Global Engineering Education: Australia and the Bologna Process

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Abstract

This paper presents a critical comparison of major changes in engineering education in both Australia and Europe. European engineering programs are currently being reshaped by the Bologna process, representing a move towards quality assurance in higher education and the mutual recognition of degrees among universities across Europe. Engineering education in Australia underwent a transformation after the 1996 review of engineering education[1]. The paper discusses the recent European developments in order to give up-to-date information on this fast changing and sometimes obscure process. The comparison draws on the implications of the Bologna Process on the German engineering education system as an example. It concludes with issues of particular interest, which can help to inform the international discussion on how to meet today's challenges for engineering education. These issues include ways of achieving diversity among engineering programs, means of enabling student and staff mobility, and the preparation of engineering students for professional practice through engineering education. As a result, the benefits of outcomes based approaches in education are discussed. This leads to an outlook for further research into the broader attributes required by future professional engineers.

Introduction

Recent years have brought about substantial economic, technological and social changes on a global scale, which in turn have led to a transformation of the engineering profession. The challenges which arise, for example, from increasing internationality, cross-disciplinary influences on traditional engineering and a changing perception of the role of engineers in society have initiated a worldwide discussion on the adequacy of current practices in the education and professional development of engineers[1, 2]. In this era of change, a rethink of the conceptions underlying teaching and learning have lead to a perceivable paradigm shift towards outcomes-based or competency-based approaches to the education of engineers. While these concepts have been widely used and accepted in such areas as human resource management[3] and vocational training (such as TAFE in Australia[4]), they have only recently entered the domain of engineering education[1].

This paper examines and critically analyses the parallel processes that have occurred in Australia with those currently occurring in Europe with respect to the shift towards an outcomes based system of education. The development of Engineers Australia's Graduate Attributes during the late 90's was an example of this move towards an outcomes orientation

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in engineering education and will be used as a point of comparison in this paper. At the same time in Europe, the aforementioned changes to the engineering profession, in particular globalisation, signified by the development of the European Union, increasing economic pressure and international competition in the educational sector[5] have triggered a general move towards accreditation and mutual recognition of higher education degrees among universities[6].

A current study at the University of Queensland into the broader conceptions and future attributes required by professional engineers has revealed interesting connections and correlations between the above mentioned events, known as the Bologna Process in Europe[6], and the Australian move towards an outcomes based engineering education system[1]. Based on one of the author's familiarity with the European processes, specifically with the German educational system, this paper contrasts these two approaches.

This paper will firstly present a brief historic overview of the Bologna Process and examine the subsequent events this pledge for a "common area for higher education in Europe"[6] has initiated. The next section focuses on the implementation of the objectives of the process in Germany with respect to the changes they brought about in engineering education. This is then compared to the development and use of the Graduate Attributes in Australia and the implications on the education of engineers in Australia.

A simple comparison revealed that both developments appeared to be quite similar in terms of their underlying intention of changing the education of engineers. However, a critical analysis yielded substantial differences in the starting points and the processes used. This ultimately raises questions concerning the final goals that are trying to be achieved through the changes in both countries. From this argument, implications which could help to inform the discussion in both Australia and Europe have been derived. Ultimately this can foster a deeper understanding of the process of the formation of engineers and add to the global discussion on how to meet the challenges this era of global change poses for engineering education.

An Overview of the Bologna Process

The higher education systems of all European countries have historically grown from distinct and varying cultural and scientific backgrounds. As a consequence, today's European educational infrastructure is highly diverse, providing not only many different degree structures and titles, but also representing very different conceptions of what engineering education is and should be. As an example, German universities, one of two different types of higher education providers in that country, the other being the universities of applied sciences, offer engineering degrees of five to six years duration leading to the "Diplomingenieur" (Diploma in engineering) as the first professional engineering qualification. France on the other hand has a three stage system with one option leading to the first professional qualification after two years of study (DEUST, Diplôme d'Etudes Universitaires Scientifiques et Techniques - Diploma of scientific and technical university studies).

Against the background of the European Union and subsequent move of the political climate towards the unification of European systems, the Bologna Accord and more generally the Bologna Process aims at the "convergent development"[6] of these diverse European higher education systems. The Accord was signed in June 1999 by twenty-nine European countries, of which fifteen represented all members of the European Union at that time[6]. In subsequent

years, more countries have joined the Accord to the extent that the total number of signatory countries has currently reached forty, exceeding today's twenty-five EU member countries. The Bologna Accord is a pledge by the respective ministers for education to move towards a "European area of higher education"[6]. However, the outcomes and recommendations are to be implemented within each country individually. This implementation process is currently taking place with its envisioned completion by 2010[6].

The motivation behind the Bologna Accord was to promote and enable student and staff mobility within Europe by achieving mutual recognition of higher education degrees between universities. As a long-term goal, mutual professional recognition is also contemplated in order to enable the professional mobility of graduates[6].

The envisaged practical objectives were to implement comparable degrees throughout Europe based on the two main cycles of higher education, undergraduate and graduate, or bachelor – masters. It is worth noting that while this is the norm in Australia, the UK and the USA to have undergraduate and graduate degrees, the higher education structures are distinctly different among most European countries[7]. In order to reach "a system of easily readable and comparable degrees"[6] the Accord recommended the "establishment of a system of credits"[6] as a baseline to describe Bachelor and Masters degrees consistently across Europe. To ensure the equivalency of courses, this European Credit Transfer System (ETCS) defined standards for degrees in terms of credit points, which represented the total study workload. Hence, the main indicator the Bologna Accord used to define equivalency of degrees was essentially an input indicator. This credit system was to be augmented by a standard grading scale and a "Diploma Supplement". This document, in addition to the actual degree certificate, describes individual country's higher education systems, details of the particular institution, the grading system used, the respective workload and the content of the courses completed. It is used because of the vast differences that still exist among European countries' engineering programs[8].

Concurrent to the introduction of the dual cycle degrees, a system of quality assurance was to be implemented in each country "with a view to developing comparable criteria and methodologies"[6]. However, apart from the input measure described above, the accord does not further specify common qualitative descriptors of degree standards[9]. The recent release of the Dublin descriptors[10] was a first attempt to develop common outcome indicators among an informal network of only some of the participating countries of the Bologna Accord (for further information see[11]). These outcome descriptors are similar to the list of the Engineers Australia's Graduate Attributes[1] and ABET's program outcomes in the US[12]. However, the attributes formulated in the Dublin descriptors do not contain any engineering specific differentiations[8]. This fact also detracts from a focus on the requirements of professional practice in engineering, which is demanded by several stakeholder groups[5, 13].

Implementation in Germany

As already mentioned, the Bologna Accord was to be implemented in each country individually. When looking at examples for the national implementation of the Accord, Germany can for several reasons be considered a particularly interesting case. Firstly, it has had a historically grown educational system of globally acknowledged excellence, which relied upon strong research traditions and close relations to industry partners as a key element. With its two parallel strands of the five to six year university program leading to the "Diplomingenieur" and the four year "Fachhochschule" (University of Applied Sciences)

degree it is distinctly different from the two level bachelor – masters degree system suggested in the Bologna Accord.

Previous to the transitions initiated by the Bologna Process, the international discussion on quality assurance did not have much impact on engineering education in Germany[9]. Additionally, the education system in Germany is under the legislative authority of the "Bundesländer" (Federal States), whilst the implementation of the Bologna Accord is a national issue. This is comparable to the Australian high school system, which is managed by the various state governments, and the higher education system managed by the federal government. These two facts have in the past lead to a national diversity across Germany in approaches to engineering education. Considering on the one hand the existing diversity and on the other hand the strong traditional system, it becomes apparent that the implementation of the Bologna Accord requires very drastic changes to the current system. These are viewed either as a chance for significant advancements[14] or alternatively as a risk to lose a well proven system[15].

According to the German Ministry for Research and Education (Bundesministerium für Bildung und Forschung – BMBF), which is the German signatory body of the Bologna Accord, as of 2004, approximately one third of all higher education courses have been changed to the two degree cycles of undergraduate and graduate. However, only one half of those programs have been officially accredited so far[14]. In the author's experience, having gone through an engineering degree at the time of these changes, they are in some cases nothing more than relabelling of the existing degree structures (see also[15]). The traditional system provided the basic math and science in the first years and after that, engineering specific electives could be chosen. Hence, when awarding a Bachelor degree after three years of study without substantial changes to the traditional curriculum, the question of how this can provide a professional engineering qualification remains open[8]. Additionally the job market for engineers in Germany does currently not provide any employment opportunities for Bachelor graduates, since industry does not accept a Bachelor degree as a professional qualification[15]. This is in part due to the novelty of the degree and the unfamiliarity among employers of what this new degree means.

This also coincides with the analysis of the BMBF. Even though the Ministry of Education and Research describes, in the author's opinion, the achievements in an overly optimistic way, it still "identifies the aspect of the transition into the profession as a crucial element" for the future acceptance of the process[14]. This aspect seems even more critical when considering that the conceptual implementation of the "National Bologna structure"[14] is incumbent on the "Post Bologna Workgroup" (Arbeitsgruppe Fortführung des Bologna-Prozesses). This is a work group of members of the government, deans of engineering schools and other stakeholders, but is does not include representatives from industry at this level. Only at the executive level in the accreditation of programs are then stakeholders from industry involved in the decision making process.

The accreditation system in Germany is decentralised, with several private agencies accrediting specific programs, governed by the "Akkreditierungsrat" (Accreditation Council) as a central public body. To illustrate the current accreditation practice, the accreditation criteria for engineering programs of the ASIIN (Akkreditierungsagentur für die Studiengänge der Ingenieurwissenschaften und der Mathematik) as one accrediting agency, are given below. Since June 2003 this agency represents Germany is a provisional member of the Washington Accord[16].

- 20% basic math and science
- 25% engineering fundamentals
- 15% engineering electives
- 15% multidisciplinary content
- 25% thesis or project work.

With these regulations the universities are ultimately responsible for actual content without, however, being provided any guidelines in terms of outcomes or the qualifications they need to achieve.

Summarising the developments in Germany and drawing on the current public discussion the following issues can be identified critical for the success and acceptance of the process. Within the discussion on attaining a professional qualification at Bachelor level, industry stakeholders are calling for a stronger focus on professional practice[13, 17]. This is connected to the fact that there is currently no focus on students and their outcomes in terms of their learning and desired attributes. Only recently various authors[8] have mentioned outcomes based approaches as having possible additional benefits. Generally the main focus seems to be on input, process and formal questions of legislation and accreditation within the German system.

Regarding Europe as a whole, there is no evidence that a substantial correlation between the higher education systems in Europe has been reached. However, the process, as the European ministers of education confirmed in their conference in May 2005[18], is to be completed by 2010. This apparent predominance of the political will and aspirational goals raises the question as to which extend this dominates realistic judgement and measured advancements[15].

Graduate Attributes in Australia

Australia was one of the foundation signatories of the Washington Accord [16] in 1989. This international agreement between eight countries recognises the equivalence of higher education degrees among the participating countries. The Washington Accord is specific to engineering, and has established the substantial equivalence of undergraduate engineering degrees in terms of their "policies, processes and practises"[19]. This means that in Australia the goal of mutual recognition of higher education degrees, which is one main issue in the Bologna process, has already been achieved.

In 1994, a major review of Australian engineering education was initiated by stakeholders from industry and community in the light of the "profound changes taking place both within engineering and in all aspects of the environment within which engineering is practised"[19]. The review process was conducted by the main professional body of engineers within Australia (Engineers Australia), the Australian Council of Engineering Deans (ACED) and the Australian Academy of Technological Sciences and Engineering in a dialog with industry, universities, community groups and the various levels of government. In 1996, the report of the review entitled "Changing the Culture – Engineering Education into the Future"[1] was published. The report promoted a fundamental cultural change of engineering education in order to meet the new challenges which may arise "if the profession is to fully assume its expanding responsibilities"[1]. The report formulated a set of aspirational goals, including a set

of graduate attributes, many of which are still to be achieved[20] and are thus a driving force for change in the design of engineering programs and courses today.

In addition to achieving "in-depth technical competence" the necessity to induce an understanding of "the social, economic and environmental consequences of professional activity" is acknowledged as a centrepiece of engineering education. Engineers produced by future higher education programs are "attuned to the real concerns of communities" such as the need for sustainable development and in order to interact with a wide variety of stakeholders they "must be better communicators". The changes in engineering courses should focus on engineering practise in order to "meet the repeated requests of industry and of the practising profession". Additionally the "need for much closer collaboration between engineering education and industry" was stated[1].

According to the report "the key to achieving this goal is to accredit courses on the basis of demonstrated possession by their graduates of those attributes necessary to practise engineering in contemporary society". This statement demonstrates the shift in educational design towards outcomes oriented learning and assessment. For the conceived new accreditation practises for engineering degrees this means that with sufficient "attention to inputs" more consideration is to be given to the "outcomes of courses"[1].

Another issue was to match the increasing diversity in all fields of engineering with an appropriate range of educational opportunities for students. The report perceived a "relative uniformity between engineering schools"[1] at that time and through the outcomes based approach to accreditation, it aimed for "different courses and different approaches"[1]. However, even though the definition of outcomes gives each institution the freedom of choice as to the means they are to be achieved, reality shows that today only few engineering programs in Australia have undergone radical changes. One reason might lie in the current accreditation practice, where a single body is responsible for accrediting all programs throughout Australia. This may be leading to the transfer of best practices from one institution to the next, but on the downside may also have a self replicating effect on the system.

Comparison of Australian and European Processes

Table 1 summarises key elements in the changes of engineering education in Australia and Europe. It is not meant to provide a comprehensive comparison, but rather captures some particularly interesting issues which allow further interpretation in a broader context.

Issues / Aspects of Comparison	Australia	Europe
Drivers for change	Industry	Political will
Formal process (name and duration of degree)	Maintain	Achieve convergence
Accrediting body	Common body / Profession	Various accrediting agencies
Accreditation approach / philosophy	Outcomes based	Input and process based
Diversity of programs	Increase	Maintain
Extend of common understanding of the educational goal	Substantially equivalent outcomes in terms of attributes	Only common name and duration?
Broader conceptions of the educational goal	Formulated as aspirational goals	Occasionally mentioned in the discussion

Table 1: Summary of the critical analysis and comparison

The development in Europe is solely driven by political will and tries to achieve convergence of the formal processes of higher education through the specification of input standards. In Australia the development of the Graduate Attributes was borne by the profession, industry and the community. It aimed at a common core of attributes which graduates acquire from all engineering programs throughout the country.

One fundamental aim of the Australian initiative was to foster and encourage diversity in programs, whereas in Europe the maintenance of the present diversity is viewed as a boundary condition of the changes. In contrast to the clear goal of an outcomes-based approach to engineering education in Australia and the precise – albeit aspirational – definition of the outcomes, the European discussion seems somewhat scattered. Even though occasionally mentioned, the definition of common outcomes standards appears to be marginal to the general discussion.

The question remains whether or not the sole purpose of the Bologna Process is to achieve a common label for higher education degrees across Europe. The bodies responsible for the changes in Australia have put a strong emphasis on broader attributes as an essential outcome of engineering education. However, the question as to which extend this stimulus leads to substantial changes in the existing degree structure still remains open for many areas of engineering education today. In Europe these issues seem to be in danger of getting lost in the rapid political changes and due not come to bear due to the lack of subject specific educational standards.

The aspects described in the section above are illustrated in Figure 1. It shows the educational process with duration, intra or international diversity and the educational outcome as parameters.

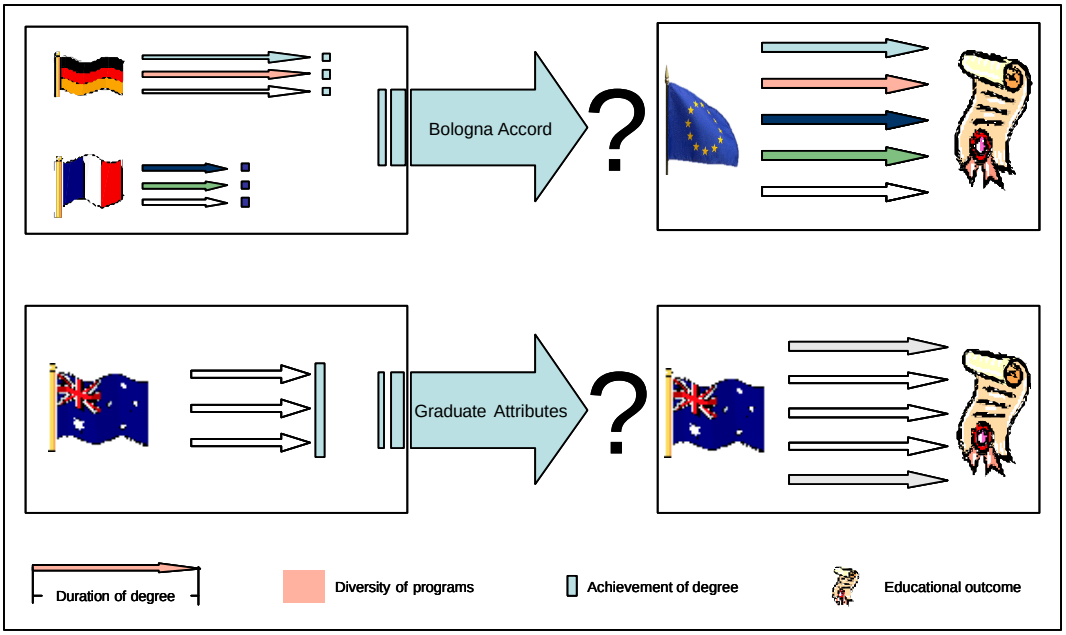

Figure 1: Educational Processes: Australia and Europe

Results: What can we learn?

By considering the above comparison, the following issues have been identified:

1. Fostering diversity

Providing that the changes in Europe remain focused on the process and the inputs of engineering education, the existing and valued diversity of engineering programs across Europe could be endangered. If uniform regulations in terms of input and process are imposed on the universities, the programs could become essentially identical. In this sense, Europe could be in danger of reaching a state similar to the situation in Australia before the introduction of an outcomes based approach. This dilemma of achieving convergence on the one hand and the necessity of maintaining diversity on the other could be addressed by formulating outcomes – similarly to the Australian approach – and leave the mode of delivery up to individual universities or countries. This way, specific countries or universities could maintain their specific strengths and traditions, while still devoted to achieving the common goal of equivalent qualifications among graduates.

In Australia, achieving diversity was one of the main goals of the process. However, the fact that in Australia one common body is responsible for accrediting all engineering degrees, can have a self replicating tendency, especially since no stimulus for change exists. In this sense the notion of one common accrediting body in Europe[8] can be misleading and have the same self-replicating effect. Since the diversity in Europe has historically grown under the strong stimulus of regionally different traditions and conditions, it can be concluded for Australia that the mere possibility to develop diversity through the definition of common outcomes may not be sufficient to reach the desired diversity between programs.

2. Preparing students for professional practice

In Australia, one of the triggers for the shift towards outcomes was that students lacked the skills industry required[1]. In the subsequent process, industry stakeholders and representatives from the profession were closely involved in the discussion on ways to take "Engineering Education into the Future"[1]. Even though this process is still taking place, some achievements have been made[20]. This indicates that, especially in engineering, industry is central to the setting of educational goals.

For the discussion in Europe, by including industry in discussions on the educational outcomes required by graduates, the employability of graduates could be improved especially against the background of lacking acceptance of the new degrees.

3. Achieving student and staff mobility

Again, referring to the lack of common outcomes standards in Europe, the question of to how the current system can enable student mobility arises. Providing that a student's transfer to a university in another country is not only a legal matter of the recognition of the previous degree but also a purposeful step in the students development as an engineer, the regulations should ensure the necessary prerequisites in terms of qualifications for the subsequent degree.

Having said that, it is worth noting that in Australia as of 1998 "student mobility was in the order of 0.2% of the undergraduate population" [21], comparable with 1% in the USA[21]. As against Germany where in 1996, before the Bologna accord, more than a quarter (27%) of the students in their higher semesters had been abroad as part of their studies[22]. This leads to the interpretation that other factors such as the availability of exchange programs might be more significant for student mobility than the mutual recognition of degrees.

Outlook: Further issues and future research

Outcomes orientation might not be the philosopher's stone[23] in education but there is evidence to suggest that it might be one contribution to solving today's challenges in engineering education. However, the drastic global changes discussed in the introduction raise the question of what the desired outcomes of engineering education ideally are.

Is engineering education currently based on traditional conceptions of the attributes required in engineering or on attributes perceived as important in current practice? Considering the rapidity of the changes facing engineering, is it even enough to ask stakeholders from industry today what these attributes are, or is it imperative to look into the future? To answer this question, we need to reach an understanding of what society could look like in the future and which roles engineers could play in this society. It may be possible then to identify the abilities students today must be equipped with in order to be able to meet future challenges on a global level.

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