. The other two criteria appear as yet to be more difficult. The debate on research methodology is starting both in the international engineering education journals and in conferences and seminars.

Presently, practitioners of EER either have a background in natural sciences or in social sciences, or in both disciplines. As a consequence, EER uses methods both from the natural sciences and from the social sciences. Researchers will have to motivate their choice between quantitative and qualitative, as well as mixed methods research designs. The choice of methods depends on the worldview and of course on the research questions. In general, quantitative research implies that there are some well-developed theories that need further confirmation. Qualitative and mixed methods research aims at building theoretical understanding from a more diffuse starting point (Creswell 2009).

2.4.2 A Taxonomy Proposal for Engineering Education Research

EER is a rich field of investigation. It covers research on learning and teaching in all engineering disciplines and also in supporting sciences, like physics, chemistry, computing and mathematics, which form the scientific base of engineering research (Malmi et al. 2012). Furthermore, EER also applies theories and research methodologies from social sciences, like education, psychology and sociology, to investigate many-faced aspects of learning and teaching engineering. In order to get an overview of the whole field, there is a need to look at both: what is being researched and how the research is carried out.

Different types of studies require a different selection of methods. The literature reports an abundance of research strategies, suitable for various purposes. As a consequence, it can be hard to compare research outcomes and relate different studies to each other. In order to gain an overview of the research in a particular field—and to take notice of gaps in the topics covered—taxonomy is needed. In a joint initiative of the Société Européenne pour la Formation des Ingénieurs (SEFI) working group EER and Line B of the EU project EUGENE, a series of workshops were organised aiming to construct a taxonomy for EER from a European perspective (de Graaff and Kolmos 2010). The resulting proposal for a taxonomy was tested on conference and journal contributions (Malmi et al. 2010, 2012). Based on these papers, the section below summarises the outline of the European taxonomy for EER.

The taxonomy could be used as a measurement tool to reveal differences between various publication forums, thus giving suggestions for authors where to submit certain types of papers. Furthermore, it could make visible hidden trends or emerging research paradigms in the field. By clarifying the difference between case reports and research papers, we can also point out how the scientific level of papers should be increased when we aim at more generalisable results and deeper insights. The taxonomy could also be used as a reference when the publication forums are defining review criteria for different types of papers. At the moment, we see it clearly problematic that the review criteria in many conferences and also in some journals do not give clear enough guidelines both for authors and for reviewers concerning what is expected for the papers.

Finally, as EER is gradually gathering recognition as an emergent field moving from the margins to the mainstream (Streveler and Smith 2010, NEERC 2006), a taxonomy can help to provide a map of the terrain for new scholars entering the field. We expect the results of this analysis to provide us with data supporting the goal of building recommendations to improve scientific writing in the EER community (Table 2.3).

2.4.3 Publication on Engineering Education Research

An active research field requires a platform for publication of research findings. In the beginning, the social-science-based researchers used to publish their findings primarily in their own professional journals and conferences. This habit emphasised the gap between the researchers and the field of practice. Only on special occasion—for instance, with an invitation as guest speaker at an engineering education conference—would they address the community of engineering educators directly.

In Europe in the 1970s, this community started to organise itself. The first international society aiming at uniting engineering teachers was Internationale Gesellschaft für Ingenieurpädagogik (IGIP), founded in 1972 at the University of Klagenfurt (Austria). In the German language, IGIP stands for Internationale Gesellschaft für Ingenieurpädagogik. A year later, the European Society for Engineering Education, known as SEFI (the French acronym for Société Européenne pour la Formation des Ingénieurs), was established in Belgium. Both societies offer the opportunity to present experiences, ideas and research on teaching and learning in engineering at annual conferences. A few times, these conferences have even been organised jointly, allowing members of both societies to mingle. Shortly after its

Table 2.3 Taxonomy for engineering education research (EER). (Malmi et al. 2012)

After processing all comments, the proposed taxonomy categorises research in six dimensions. In principle, we consider the dimensions independent of each other, but we recognise that certain research paradigms prefer certain types of collected data and analysis methods
1. Explanatory framework (EF) dimension
Neither research nor practical development takes place in isolation. We are building on previous work by other researchers and practitioners. This is the basic premise of all academic work. Scholarly work should also always recognise the premises of one's work and methods. Equally important is to give credit to others' work on which we are building our own work by mentioning this in the text and properly referencing their publications and works. The EF dimension aims at making visible how the target publication is linked to previous work (Jolly et al. 2011). We limit our investigation to such conceptual constructs that we expect to be known in a wider community of EER researchers. These constructs, which we call EFs, can be, for example, the following
Theory can refer to well-established theories, such as constructivism, situated learning or cognitive load theory
Model/framework/taxonomy/formal construct refer to established conceptual constructions, which are not generally called theories. Some examples could be Bloom's or Solo taxonomies, concept maps, IEEE curriculum definitions and pedagogical patterns
Very often, papers build on previous research, which does not have an established widely known status, in various ways. These could be the following
Using previous work as motivation. For example, addressing open questions, which were identified in other publications
Extending previous research to a new data set or reanalysing previous data sets in a new way
Using previous results as a starting point for new research
Applying a methodology, which was developed in another paper
To simplify the analysis, we will not classify the latter types of references, but consider only such EFs that we consider well-known within the EER community. Though, at the same time, we recognise that 'well-known' is an ambiguous concept and thus needs to be negotiated
We also do not list links to technical tools or frameworks. There is a multitude of such applied in EER, as engineering is about designing, implementing and applying technologies. Neither do we classify methodological references here, such as phenomenography, content analysis or various statistical tests or analysis methods. The methodologies are captured by other dimensions
Each EF is accepted on face validity. If the authors claim they are using it, we do not question this, as we can analyse in reasonable time only the publication we have. We will not report EFs, which are not explicitly mentioned in the paper, that is, we will not try to interpret from the paper whether the work is based on some EF
2. Research strategy (RS) dimension

Table 2.3 (continued)

There are many different ways how research is carried out. Here, we differentiate the general research design from more detailed-level data analysis methods. The former captures the choice of research questions and how they are generally approached, while the latter concern the concrete analysis methods used in processing collected data. Here, we face a problem which terminology we should use for the wider design of the research. In some contexts, we could use here either term research paradigm or research approach, but these are not used in all cases we cover, and especially the term paradigm is a too wide concept for us. On the other hand, the term research design typically refers to a rather detailed description of the research setting. Malmi et al. (2010) used the term research framework: Research framework '…is an overall orientation or approach that guides or describes the research, as opposed to a specific method or technique. A research framework may have associated theoretical, epistemological and/or ontological assumptions (e.g. phenomenography); may prescribe or suggest the use of particular methods (e.g. grounded theory); or may simply be a descriptive term for a kind of research activity that has certain characteristics (e.g. action research (AR), case study). Not all papers will have a research framework'
A similar dimension has also been proposed by several other researchers, though with different names: emerging methodologies (Case and Light 2011) or research strategies (Chism 2010). Also Merriam (2002), Creswell (2007) and Denzin and Lincoln (2005) present a similar type of classification for methodologies. We will adopt the term research strategy, instead of research framework, to avoid confusion with explanatory framework
We propose the following set of research strategies, though we recognise that the list can be expanded (definitions from Malmi et al. 2010)
Action research (AR)
A self-reflective systematic inquiry undertaken by participants to improve practice. Typically conducted as an iterative cycle of planning, action, change and reflection. A large number of EER papers have these characteristics—as their goal is to improve EER practice, and in many cases the teacher is participating in the development project. However, we do not classify reports on single research/development activities as AR (but classify them based on how they have been implemented). Instead, AR should be restricted to papers reporting on a longer term or sequential development activities where the authors have been participating themselves. AR often also involves people who are part of the activity that is under the study. The role of the researcher can be anything from an external expert who tells what to do differently (technical AR) to the catalyst who gets the things moving and gets people to participate and act themselves to improve the situation they are in (critical AR). Action research may be found under other names, like participatory research, collaborative inquiry, emancipatory research, action learning, and contextual action research.
Case study (CS)

Table 2.3 (continued)

A case study is an in-depth, descriptive examination conducted in situ, usually of a small number of cases/examples. Typically, a case study includes using several different data sources, which provide a rich description of the investigated case and possibly allows triangulating the investigated topic. We note that case study is not a clearly defined concept, and there are different interpretations of it. If the authors claim they have used the case study approach, we accept it by face validity
Constructive research (CR)
Research that aims to demonstrate and/or evaluate the feasibility of a proposed idea (concept implementation, proof-of-concept research). It revolves around the development of, for example, software, technology, a teaching approach or an evaluation instrument. Papers concerning educational technology fall within CR if the paper focuses on presenting the novel tool/learning environment and its functionality. In many cases, the paper also includes some kind of evaluation study, which adds another research strategy, like experimental research (Exp). Also, papers that present a novel teaching method and focus on how it is implemented and why it is used, with possible evaluation, fall within CR
Delphi
A specific method of seeking consensus by showing a group of raters a summary of their ratings, with justifications, then iteratively inviting them to reconsider their ratings in the light of what the others have said. Papers that apply this method usually identify it explicitly
Ethnography (Eth)
A branch of anthropology that deals with the scientific description of individual cultures
Experimental research (Exp)
Quantitative research based on manipulating some variables while varying and measuring others. This requires formation of control and experimental groups of participants with random assignment of participants or use of naturally formed groups. All papers reporting on a treatment-control group setting include this strategy. The focus is on testing the effect of some treatment. Survey research papers may have similar outlook, but there the focus is on investigating the variables without explicit treatment
Grounded theory (GT)
Qualitative, data-driven research in the tradition of Glaser and/or Strauss that aims to formulate theories or hypotheses based on data. A qualitative study that analyses data to build a model to explain that the working of the investigated topic fits well here
Phenomenography (PhG)
Investigation of (other) people's ways of experiencing a phenomenon (2nd-order perspective). Phenomenographic research is well established and all papers applying it say it explicitly
Phenomenology (PhL)
Investigation of one's own experience of a phenomenon (1st-order perspective)

Table 2.3 (continued)

Survey research (Survey)
Quantitative research based on exploring the incidence, distribution and/or relationships of variables in nonexperimental settings. Survey research focuses on an investigated topic as it is, not with a treatment. For example, the effect of gender or age group on study success
A paper may have more than one research strategy. On the other hand, a paper may not have any research strategy that we can identify. Each explicitly mentioned research strategy will be accepted on validity. If the authors claim they are using it, we will not question this
Contrary to EFs, we will distinguish between cases where the authors explicitly mention a research strategy (though probably they do not use this term but say, for example, that they were carrying out AR), and cases where we conclude from the report that some research framework was used. The reason for this is that mentioning a research strategy/framework/paradigm/approach is not a common convention. For instance, we record case study as one research strategy, but many times this is not explicitly written in a paper. In summary, we give research strategy an additional tag 'explicit', 'implicit' or 'none' if no research framework can be identified in the paper
3. Data source (DS) dimension
Data collection implies what kind of data has been used in the empirical part of the work. Most papers have at least one data source, but very often include several. Examples of categories in this dimension include the following (the list is not exhaustive)
Students' submitted work (essays, project reports, learning diaries…)
Examinations and tests
Questionnaires
Instruments
Interviews
Observation data
Databases (e.g. study register data)
Software log data
Researchers' own experiences (e.g. 'lessons learned')
Literature (e.g. literature reviews, meta-studies)

Table 2.3 (continued)

An instrument is a special case of a questionnaire. It is a psychometrically validated questionnaire, which is used to measure some aspect of human behaviour, such as the Myers–Briggs personality test. We list such instruments, if encountered, as they are useful tools in many aspects of EER, and we wish to promote their wider application, instead of building similar tools ad hoc. Typically, most papers report some of researchers'/teachers' own experiences and reflections. However, we will report them as data source only if their share of the paper is significant compared to other collected data. We will not any more identify data sources as intrusive or natural data. We just mention that certain data sources like interviews are always intrusive, whereas some are natural, like study register data, and some can be used in both ways
Finally, we will register what is the scope of data collection (as a whole), that is, has it been carried out in the individual level, group level (like classroom, student group in one course/unit, whole course/unit), institution level (curriculum, program, university, …) or multi-institutional level (many universities, whole country, …)
4. Data analysis (DA) dimension
The data analysis section will describe how empirical research data are being analysed or what other means are used to draw conclusions in the paper. Most papers feature at least one kind of analysis method. If a paper has an RF, the framework often directs the analysis methods that are used. However, the same analysis method can, of course, be found in a paper that is applying some other framework or has no specified RF at all. The number of possible analysis methods is extensively large, and we need to gather them into rough categories. We will apply the following categories to cover the data analysis method dimension
Quantitative complex
Any form of statistical methods exceeding simple descriptive statistics, such as statistical tests, correlations, regression analysis, factorial or cluster analysis, data mining techniques, …
Quantitative simple
Descriptive statistics including cross tabulation and graphics
Qualitative enhanced
Any qualitative methods which have a clearly specified analysis process (is it reported to such aspect that it could be repeated?)
Qualitative simple or not specified
Qualitative analysis which only includes identifying important themes/topics/items of interest, like interviews without specifying a method or structure. This category will also be used in cases where it seems that some method has been applied, but due to missing description we cannot know what it was
Other
Other methods, to be described
None
Plain common sense and using one's own reflections as a kind of analysis method are counted here as well

Table 2.3 (continued)

A paper can include several of the above methods, and we will list all that we recognise regardless of whether it is explicitly stated or implicitly included. Based on that, we can later on derive whether the paper is a quantitative/qualitative/mixed methods paper
5. Reporting (RP) dimension
Reporting the research setting and process is a central part of good scientific communication. We will make observations in the text on the following aspects
1. Research questions
a. Research questions/research goals are explicitly emphasised in the text. This means that they can be found easily with some visual cue, such as within bullet or number lists or italicised within other text
b. Research questions/goals can be found in other text, typically in the introduction or in the beginning of the section which describes the paper contribution (implicit). This means that we can identify some text in the paper, which presents the goals of the research and/or questions to which the research seeks answers. We do not require that these are presented as questions, but may be written as ordinary text
c. No research question or goal can be identified in the text (none). It is not possible to identify any text presenting the goals of the paper, either in the abstract, introduction or before the method/results section
2. Methodology section
a. Methodology has clearly its own section in the paper (explicit). This can be identified based on paragraph titles
b. Methodology is implicitly described within other text, typically in the results section (implicit). It is possible to identify that there is text that presents the methodology used, regardless of where it is in the paper. Some educational technology papers, for instance, simply describe the design, implementation or functionality of a novel software or tool without any specific method section. We categorise these papers as technology papers
c. No clear methodology description can be identified in the text (none)
3. Validity/generalisability discussion
a. The paper has a separate section/subsection discussing the validity/generalisability/trustworthiness/limitations of the research (explicit)
b. The paper has some critical discussion of some of these issues in the text, typically in the results section or conclusion (implicit). It is possible to identify a discussion of limitations of the paper regardless of where it is and whether it is in one or several places in the text
c. No critical discussion can be found or it is very vague (none)
6. Nature (NT) dimension
Finally, the NT tries to capture the general character of the paper as a whole. We categorise the NT as follows
Empirical paper: It is a paper, which has the basic elements of empirical research, including clear data collection, analysis and reporting results. The paper may or may not have hypotheses. Data analysis may be based on quantitative or qualitative or mixed methods

Table 2.3 (continued)

Case report: It describes a novel educational setting, such as a new teaching method, assessment method, learning resource, learning specific software, etc. The focus of the paper is on describing the new contribution. There is no evaluation, or the evaluation is very shallow, typically reporting some student results, student feedback and/or teachers' experiences with no clear research setting (such as comparison to previous year). A case report typically has a limited scope, related to some specific course, and the research setting and method aspect of the paper is vague—the focus is on the novel thing, whether it be teaching method, software or something else. Usually, the focus of the paper is to improve practice
Position paper/proposal: This is a paper where the authors want to raise some issue for discussion among the EER community or propose something new to be considered in engineering education practice or EER
Theory paper: It discusses theoretical aspects of teaching and learning; for example, it compares some learning theories in some context. The paper is based on theoretical discussion and argumentation and has little or no empirical data to support its claims
We will not differentiate whether the nature of the paper is explicitly or implicitly stated as this is basically our interpretation of this issue. All papers have some nature

foundation, in 1975, SEFI initiated the publication of a quarterly publication. At the start, the journal was a mixture between a society newsletter and a platform for scholarly articles on engineering education. Since 1975, *European Journal of Engineering Education* (EJEE) gradually became more focused on research papers and review articles with a theoretical foundation.

In the USA, the American Society for Engineering Education (ASEE) *Journal of Engineering Education* (JEE) has a much longer history, publishing on engineering education for over 100 years (Wankat 2004). A third journal, with no ties to a specific organisation, is the *International Journal of Engineering Education*. Presently, there are also several other national journals on engineering education, for instance in Australia and Brazil.

International recognition indicates that JEE and EJEE have developed into leading journals in the field of engineering education (Osorio and Osorio 2004).

Recently, this was confirmed by the keynote presented by Phil Wankat at the 40th Annual SEFI conference in Leuven. Together with a few colleagues, he made a bibliometric analysis comparing the US-based JEE with the EJEE. The paper based on the text of the keynote is published in the EJEE (Wankat et al. 2014).

The analysis clearly demonstrates that both journals gradually developed a more pronounced research orientation: 'Initially there were little or no research papers in the 70's and 80's and then there was gradually increasing research content' (Wankat et al. 2014). The conclusion of the study states that both journals became more frequently cited and that there was a qualitative evolution in breath of scholarship with increasingly interdisciplinary research articles with more collaboration and more references. While the international character of both journals also evolved over the 40 years, geographical spread is notably broader in EJEE.

During the past years, several new conferences and symposia created new opportunities for presenting studies on engineering education, like the international Research in Engineering Education Network (REEN) and the International Research Symposium on Problem-Based Learning (IRSPBL). Also a number of online journals emerged, further enriching the possibilities of engineering education researchers to publish their work. In any case, nowadays there are ample opportunities for publishing.

2.5 The Future of Engineering Education and Research in Europe

2.5.1 Introduction

To achieve the political ambitions of Europe as a knowledge society, we need many engineers with leadership skills and creativity who are capable of coping with the increasing complexity of the technological foundations of our society. To train engineers who can meet these challenges, we need to innovate our approaches to teaching and learning at the universities of technology and polytechnic schools.

Participation in higher education is expected to remain at a high level. A lot of efforts are made trying to attract more young people to choose a career in engineering. Engineering could possibly attract more female students, and most importantly, as some people say that the present day half-life of technical knowledge is said to be less than 5 years, modern engineering requires a lifelong study. As a consequence of this development, the ability to access and manage information becomes more important than knowledge per se.

A fundamental change of the process of teaching and learning is the result. In fact, this may be one of the most striking factors of change in the present era. Traditionally, the primary task of teachers is transfer of knowledge. A teacher possesses expert knowledge or skills in a particular field, which consists of the basis of teaching. For a long period of time, lecturing has been the dominant educational format in higher education. As a dispenser of knowledge, the lecturer used to be responsible for both the content and the structure of teaching.

Due to the rapid developments of information and communication technology (ICT) over the past decades, the old-fashioned method of lecturing is now all but obsolete. The increased use of ICT leads to an increase in the dynamism of organisations. Consequently, people in those organisations will have to learn to deal with new and unexpected situations. Teachers in higher education for instance will have to face the fact that they do not hold the monopoly on knowledge anymore. Information is freely available and can be accessed from anywhere at all times. Moreover, in many areas, the state of the art is changing so rapidly that it is hard for teachers even to keep up with their students.

All over the world, institutes in higher education have seen this change coming, and they have tried to adjust to it in various ways. Internet and e-mail are widely used as means for communication between teachers and students. Learning content, full text as well as supporting slides, is available online.

Following the example of the open courseware project of Massachusetts Institute of Technology (MIT), several universities make learning content of their study programmes available for free on the Web. Materials may comprise streaming video lectures, interactive Web demonstrations, homework problems and exams. A recent trend is to offer massive online open courses (MOOCs).

Nowadays, students can exercise their skills in many ways supported by software packages rather than by a teacher. However, several people already recognised that it does not suffice simply to transfer the old content to the new media. To take full advantage of the opportunities offered by the ICT technology, the learning environment needs to be redesigned completely.

2.5.2 Scenarios for Future Developments

The challenge for the field of higher education is to take full advantage of the wealth of opportunities that are opened through the new teaching and learning tools. In order to prepare a policy for dealing with higher education/research relations in

Europe, a Strategic Analysis of Policy Issues - European Technology Assessment Network (STRATA–ETAN) expert group was set up by the EU in December 2001 with the mission to prepare a Foresight report. The 21 members of the expert group, chaired by Maurice Godelier and rapporteur Etienne Bourgeois, come from a wide variety of countries (EU states members, Accession countries and Canada) and disciplinary background. Each one of them wrote ‘issue papers’. In 2002, the final report of the STRATA–ETAN Expert Group on Foresight for the Development of Higher Education/Research Relations was presented (Bourgeois 2002). The following section draws upon the issue paper I prepared for the STRATA–ETAN Expert Group (De Graaff 2002).

In this issue paper, I propose two scenarios depicting projected developments in higher education. The focus of the first scenario is on the potential of individual freedom and self-direction in learning. The second scenario highlights the collective aspect of collaboration and communication in teams. A development that is deemed unavoidable is a further differentiation in the tasks of a teacher. In both scenarios, three different teacher roles will be identified: the facilitator, the educational designer and the assessor.

Scenario 1: The Individualist

As a result of the rapid technological development, an increasing number of tools are available that reduce our dependency on other people. In order to prepare a text for printing, an author used to need at least a dozen people, skilled in typesetting, layout, correction, etc. Presently, anyone with a PC can easily deliver a camera-ready print proof, corrected for spelling errors and grammar. An example even closer to the school can be found in the widely available software packages that support learning to speak a foreign language. Until recently you needed an expert, preferably a native speaker, to correct your pronunciation—a tiring exercise, boring both for the students and for the teacher. Nowadays, a student can do these exercises whenever and as many times he wants. The advantage of not needing anyone will tempt some people to isolate themselves. They can get whatever they need and they can do whatever they want without having to see anyone.

The Individualist as a Facilitator As a facilitator, the individualist has a hard time. He will have to focus his attention on the interaction process among learners, and, in a sense, act as an expert in group dynamics. The individualist tends to feel uncomfortable in this position, and he will easily fall back in the old role of the expert providing the answers. It is not so much that the individualist is incapable of fulfilling this task; he will probably not enjoy doing it.

The Individualist as an Educational Designer In the role of a designer, the individualist probably feels more at home. However, the present-day educational design projects usually involve teamwork. Even if the creative spark of the individual constitutes an essential element in the design process, the filial of each member’s contribution depends on the ability to communicate and co-operate. The individualist will have to learn to compromise in this respect in order to become an effective team member.

The Individualist as an Assessor The role of the assessor also involves a strong element of communication. However, in this position the individualist retains the authority of the content expert. In order to be successful in this task, it is important that the individualist learns to be specific with respect to the criteria that he applies. Such criteria specifying the core characteristics of expertise within a particular domain are at the same time concrete learning objectives for the students.

Scenario 2: The Team Player

As a result of the rapid technological development, things get so complicated that you cannot virtually do anything on your own anymore. A single person never will possess all relevant information. Therefore, in order to achieve something worthwhile, you need the participation of others. Each individual tends to focus on his own specialty. Sharing the own expert information with other team members becomes a crucial skill. Presently, organisational structures are becoming more flexible, and teams within organisations are only temporary structures. The ideal team member is adapted to the volatile interpersonal relationships within a network structure.

The Team Player as a Facilitator The team player usually feels quite comfortable in the role of a facilitator. The main risk with this type of person is that he becomes too much involved in achieving the objectives. When there are problems in the group, he may tend to give practical solutions rather than helping the group to find their own way out. When the group is doing fine without his advice, such a person may feel obsolete and frustrated. However, a natural team player has the ability to enjoy the sharing of experiences in the team, including his own.

The Team Player as an Educational Designer Present-day educational design is a typical team task. This teamwork calls for specialist expertise in particular domains, creative ideas and critical reflection on the input of others. As a member of such a team, a teacher who is a natural team player can fully blossom.

The Team Player as an Assessor The role of the assessor will be less easy for a team player. Judging others is usually not the best way to inspire collaboration within a team. A team player will tend to emphasise the feedback value of an assessment and hesitate before taking pass/fail decisions. A common error in project work, for instance, is the tendency to focus on the collective group product and to neglect the individual contributions. Another problem in this respect is that the assessor may feel insufficiently equipped to judge the overall performance, as this will go beyond his own area of expertise. However, in general, team players can operate satisfactory as assessors, provided they feel the assessment does justice to the individual team member.

Maybe at first glance, the two scenarios depicted above appear to be mutually exclusive. However, it is possible to regard the scenarios as the two extreme ends of a bipolar scale. Training teachers to operate effectively within the emerging new structure of higher education involves getting them to know themselves. The scenarios could be used as a point of reference.

2.6 Concluding Remarks

For a long time, Europe dominated the world in political and economic respect as well as in culture and science. France, Germany, England, Italy and even a small country as the Netherlands competed mostly among themselves. The Industrial Revolution started in Europe and spread around the world from there.

It was a bit of shock to recognise the increasing impact of former colonies like the USA at the beginning of the last century. For some, it may have lasted until after the World War II before they could accept the fact that Europe was no longer at the centre of world power.

With the political and economic power, the centre of gravity of science and technology also shifted. For years now, the five highest-ranking universities in the category Engineering and Technology of the Times Higher Education World University Ranking are situated in the USA. Different ranking systems show a slightly different picture. In the Shanghai ranking, the top 11 positions are taken by US institutes. However, the Quacquarelli Symonds (QS) ranking allows three universities from the UK, two from Switzerland and one from Singapore in their top ten. The QS ranking is also the one that most clearly shows the on-going worldwide development, with increasingly high rankings for universities from China and other countries in Asia. The power balance is shifting again, and science and technology seem to follow.

In the meantime, these past years we have experienced a period of economic crisis. In particular, Europe appears to have been hit hard, spreading from banks to governments. As a result, now all over Europe, budgets for higher education are being cut. When things get difficult, people tend to play safe. Universities, like commercial companies in trouble, tend to choose to layoff tenured staff. As the Delft professor of economics of innovation Alfred Kleinknecht (2013) points out in his farewell lecture, letting go people too easily is detrimental for innovation.

Unsurprisingly, the funding of research on higher education has become problematic. Yet, in order to increase the efficiency of our universities, we still need research to find out what really determines the effectiveness of learning in higher engineering education. Economising by sending away the experts that can direct this research may prove highly inefficient in the long run. As far as engineering education is concerned, Europe is truly becoming the land of the setting sun, unless we manage to build a machine to reverse the tide.

References

Bartelds, J., Brants, K., van der Hoop Gerritsen, W., Hulshof, M., & van der Weiden, M. (Eds.) (1987). *Studiedag Contactgroep Research Wetenschappelijk Onderwijs [Study Conference Contact Group Research Higher Education]*. Nijmegen/Utrecht: IOWO/VSNU.

Borrego, M., & Bernhard, J. (2011). The emergence of engineering education research as an internationally connected field of inquiry. *Journal of Engineering Education, 100*(1), 14–47 (January 2011).

Bourgeois, E. (2002). *Higher education and research for the era: Current trends and challenges for the near future; final report of the Strata-Etan Expert Group on foresight for the development of higher education/research relations*. Brussels: European Commission, Directorate-General for Research (October 2002).

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate*. San Francisco: Jossey-Bass.

Case, J. M., & Light, G. (2011). Emerging Methodologies in Engineering Education Research. *Journal of Engineering Education, 100*(1), 186–210.

Chism, N. (2010). Qualitative research basics: A guide for engineering educators (pp. 9–10). http://cleerhub.org/resources/8.

Creswell, J. W. (2007). Qualitative inquiry and research design: Choosing among five approaches (2nd edn.). Thousand Oaks: Sage.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative and mixed methods approach* (3nd edn.). Thousand Oaks: Sage.

de Graaff, E. (2002). Educating independent learners in a digital learning environment; 'Past performance is no guarantee for future success'. Issue paper Stratan Etan Group. Delft: 2002.

de Graaff, E., & Borri, C. (2006). Research and innovation of engineering education in Europe the contribution of SEFI. Proceedings of the 2006 JSEE annual conference (pp. 12–17).

de Graaff, E., & Kolmos, A. (2010). Research methods in engineering education research. Proceedings of Joint International IGIP-SEFI annual conference 2010.

de Graaff E., & Kolmos, A. (2013). Innovation and research on engineering education. In J. Michael Spector, M. David Merril, J. Elen, & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 565–571). New York: Springer.

de Graaff, E., & Sjoer, E. (2006). Positioning educational consultancy and research in engineering education. Proceedings of the 34th Annual SEFI Conference (pp. 98–101). Uppsala: Uppsala University.

Denzin, N. K., & Lincoln, Y. S. (2005). Introduction: The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd edn., pp. 1–32). Thousand Oaks: Sage.

Galison, P. (Ed.). (2003). *Einstein's clocks, Poincaré's maps*. London: Hodder and Stoughton.

Huber, M. T., & Hutchings, P. (2005). *The advancement of learning: Building the teaching commons*. San Francisco: Jossey-Bass.

Jolly, L., Willey, K., Tibbits, G., & Gardner, A. (2011). Conferences, reviews and conversations about improving engineering education, Proceedings of the Research in Engineering Education Symposium (REES 2011). Madrid, Spain.

Kleinknecht, A. (2013) *'Een Erfenis van Schumpeter'* Afscheidsrede. ('An inheritance from Schumpeter', farewell lecture). Delft: TU Delft.

Malmi, L., Sheard, J., Simon, Bednarik, R., Helminen, J., Korhonen, A., Myller, N., Sorva, J., & Taherkhani, A. (2010). Characterizing research in computing education: A preliminary analysis of the literature. Proceedings of the sixth international workshop on Computing Education Research (ICER'10). New York: ACM. pp. 3–12. doi:10.1145/1839594.1839597.

Malmi, L., De Graaff, E., Adawi, T., Curmi, R., Duffy, G., Kauz, C., Kinnunen, P., & Williams, B. (2012). *Developing a taxonomical classification of EER papers*. Paper presented at the 34th Annual SEFI Conference Engineering Education 2020: Meet the Future, Thessaloniki, Greece.

Merriam, S. B. (2002). Qualitative research in practice: Examples for discussion and analysis. San Francisco: Jossey-Bass.

NEERC. (2006). National Engineering Education Research Colloquies' special report "The Research Agenda for the New Discipline of Engineering Education,". *Journal of Engineering Education, 94*(4), 257–261.

Osorio, Nestor L., & Mary A. Osorio. (2004). Engineering Education in Europe and the USA. *Science & Technology Libraries, 23*(1), 49–70.

Streveler, R., & Smith, K. (2010). Guest editorial: From the margins to the mainstream: The emerging landscape of engineering education research. *Journal of Engineering Education, 99*(4), 285–287.

van der Vleuten, C. P. M. (1997). De intuïtie voorbij [Beyond intuition] Tijdschrift voor Hoger Onderwijs, 15.1. pp. 34–46.
Vroeijensteijn, A. (red.). (1981). Kwaliteitsverbetering Hoger Onderwijs [Improvement of quality in Higher Education]. Proceedings of the fourth national convention Research in Higher Education, December 1-180-1981. Eindhoven: Stichting Nationaal Congres/1981.
Vroeijensteijn, A., & van Woerden, V. (red.). (1976). *Onderwijsresearch & Praktijk deel 1 en 2 [Educational Research & Practice]*. Delft: Delftse Universitaire pers.
Wankat, P. (2004). Analysis of the first ten years of the Journal of Engineering Education. *Journal of Engineering Education, 93*(1), 13–21.
Wankat, P., Williams, B., & Neto, P. (2014). Engineering education research in EJEE and JEE: Citation and reference discipline analysis. *European Journal of Engineering Education, 39*(1), 7–17.
Wiegersma, S. (1989). *Innovatie van het hoger onderwijs [Innovation in Higher education]. Hoger onderwijsreeks*. Groningen: Wolters-Noordhoff.

Erik de Graaff is trained as psychologist and holds a PhD in social sciences. He started his academic career at the University of Maastricht in 1979, working with Problem Based learning (PBL. In 1994 he was appointed as associate professor in the field of educational innovation at the Faculty of Technology Policy and Management of Delft University of Technology. Dr. de Graaff has been a visiting professor at the University of Newcastle, Australia in 1995 and a guest professor at Aalborg University in Denmark in 1997. The collaboration with Aalborg University led to an appointment as full professor at the department of Development and Planning in 2011. Dr. de Graaff is recognized as an international expert on PBL. He contributed to the promotion of knowledge and understanding of higher engineering education with numerous publications and through active participation in professional organizations like SEFI, IGIP, IFEES and ALE. He has published over 200 articles and papers and he has presented more than 70 keynotes and invited lectures on various topics related to PBL in higher education, like: Working with PBL, Management of change, Assessment and evaluation, Methods of applied research and Collaboration between university and industry. Since January 2008 he is Editor-in-Chief of the European Journal of Engineering Education.

Springer

http://www.springer.com/978-3-319-15322-3

Advances in Engineering Education in the Middle East and North Africa
Current Status, and Future Insights
Abdulwahed, M.; Hasna, M.O.O.A.; Froyd, J.E. (Eds.)
2016, XXVI, 454 p. 106 illus., 57 illus. in color., Hardcover
ISBN: 978-3-319-15322-3