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European Journal of Engineering Education

ISSN: 0304-3797 (Print) 1469-5898 (Online) Journal homepage: http://www.tandfonline.com/loi/ceee20

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To cite this article: J. Bennedsen, S. Rouvrais, J. Roslöf, J. Kontio, F. Georgsson & C. D. McCartan (2018): Collaborative quality enhancement in engineering education: an overview of operational models at a programme level, European Journal of Engineering Education, DOI: 10.1080/03043797.2018.1443058

To link to this article: https://doi.org/10.1080/03043797.2018.1443058

Published online: 28 Feb 2018.

EUROPEAN JOURNAL OF ENGINEERING EDUCATION, 2018
https://doi.org/10.1080/03043797.2018.1443058

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Collaborative quality enhancement in engineering education: an overview of operational models at a programme level

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ABSTRACT

This article discusses the tension between quality assurance and quality enhancement in engineering education at a programme level. It acknowledges that accreditation has evolved for many years, but does not agilely support innovation or implement changes in educational programmes. Existing quality assurance systems, institutional collaboration networks, as well as new innovative quality enhancement models and processes are described, contrasted and synthesised. Quality enhancement is analysed based on its function as a source of inspiration and dissemination of good practice. The article reflects on a novel and more collaborative approach to quality enhancement, built on the foundations of specific pedagogical standards and rubrics (e.g. CDIO). One solution leading to real continuous quality enhancement could be flexible and agile evaluation processes. These are founded on measurement and rating frameworks and complemented with quality assurance for engineering education. Incremental enhancement is based on relevant needs identified collaboratively between programmes.

ARTICLE HISTORY
Received 16 March 2017
Accepted 12 February 2018

KEYWORDS
Quality assurance; quality enhancement; cross-sparring; accreditation; curriculum development

1. Introduction

Quality assurance and enhancement are very much in the focus of European higher education institutions (HEIs), e.g. Rosa and Amaral (2014). There has been an enormous investment from society in higher education, e.g. Council of European Union (2011), and there is a need to ensure that this investment is worth while. Added to that are the professional and accreditation bodies such as ABET (www.abet.org), EUR-ACE (www.enaee.eu) or the French *Commission des Titres d'Ingénieur* (www.cti-commission.fr/), describing codes for what an engineer is. HEIs consequently see these codes, frameworks and requirements as a key consideration in how they develop their programmes, and consider the teaching and learning experience of their students. This article provides understanding and support for HEIs, faculties and programmes on these matters. The authors review different formal and informal quality improvement processes and forums, and discuss how these can be supplemented with more collaborative elements accepted not only by senior management, but academics in general.

One specific element of this article is to propose a shift from quality assurance and accountability to quality enhancement that is constantly present. This tension between accountability and enhancement has been discussed by several authors (Filippakou and Tapper 2008; Houston 2008). Amaral and Rosa (2010) argue that the accountability and quality requirement as seen by the government is based on four factors: (i) massification of higher education, (ii) market regulation, (iii) new public

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management and (iv) a loss of trust in HEIs and their professors. According to the last factor, Gray, Patil, and Codner argue:

> This emphasis on *Accountability*, i.e. value for the money as measured by objective output data, has not only come with higher education institutions being given 'autonomy to do more with less', but also more importantly such policies suggest a breakdown of the trust that society has traditionally had in the quality and value of higher education. (Gray, Patil, and Codner 2009, 16)

Others, e.g. Amaral (2007), have debated the same idea: the reduction of trust in HEIs has moved quality assurance activities from improvement to accountability. One way to test quality assurance and accountability is via accreditation systems. These systems have been in place for many years, but they seem restrictive when faced with the challenge of reactive innovations (a typical accreditation timespan is four–six years). The problem is how to proceed in order to support innovation and implement changes in shorter timescales and to enhance educational programme quality. The authors argue that one solution for enhancing the quality in engineering education is the use of maturity levels with flexible and incremental enhancement based on relevant needs achieved collaboratively by middle management (e.g. programme leaders, educational developers). This leads to continuous and collaborative quality enhancement complemented with quality assurance done at the national and international levels. A good starting point for this kind of quality enhancement is systemic educational frameworks such as the CDIO approach (Conceive–Design–Implement–Operate). The authors argue that such educational frameworks can be supplemented with tools and processes to support more active and focused interchange of innovative ideas.

In Section 2, the authors elaborate on elements in tension between accountability and improvement. This is followed with insights from experiences to improve engineering education and practices that can contribute to significant educational improvements at the programme level. Section 3 describes and contrasts different reference models for a continuous development of engineering programmes such as the CDIO approach. Section 4 overviews collaborative processes for quality enhancement and introduces some different international communities as well as regional and national networks. These models and processes were selected due to being robust and effective, as experienced in European engineering education HEIs in the last decade, with various levels of formality and flexibility. Section 5 discusses and reflects on transferable collaborative quality enhancement practices that have been applied in Europe more recently and gives a more concrete example of such a process. Section six discusses the challenges and benefits of the different models and frameworks presented in the previous sections. Following this is a section on future directions to fill the gap between quality assurance and quality enhancement. Finally, the conclusion of this article provides the potential to inspire and impact practice within the wider engineering education community.

2. Contextual and conceptual gaps between the renewal and quality assurance requirements of educational programmes

Many have described the tension between accountability (that the HEI accounts for its quality) and the improvement of its quality. As Sursock (2002) affirmed as the voice from the European universities:

> a quality assurance system that is perceived as creating work instead of creating quality will not yield the anticipated results. It induces compliance and window dressing.

This section will elaborate on some of the elements in this tension.

2.1. Accreditation requirements: accountability concern in a competitive context

As stated by Gray, Patil, and Codner (2009) in their comprehensive review on quality assurance in higher engineering education, the ultimate test of an institution's quality is the *success of its students*. That is, has the HEI been able to foster the desired knowledge, skills and competences needed. Yet,

competition and globalisation require that an HEI's quality should be made understandable by the use of evaluation and assessment systems that are trusted by governments, peers, students and other partner organisations. The need for the transnational accreditation of education is also becoming increasingly important for reasons such as increased physical and virtual mobility, the growth of new degrees and the increase in new educational institutes, see e.g. Abu-Jdayil and Al-Attar (2010) describing why and how they were accredited by ABET.

In the context of engineering education, as also noted by Gray, Patil, and Codner (2009), the terms *evaluation* and *assessment* are not uniformly used. On the one hand, *Quality Evaluation* refers to a systematic examination of the extent to which an entity is capable of fulfilling specified requirements. On the other hand, *Quality Assessment* relates to a determination of the extent to which the organisation's standard processes contribute to the achievement of its business goals and to help the organisation focus on the need for continuous process improvement. The term assessment is more linked to continuous improvement, whereas the term evaluation is more related to the decision of acceptance of a final product or system.

In addition to an institution's internal quality assurance system and processes, the main approaches to address accountability and quality include international and national accreditation requirements and/or audit processes. An accreditation process evaluates if an institution qualifies for a certain status. An audit, e.g. the Finnish national higher education audits by FINEEC (www.karvi.fi), is a check of an institution's claims about itself; an evaluation on the extent to which the institution is achieving its own objectives. Some countries or HEIs use more than one approach simultaneously. The result of an accreditation or an audit may be a label of quality or even be directly connected to the institution's permission to operate (Woodhouse 1999).

From a study of 29 case studies in 14 countries of HEI's experiences of quality assessment, Brennan and Shah (2000) concluded that:

> This shift has favoured the institutional level at the expense of the basic unit (the academic). It has also tended to strengthen extrinsic over intrinsic values as both managerial and market concerns have acquired greater importance compared with disciplinary academic concerns.

The objectives of these formal quality assurance processes, usually implemented by external bodies, typically focus on accountability. Yet, they are also to enhance the quality of higher education programmes based on the institution's internal activities, including self-assessment. The self-assessment is most often conducted by programme managers, delivering analyses including identified strengths and weaknesses. Self-assessment is often the first stage in a process leading to an external assessment, but these assessments are supposed to contribute to internally led processes as well. In practice, there are several dimensions affecting the real impacts of an assessment: who initiated the process and who carried it out and who is expected to act on the results? (Brennan and Shah 2000).

Although accreditation and formal audits are important procedures and tools to initiate continuous improvement at a strategic level, they deal especially with the *what* perspective, ensuring that everything is in place on a normative institutional level. With accreditation cycles lasting years (e.g. classically 4–6), there is a risk that the assessment results remain on internal reports, and the real impact on the development or renewal of the educational programme will be limited. Thus, there is a need for movement of the focus, not only on the topics in *what*, but also in *how* more agilely.

2.2. Quality enhancement: complementing with the how concern

There are several different approaches to quality assurance, and most of the HEIs use a combination of these depending on their internal strategies and traditions, as well as national requirements. Gray and Patil (2009) have presented a conceptual canvas for describing the approaches to quality assurance in higher education (see Figure 1).

This canvas maps the approaches based on the level of internal and/or external control (horizontal) in relation to the intended goals' focus on the level of accountability and/or improvement (vertical). For

example, the upper left corner position (internal-improvement) represents internal initiatives that are intended to produce information developing quality on the perimeter. The ability to recognise and benefit from the different characteristics and strengths of these approaches and the power structures created by them is significant to the success of the HEI's concrete and effective development. Both internal and external stakeholders should be participating in a continuous development process leading to real improvements as well as meeting the requirements on accountability.

However, the problem of obtaining operational quality enhancement actions and improvements from the different quality assurance processes in a shorter time frame remains. This is because the majority of the criteria used in accreditation still represent the *whats* stating what should be achieved, but leaving the HEIs to determine how these goals can be met (Malmqvist 2012). Without undermining the importance of the HEI's internal expertise and continuous development activities, a key question is how to facilitate local quality enhancement, understanding that there will be inevitable resistance and inertia (Rouvrais and Landrac 2012), and at the same time, strengthening the return on investment in quality assurance activities more globally and continuously. That is, how to respond more efficiently to the global challenge in a flexible and reactive way, and make things happen? One answer to this question is to support such activities by creating communities of practice to share best practices, innovative ideas and experiences on the different levels of higher education, including course-level solutions, curricular and programme structures and institution-wide innovative solutions.

2.3. Are developer and innovator digests a key?

Adopting new innovations and gaining inspiration from the experience of peers is also important for quality enhancement in higher education. In addition to formal quality assurance processes, the circulation of these innovations and really effective experiences are facilitated by focus group reports (e.g. *Commission d'Etudes sur les Formations d'Ingénieurs* (http://tinyurl.com/j229o6f in France) or educational development seminars and conferences (e.g. at international levels in SEFI, WEEF, CDIO conferences or at national speaking levels in *Conference des Grandes Ecoles* and international *Questions de Pedagogies dans l'Enseignement Supérieur*). For example, the CDIO Initiative organises an annual international conference (with hundreds of participants) that includes disseminating case studies from its partner institutions, which are based on implementation activities according to set standards, see e.g. Björkqvist et al. (2016). Sharing and discussing experiences openly provide fruitful and less formal arenas, which can potentially open doors to support concrete and effective quality enhancement worldwide.

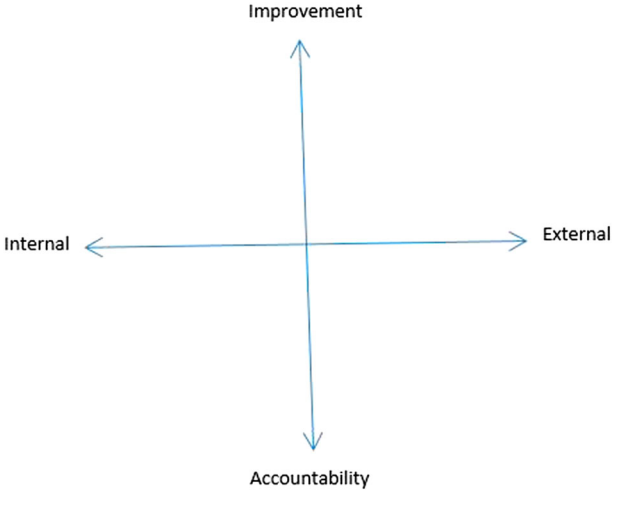

Figure 1. A canvas for describing approaches to quality assurance from Patil and Gray (2009).

The individuals participating in educational development conferences, working groups or other similar events are typically active professionals, e.g. lecturers, academic developers, deans, who benefit from the collaboration, and bring new ideas to their home institutions. These change facilitators may play an important role in the process of adopting new educational innovations flexibly, without being constrained by the inertia of heavy accreditation procedures. But facilitators and innovators may sometimes be lonely in their home institutions. It may not be easy to fully benefit from identified good practices. A new innovation or best practice may not fit easily in an organisation, it may need to be adapted to the existing environment and culture (Boxwell 1994). Making change actually happen often requires both initiative and organisational commitment, as well as managerial support and resources. Models for continuous improvement of educational programmes at a systemic level are required. As Sursock (2012) concludes:

> In order to ensure that quality assurance is really about quality, it needs to engage with all the institutional actors, minimise routine and bureaucratic processes, clearly reserve a role for institutions in managing quality, focus on improvement and enhance the innovative capacity of institutions.

3. Maturity in reference models for continuous improvement of educational programmes

New courses or pedagogical approaches, which might be considered innovative at local levels (but routine in more progressive, reactive and adaptive institutions), may agitate existing practices, result in short-term low systemic impacts and even discourage innovators or facilitators. Exploiting new innovative and concrete ideas, inspired by other contexts (e.g. create a course/module), requires time to implement and operate effectively and efficiently to coherently meet more global quality requirements. To confront institutional inertia in educational programme change or renovation at a systemic level, rather than at a course level only (via a motivated lecturer), benefits from maturity assessment on an ordinal scale to smoothly facilitate quality enhancement. This section provides an overview of the common maturity models used in engineering education quality, from the lowest semantic ones to the more formal ones. The selected models are those which are well recognised and currently in operation in Europe.

3.1. U-Multirank

U-Multirank (www.umultirank.org) is a multi-dimensional ranking of HEIs. It facilitates comparisons between universities on a like-with-like basis. This framework offers profiles of hundreds of universities from all over the world, i.e. in 2016, over 1300 universities from more than 90 countries. In the U-Multirank framework, indicators cover five areas: (i) teaching and learning, (ii) research, (iii) knowledge transfer, (iv) international orientation and (v) regional engagement.

The U-Multirank model rates universities on a much wider range of factors than existing international rankings. More than 30 separate indicators are proposed, each rated in 5 performance groups, from 'A' (very good) through 'E' (weak). The U-Multirank does not produce a combined score across the different areas of performance as there is no theoretical or empirical justification for such composite scores at this time. Even if there are still doubts about the consistency of data in U-Multirank self-mapping, the tool provides more transparency for educational quality at an international level (van Vught, Westerheijden, and Ziegele 2012).

3.2. The EU QUESTE-SI framework

Various initiatives have recently proposed sustainability and social responsibility criteria as indicators for HEIs. Currently, there are more than a dozen sustainability referents throughout the world that apply to HEI certification or performance measurement. In Europe, various initiatives have proposed

specific sustainability dimensions and criteria for the evaluation of universities or graduate schools. Inspired by the ISO 26000 guidelines for Social Responsibility (i.e. a set of international standards for all sustainable development initiatives of companies and organisations), a European project piloted by EFMD (2013), proposed the QUESTE-SI referent that covers four dimensions for HEIs in engineering (plone.queste.eu).

A fair evaluation of social responsibility and sustainable engineering education should not be limited to teaching and learning methods or only curricular content. As indicated by Rouvrais, LeLocat, and Flament (2013), each dimension is given a rating to reflect the level of quality and maturity reached on a continuous improvement basis.

3.3. The international CDIO maturity model

One goal of the CDIO Initiative (www.cdio.org) is to improve the quality of engineering education worldwide (Crawley et al. 2007). The CDIO approach consists of three core components to ensure the quality of developing programmes: (i) the CDIO syllabus defines the programme goals, (ii) the CDIO standards present guidelines on designing and operating the programme, and (iii) the CDIO self-evaluation measures the programme 's progression against the standards. The first pivotal component, the CDIO syllabus, contains a collection of intended programme outcomes, the *whats*, the key attributes that engineering students should acquire. The CDIO standards and self-evaluation represent the *hows*, providing guidelines and a framework for continuous development.

Overall, the 12 CDIO standards describe important elements of teaching and learning in engineering education. These standards, or reference models, address education from different aspects, such as the educational context, curriculum, competences, workspaces, learning methods, staff skills and competences, assessment and continuous improvement. Each CDIO standard is evaluated against a rubric containing six maturity levels, from the lowest at 0 to the highest at 5. Each maturity level has a specific description to help guide the evaluation. The levels are defined in such a way that being on level n also implies that the requirements for levels $0,1,\ldots,n-1$ are met. All 12 CDIO standards are essentially evaluated against the same generic rubric as seen in Table 1.

The CDIO standards are used for self-evaluation purposes and an institution or a programme typically identifies arguments for their chosen maturity level per standard and the key benefit is the insight gained from engaging in the self-evaluation process, not the actual level number selected.

3.4. The QAEMP maturity model

The QAEMP (Quality Assessment and Enhancement Market Place) model (Bennedsen et al. 2015) has – like the CDIO model – a focus on self-evaluation. It seeks to foster a deep awareness of elements to improve by ensuring clear evidence is provided (via argumentation and indicators) for its specific evaluation criteria. This facilitates the comparison of institutions and programmes.

The model is a super-set of many different accreditation systems and quality enhancement models. The model has 10 focus areas. Each focus area has from one to four criteria. There are 28 criteria in total. The evaluation of the criteria is based on the same general rubric as the CDIO

Table 1. Generic rubric applied to each of the 12 CDIO standards.

Level	Description
5	Evidence related to the standard is regularly reviewed and used to make improvements.
4	There is documented evidence of the full implementation and impact of the standard across programme components and constituents
3	Implementation of the plan to address the standard is underway across the programme components and constituents
2	There is a plan in place to address the standard
1	There is an awareness of need to adopt the standard and a process is in place to address it
0	There is no documented plan or activity related to the standard

model and all criteria have a name, a rationale and a rubric for scoring. One example of a criterion is '19: Student retention and progression is monitored'. The rubric is described in Table 2. For a more detailed description of the 28 criteria, see Clark et al. (2015).

3.5. An ISO reference for maturity assessment of process capability

ISO/IEC 33020:2015 International Organization for Standardization (2015) defines a process measurement framework that supports the assessment of process capability. The process measurement framework conforms to the requirements of ISO/IEC 33003 and is applicable to any domain, e.g. HEI programmes as proposed by Rouvrais and Lassudrie (2014). The process measurement framework may be included in any process assessment model for the assessment of process capability. It provides a schema that can be used to construct a process assessment model.

In ISO/IEC 33020, the process capability is defined on a six-point ordinal scale that enables capability to be assessed from the bottom of the scale (i.e. incomplete), through to the top end of the scale (i.e. innovating). The scale represents increasing capability of the implemented process, from failing to achieve the process purpose through to continually improving and able to respond to organisational change. It is defined in Table 3.

Process attributes, per level, are extensively informed in the ISO/IEC 33020 documents, as a source of good practices and indicators. A process attributes ordinal rating scale is also proposed: (N) Not achieved, (P) Partially achieved, (L) Largely achieved, and (F) Fully achieved.

3.6. Comparison and discussion

To support continuous improvement in the field of engineering education, standards and criteria form parts of reference models, which are sometimes associated with measurement models for interpreting the data and providing evidence. Applying these criteria is a serious challenge for programme managers and leaders.

If fairly conducted, the U-multirank and multi-dimensional models may indicate where enhancements may be achieved. At the European level, for a more precise measurement of the sustainability and social responsibility performance of HEIs or programmes, it was shown that the QUESTE-SI project approach permitted the comparison of several institutional units, rather than ranking them. It achieved this by rating dimensions and progress in terms of objectives and indicators, but used a rather informal maturity scale (Rouvrais, LeLocat, and Flament 2013). The aforementioned CDIO and QAEMP models are precise enough to highlight enhancement concerns and provide guidance on how to proceed in a flexible manner.

Another example, the EFQM model, used by Steed, Maslow, and Mazaletskaya (2005), defines eight Fundamental Concepts of Excellence as a Reference Model. These concepts address the purpose of the organisation, its outcomes, responsibilities, etc. The assessment of each Concept is based on nine criteria that are common to all the concepts: five enablers that cover what the organisation does and four results that cover what the organisation achieves. The complexity of this model requires a cohesive institutional strategy and may diverge from flexibility issues.

Table 2. Maturity rubric for 'QAEMP criterion 19: student retention and progression is monitored'.

Level	Description
5	The programme team uses the student retention and progression data to create an action plan that promotes continuous programme improvement
4	The programme team has student retention and progression data and reflects on what has happened
3	The programme team is monitoring student retention and progression
2	The programme team has a plan to monitor student retention and progression
1	The programme team is aware of the need for student retention and progression to be monitored
0	There is no monitoring of student retention and progression on a programme

Table 3. ISO 33020 process capability maturity rubric.

Level	Description
5	Innovating process. The previously described predictable process is now continually improved to respond to change aligned with organisational goals
4	Predictable process. The previously described established process now operates predictively within defined limits to achieve its process outcomes. Quantitative management needs are identified, measurement data are collected and analysed to identify assignable causes of variation. Corrective action is taken to address assignable causes of variation
3	Established process. The previously described managed process is now implemented using a defined process that is capable of achieving its process outcomes
2	Managed process. The previously described performed process is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained
1	Performed process. The implemented process achieves its process purpose
0	Incomplete process. The process is not implemented or fails to achieve its process purpose

A problem with self-evaluations is objectivity, especially when their base is not well defined. Ratings of programme quality or its reference models could be different between experts, programme developers or innovators, alumni, programme directors, deans or quality assurance leaders. Nevertheless, it was discussed earlier in this section that a process measurement framework, as defined formally in ISO/IEC 33020 International Organization for Standardization (2015) and more flexibly by the CDIO community, facilitates self-assessment transparency between stakeholders, with indicators, and thus provides a basis for far-seeing process quality determination and process improvement. ISO/IEC 33020 is applicable across domains and sizes of organisation, and can therefore be applied in several HEIs at course, programme or even institutional levels.

4. Effective examples of collaborative quality enhancement at an educational programmelevel

Most of the aforementioned quality enhancement models, with their maturity scales, were not initially designed with a collaborative focus. They rely on a self-assessment process, which is verified at times by an external body. Therefore, they are intended to make things happen internally, in their time frame, and rely on constructiveness. But external collaboration with peers, rather than external bodies, may be a key. The collaborations would be at international, national or local levels.

4.1. Communities and networks of good practice exchanges

Many informal networks for quality enhancement exist. Some of the most important are described in this section.

4.1.1. International communities

Internationally, the CDIO Initiative started in 2000 when a group of engineering educators investigated the gap between the working life expectations and the outcome of engineering education. A need to create a new vision and concept for undergraduate education was recognised and the CDIO approach to engineering education was developed with input from various stakeholders including academics, industry, engineers and students (Crawley et al. 2007). The goals of the CDIO approach are to:

- Educate students to master a deeper working knowledge of the technical fundamentals,
- Educate engineers to lead in the creation and operation of new products and systems,
- Educate future researchers to understand the importance and strategic value of their work.

The CDIO approach is adaptable to all engineering schools and higher education institutes, including graduate education. CDIO only considers organisational memberships and there is an application

procedure to apply for CDIO membership and become a CDIO collaborator. As of October 2017, there are more than 145 institutions worldwide listed as CDIO collaborators. The collaborators are divided into regions with one or more regional leaders. The CDIO Initiative provides the collaborators with a common framework to discuss, and tools to enhance, their engineering education. The three main elements of the CDIO approach are the context, standards and syllabus. A CDIO collaborator is to continuously evaluate these elements (e.g. yearly basis), as well as to develop and update them. The CDIO meetings are important tools to share best practices, tested practices and learning from the experiences of the other CDIO collaborators. The development work is mostly achieved in activities between the meetings. The meetings are open to all interested parties, even non-collaborators.

In Europe, the *Societé Européenne de Formation des Ingénieurs* (SEFI, www.sefi.be) connects institutions, individuals, industries and associates interested in contributing to the policies and actions for improving higher engineering education, and in facilitating regular contact with colleagues from other engineering education institutions, associations, students groups and corporate representatives. Considered as the backbone of SEFI, the working groups bring together its members to discuss and analyse specific topics of engineering education and the largest forum where this happens is at the annual conference arranged by SEFI. The working groups, Standing Committees and Task Forces' activities reflect the mission and goals of SEFI.

4.1.2. Regional and national networks

Collaboration is anticipated between countries sharing common principles and similarities in their educational systems.

One example is the Nordic Five Tech (N5T), which is a strategic alliance of the five largest technical universities in Denmark, Finland, Norway and Sweden (www.nordicfivetech.org). N5T collaborates in many different ways. They provide a number of joint master's programmes. In addition, they have working groups on various topics such as entrepreneurship education, quality assurance, industry collaboration, and pedagogical development.

More nationally, *Conference des Grandes Ecoles (CGE)* (cge.asso.fr), created in France in 1973, brings together higher education in France and abroad, which train their graduates with a view towards excellence, in partnership with the business world, economic players and civil society. Its aim is to foster and coordinate discussions and work on teaching, education and research, in order to improve social well-being and sustainable development. Today, around 220 French engineering schools offer courses leading to a degree in engineering. CGE has taken the decision, on ethical grounds, not to release information, which would allow comparisons or classifications of its member schools. Its role is to build up internal information, cooperation and solidarity between its members, promote the schools nationally and internationally, develop training courses and research, so as to foster initiatives of common interest in dealings with government authorities. There are 12 committees, where the majority of *Grandes Ecoles* engineering schools are active members. Once a year, all the organisers of the committees meet in a plenary session to review their activities and receive the roadmap for the coming academic year.

In Scotland since 2003, via the Scottish Quality Assurance Agency, each of the HEIs has a Quality Enhancement team, which participates in collaborative enhancement activities and sharing resources. Drawing on this experience, an ongoing collaborative quality enhancement process is in place in South Africa, including specific focus areas. Institutional self-evaluations lead to groups of institutions that can usefully interact with each other around selected focus areas (Council on Higher Education 2014).

4.2. Discussion

Self-assessment models and scoring are the cornerstones for continuous enhancement. But, as stated by Rouvrais, LeLocat, and Flament (2013, 7):

self-evaluation or assessment of educational programmes, conducted internally but scored externally, is not so often objective. Due to a lack of detachment and for accountability purposes, an institution may blur its own weaknesses and tend to mask some problems.

The non-ranking objective of several references, such as CDIO or QAEMP, facilitates the exchange of good practice between evaluated institutions. These evaluations could be effectively conducted in parallel by groups external to the institutional unit, but belonging to a similar type of HEI to facilitate discussions. This approach would be beneficial for both the institution analysed, which would get a more objective view on its strengths and weaknesses, and for the collaborating evaluation team, which would be able to identify best practices possibly useful for its own institution.

Being at international or national levels, networks or societies of HEIs in engineering can offer a medium for lobbying for strategic exchanges and for sharing good practices. However, they are also an exceptional pool for collaboration to make things happen internally, hand-in-hand, in a classical counselling model.

5. Exchanging and capitalising best practices: insights from concrete experiences toimprove education

Collaboration between HEIs is not new. But competition and accountability purposes tend to make the exchange of good practices and innovations more difficult. In this section, some examples of ways to foster collaboration are described. The examples take as a starting point the CDIO self-evaluations and how these can be concretely used for quality enhancement.

5.1. Self-evaluation reference models to promote collaboration: a starting point in the Nordic countries

In 2009, four Scandinavian universities decided to use self-evaluation to promote deep formative collaboration. The collaboration initiated an international Quality Assurance in Higher Education project (Kontio et al. 2012). This project focused specifically on self-evaluation. The main goal was to develop and implement a self-evaluation model in the participating HEIs to support their quality assurance work and continuous curriculum development. The self-evaluation model was strongly based on the CDIO standards. During the process, a programme description with a maximum of 10 pages was created and a self-evaluation was conducted. They were supposed to contain the actual CDIO ratings of the programme and recommendations for improvements. Furthermore, three good practices in teaching and learning and five students' theses were expected to be presented. The project included a cross-wise evaluation with one-day site visits at both universities.

Following the success of the 2009 project, a follow-up project was started in 2011. This project continued the themes and ideas including self-evaluation and cross-evaluation but it also introduced a new phase in the process: workshops. These workshops supported pedagogical development, quality assurance and evaluation phases in the partner universities. During the project, new programmes worked on their quality enhancement. The main goal of the project was to disseminate the quality assurance methods and tools developed in the first project.

One of the key ideas was to complement internal quality assurance processes with an external perspective including a site visit and a report resulting from an external assessment.

5.2. Towards collaborative quality enhancement with cross-sparring

HEIs typically claim, e.g. by using accreditation processes, that they have good practices for the development of their programmes. The QAEMP project's view was that discussing, debating, seeing and hearing about these good practices is a productive way to enhance the quality of a programme (Kontio et al. 2015). The QAEMP process was inspired by the notion of a sparring partner in sport

(i.e. someone who helps, for example, a boxer to train for a fight by playing the role of an opponent) and is carried out by physical meetings called cross-sparrings. A sparring partner helps to keep focus on objectives, learn from experiences and stimulate reflectivity. This approach is beneficial both for the institution being assessed, who will gain a more objective view on their strengths and potential improvements, and for the sparring partner, who may identify good practices that can be useful for their own institution. One of the key findings in the collaboration process was the benefit from a well-prepared site visit.

The CDIO framework was a good starting point for two reasons: (i) it gave focal points and structure for the meeting and (ii) it identified good practices. But the connection between the CDIO standards and the accreditation process was not obvious and some elements, e.g. monitoring and acting upon student retention and progression, were not included. Consequently, the QAEMP model was developed (see Section 3.4) and strengthened with the idea of cross-sparrings.

Bennedsen and Rouvrais (2016) discuss the cross-sparring process in detail. For example, it is not obvious what makes a good pairing of two programmes. Should they be in the same discipline so that they can discuss subject matters in detail, or should they be from different subjects so that they can inspire each other with good practices from their specific areas? Should they be from the same culture or from different ones? The matching should be flexible enough to handle different contextual parameters. Finding the right match with respect to which criteria a given programme wants to learn-and-inspire is also debatable. Should the match be a programme with a self-evaluation that is similar so that a detailed discussion can take place, or a programme with a large difference so that it is the more general ideas that can inspire?

5.2.1. Finding a perfect match?

Typically, it is neither efficient nor possible to focus on enhancing all criteria. The self-evaluation, whatever its reference models or maturity scale, gives a good starting point for identifying criteria where a given programme could improve. The QAEMP project suggests that a programme selects 3–7 criteria to improve (from a total of 28 criteria). It suggests that two areas are taken into account when the best match is to be found:

(1) *Contextual parameters*: Parameters describing the context of the programme: the size of the programme, the level of the programme, the geographical area, the study area, private or public institution, etc.
(2) *Learn-and-inspire criteria*: The three to seven selected self-evaluation criteria (the learn-and-inspire criteria), where the programme wants to be inspired from the spar.

The QAEMP project completed four pilot studies (Bennedsen and Schrey-Niemenmaa 2016; Clark et al. 2016; McCartan et al. 2016; Rouvrais et al. 2016) to test several combinations of contextual parameters: a bachelor programme matched with a master programme as well as two on the same level, two programmes from the same discipline as well as two from different disciplines, small and big, etc. The project could not find any conclusion for what was the best combination of contextual parameters. When pairing, the QAEMP process looks for two programmes that contrast each other. In other words, if $programme_i$ wants to be inspired on $criterion_i$, it needs to be paired with another $programme_j$, whose score on $criterion_i$ is higher than the score of $programme_i$ and vice versa (Bennedsen and Rouvrais 2016).

5.2.2. Cross-sparring process

The QAEMP process is performed in five steps as described in Figure 2:

(1) *Self-evaluate:* Evaluate one's programme and identify 3–5 criteria you want to improve (the learn-and-inspire criteria);
(2) *Pair:* Two programmes are paired as described in Section 5.2.1;

(3) *Cross-spar:* The two programmes visit each other to learn from and to inspire each other. During the visits, the study programmes discuss in detail how they do things related to the selected learn-and-inspire criteria;
(4) *Enhance:* Based on inspiration and observations, actions to develop one's own programme are planned;
(5) *Share:* Each participating programme should describe three good practices from the visited programme and make them available on a public website.

The process is initiated by a self-evaluation that is typically completed by the main stakeholders of the programme: the programme director, core teachers and administrative staff. The QAEMP project found that having this core group of people was both efficient and productive. The self-evaluation was typically done in around half a day and gave rise to many debates on how the given programme should score itself – and why it should have that score (Bennedsen and Schrey-Niemenmaa 2016).

The cross-sparring has the goal of inspiring the visited programme. Before the actual meeting, an agenda is agreed upon. The responsibility for the agenda is the programme visited as it has the highest scores in the relevant criteria. Typically, the agenda can start with an introduction to the context of the programme continued by discussions on the examples and innovations from the institutions. Finally, the visiting programme makes an action plan – how will the selected innovations be implemented back home to enhance the quality of their programme. It is the responsibility of this visiting institution to describe and document the good practices found.

The obvious question to ask is 'where do we find a good sparring partner?'. The QAEMP project's answer to this was to create a virtual marketplace where institutions can upload their self-evaluation and associated criteria for improvement – like making a profile on a dating site. This platform then matches with all other registered programmes and looks for the best available match (Bennedsen and Rouvrais 2016).

5.2.3. Planning educational developments

In most accreditation systems, the assessor ends up giving the accredited programme advice on how they can improve. But the improvements are restricted to that programme (and the advice the assessors have).

On facing a problem, the typical answer is to see if someone else has faced the same problem and evaluate their solution. Why is the same not possible with good, innovative ideas for improving a programme? When a programme is enhancing in the QAEMP process, there are two sources of

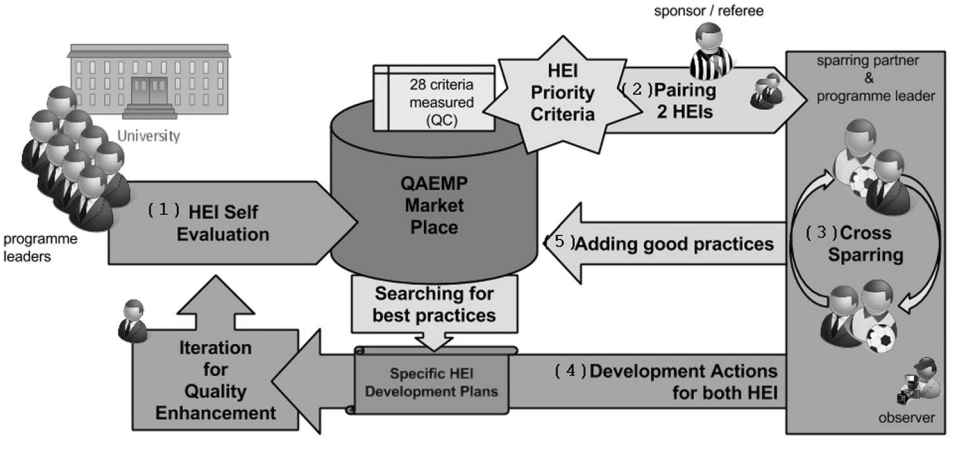

Figure 2. The QAEMP process (modified from Bennedsen et al. 2015).

inspiration: (1) ideas from the spar and (2) ideas from the QAEMP marketplace. One of the outcomes of the cross-sparring meetings are identification of good practices that could be useful for other institutions (step 5 in the process, see Figure 2). These are tagged with the relevant criterion so that others can find inspiration when considering options to enhance on that specific criterion. More information on the QAEMP project can be found at www.cross-sparring.eu.

6. Discussion

Continuous development of engineering education is a necessity. Around the world universities and HEIs are pushed to change, more rapidly. New technologies are emerging, new or more specific skills are required, and global competition is present. Engineering is needed to solve these challenges, but the question is how to ensure that engineering education is continuously developing to meet these challenges? When the CDIO Initiative was established in the 2000s, *for producing the next generation of engineers*, one of the main ideas was to get *back to the roots* of engineering education – combining theoretical knowledge with personal, inter-personal and professional competences. The argument was that engineering students did not really know how to engineer. Today this *how to engineer need* might not be the same. As one example, Kamp (2016) identified four different engineering career choices: technical experts, change agents, system architects and system integrators. These four types of engineers call for very different sets of competences. The role of situational context in process definition, adaptation and assessment, is to be a key for quality enhancement.

Many European countries have accreditation systems in place as an external force to make things happen at institutional levels and for regulation purposes as recalled recently by the European Council of Engineers Chambers (2016). These systems are sometimes seen to limit academic freedom and slow the capability of HEIs to sense and react to the changes happening in industry and society in the short term. A more flexible quality enhancement process than those defined by today's accountability focused processes could lead to a better alignment with the rapidly changing competence sets for the engineer. The accreditation process should be worthwhile and something that supports programme development besides the label, not only a conformity assessment approach every four to six years.

One of the problems with today's accreditation systems is the lack of sharing of good and innovative ideas between institutions. The authors argue that supplementing the accreditation process with a light-weight collaborative process at the programme level will foster more innovation and sharing of good practice. It is important that quality enhancement and quality assessment /accreditation activities support each other. For example, the European Network for the Accreditation of Engineering Education (ENAEE) awards the EUR-ACE label with defined framework standards and guidelines, but still more operational tools are needed to really impact on the quality of the education. The CDIO Initiative and tools and practices piloted in the QAEMP project are examples that can further support fulfilling the accreditation requirements by linking learning objectives and programme contents and outcomes and help to assess students' achievements. One way to pronounce this within the CDIO community would be to incorporate a cross-sparring element in the application process so that all institutions applying for membership should cross-spar with a member-institution. This will give the applicant an introduction to the core values of CDIO (the standards), ideas for improvement and personal inclusion in the community. The member-institution will have a peer's view on their quality and thereby probably find elements that could enhance their quality as well. On a larger scale, an accreditation body could include cross-sparring in their process, either by suggesting a particular spar or by using a platform like the marketplace to find a suitable spar.

Active HEIs are already working on several networks. The number of different networks proves the need and readiness of HEIs for engineering education collaboration. Often the main purpose of networks or educational communities is to share experiences and learn from others, and also to strengthen and diversify their own position in higher education. As has been shown, one example of such a network is the CDIO Initiative, which has proven to be a way to enhance quality by its

open and inclusive community. However, even in this network, some of the more experienced CDIO collaborators would like to see more structured and innovative ways to foster collaboration. The CDIO community may look towards new innovative concepts in educational quality, for institutional or programme level maturity, including collaboration with various stakeholders (e.g. programme leaders, programme developers, industry, quality experts, accreditation bodies). The QAEMP process could be one such way forward for the future of engineering education quality.

7. Future directions

The authors invite engineering programmes leaders, and other HE programmes than engineering, in Europe and around the world to use self-evaluation models and upload their results into a shared Market Place (hopefully on-line as in QAEMP). The more programmes that do so, the greater the selection of possible cross-sparring partners for participating institutions, and the more good practices and improvements that will be shared and institutionalised. The QAEMP project piloted this with eight recognised engineering programmes, from six different countries (Bennedsen and Schrey-Niemenmaa 2016; Clark et al. 2016; McCartan et al. 2016; Rouvrais et al. 2016). However, enhancement of these few programmes does not suffice to make things happen at a global level. These eight are a small subset of the CDIO collaborators or, for example, of the 844 registered schools in ABET. The more programmes that collaborate between their respective perimeters for quality enhancement, the more good-to-best practices will be shared, regionally, nationally or internationally.

8. Conclusion

The earlier sections of this article provided overviews of the many levels of collaboration in engineering education. There are levels focusing on accreditation such as EUR-ACE, ABET and CTI quality standards, but more and more levels fostering other collaboration dimensions too. These other levels of collaboration are national, regional and/or international forms with peers. They start from a different perspective – the key is to provide concrete and effective education, not to prove something. Such levels assure flexible and versatile ways to continuously develop programmes. This article reported and reflected on insights from various operational models and processes to improve engineering education quality in a flexible and continuous way, based on measurement and rating frameworks. The models and processes presented in this article ultimately give the potential to inspire and impact practice within the wider engineering education community for the definition and implementation of flexible and agile assessment processes – to fill the actual gap between quality assurance and quality enhancement in higher education.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Abu-Jdayil, Basim, and Hazim Al-Attar. 2010. "Curriculum Assessment as a Direct Tool in ABET Outcomes Assessment in a Chemical Engineering Programme." *European Journal of Engineering Education* 35 (5): 489–505.

Amaral, Alberto. 2007. "Higher Education and Quality Assessment. The Many Rationales for Quality." *Embedding Quality Culture in Higher Education, EUA Case Studies*, 6–10.

Amaral, Alberto, and Maria J. Rosa. 2010. "Recent Trends in Quality Assurance." *Quality in Higher Education* 16, 59–61.

Bennedsen, Jens, Robin Clark, Siegfried Rouvrais, and Katriina Schrey-Niemenmaa. 2015. "Using Accreditation Criteria for Collaborative Quality Enhancement." Proceedings of World Engineering Education Forum 2015, Florence, September 20–24.

Bennedsen, Jens, and Siegfried Rouvrais. 2016. "Finding Good Friends to Learn from and to Inspire." 2016 IEEE Frontiers in Education Conference Proceedings, Erie, October 12–15.

Bennedsen, Jens, and Katriina Schrey-Niemenmaa. 2016. "Using Self-Evaluations for Collaborative Quality Enhancement: A Case Study." Proceedings of the 12th International CDIO Conference, Turku University of Applied Sciences, Turku, June 12–16.

Björkqvist, Jerker, Kristina Edström, Ronald J. Hugo, Juha Kontio, Janne Roslöf, Rick Sellens, and Seppo Virtanen, eds. 2016. The 12th International CDIO Conference – Proceedings, Full Papers, Turku University of Applied Sciences, Turku.

Boxwell, Robert J., Jr. 1994. *Benchmarking for Competitive Advantage*. New York: McGraw-Hill.

Brennan, John, and Trala Shah. 2000. "Quality Assessment and Institutional Change: Experiences from 14 Countries." *Higher Education* 40, 331–349.

Clark, Robin, Jens Bennedsen, Siegfrid Rouvrais, Juha Kontio, Krista Heikkinen, Fredrik Georgsson, Asrun Matthiasdottir, et al. 2015. "Developing a Robust Self Evaluation Framework for Active Learning: The First Stage of an ERASMUS+ Project (QAEMarketPlace4HEI)." Proceedings of the 43rd SEFI Annual Conference, SEFI, Orleans, June 29–July 2.

Clark, Robin, Gareth Thomson, Elina Kontio, Janne Roslöf, and Paula Steinby. 2016. "Experiences on Collaborative Quality Enhancement using Cross-sparring between Two Universities." Proceedings of the 12th International CDIO Conference, Turku University of Applied Sciences, Turku, June 12–16.

Council of European Union. 2011. "Modernization Agenda, Supporting Growth and Jobs – An Agenda for the Modernisation of Europe's Higher Education Systems, COM(2011) 567 Final." Accessed March 3, 2017. http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0567.

Council on Higher Education. 2014. "Quality Enhancement Project: The Process for Public Higher Education Institutions." https://www.uj.ac.za/corporateservices/quality-promotion/Documents/quality%20docs/national/QEP%20Process%20for%20Public%20HEIs%20Feb%202014.pdf.

Crawley, Edward F., Johan Malmqvist, Doris R. Brodeur, and Sören Östlund. 2007. *Rethinking Engineering Education – The CDIO Approach*. Berlin: Springer.

EFMD. 2013. "Quality System of European Scientific and Technical Education – Sustainable Industry, Project Founded with the Support from the European Commission." Accessed February 3, 2017. plone.queste.eu.

European Council of Engineers Chambers. 2016. "Common Training Principles for Engineers: Survey Report." http://www.ecec.net/fileadmin/user_upload/ECEC_CTP_Survey-Report_Draft_15_September_2016.pdf.

Filippakou, Ourania, and Ted Tapper. 2008. "Quality Assurance and Quality Enhancement in Higher Education: Contested Territories?" *Higher Education Quarterly* 62, 84–100.

Gray, Peter J., and Arun S. Patil. 2009. "Internal and External Quality Assurance Approaches for Improvement and Accountability: A Conceptual Framework." In *Engineering Education Quality Assurance: A Global Perspective*, edited by A. Patil and P. Gray. Boston, MA: Springer.

Gray, Peter J., Arun S. Patil, and Gery Codner. 2009. "The Background of Quality Assurance in Higher Education and Engineering Education." In *Engineering Education Quality Assurance: A Global Perspective*, edited by A. Patil and P. Gray. Boston, MA: Springer.

Houston, Don. 2008. "Rethinking Quality and Improvement in Higher Education." *Quality Assurance in Education* 16, 61–79.

International Organization for Standardization. 2015. "ISO/IEC 33020:2015, Information Technology – Process Assessment – Process Measurement Framework for Assessment of Process Capability, JTC1/SC7, Stage 60:60." Accessed February 3, 2017. www.iso.org/iso/catalogue_detail.htm.

Kamp, Aldert. 2016. *Engineering Education in a Rapidly Changing World: Rethinking the Vision for Higher Engineering Education*. 4TU.Centre for Engineering Education: Delft Technical University.

Kontio, Juha, Krista Heikkinen, Fredrik Georgsson, Jens Bennedsen, Robin Clark, Asrun Matthiasdottir, Paul Hermon, Siegfried Rouvrais, and Markku Karhu. 2015. "QA and Enhancement Marketplace for HEIs: An Erasmus+ Project." Proceedings of the 11th International CDIO Conference Conceive Design Implement Operate: Collaboration and Extension, Chengdu, June 8–11.

Kontio, Juha, Janne Roslöf, Kristina Edström, Sara Thyberg Naumann, Peter Munkebo Hussman, Katriina Schrey-Niemenmaa, and Markku Karhu. 2012. "Improving Quality Assurance with CDIO Self-evaluation: Experiences from a Nordic Project." *International Journal of Quality Assurance in Engineering and Technology Education* 2 (2): 55–66.

Malmqvist, Johan. 2012. "A Comparison of the CDIO and EUR-ACE Quality Assurance Systems." *International Journal of Quality Assurance in Engineering and Technology Education* 2 (2): 9–22.

McCartan, Charles D., Paul Hermon, Fredrik Georgsson, Henrik Björklund, and Johnny Pettersson. 2016. "A Preliminary Case Study for Collaborative Quality Enhancement." Proceedings of the 12th International CDIO Conference, Turku University of Applied Sciences, Turku, June 12–16.

Patil, Arun S., and Peter J. Gray. 2009. *Engineering Education Quality Assurance: A Global Perspective*. New York: Springer.

Rosa, Maria J., and Alberto Amaral. 2014. *Quality Assurance in Higher Education: Contemporary Debates*. Hampshaire, United Kingsdom: Palgrave MacMillan. ISBN 978-1-137-37463-9.

Rouvrais, Siegfried, Haraldur Audunsson, Ingunn Saemundsdottir, Gabrielle Landrac, and Claire Lassudrie. 2016. "Pairwise Collaborative Quality Enhancement: Experience of Two Engineering Programmes in Iceland and France." Proceedings of the 12th International CDIO Conference, Turku University of Applied Sciences, Turku, June 12–16.

Rouvrais, Siegfried, and Gabrielle Landrac. 2012. "Resistance to Change in Institutionalizing the CDIO Standards: From a Waterfall to and Agile Improvement Model." Proceedings of the 8th International CDIO Conference, Brisbane, July 1–4.

Rouvrais, Siegfried, and Claire Lassudrie. 2014. "An Assessment Framework for Engineering Education Systems." Proceedings of the 14th international SPICE Conference, Springer CCIS Series, 447, Vilnius University, Vilnius, November 4–6, 250–255.

Rouvrais, Siegfried, Cendrine LeLocat, and Stephane Flament. 2013. "Return on Experience from Sustainability Audits in European Engineering Educational Institutions." Proceedings of the 41st international SEFI and ENAEE Conferences: Engineering Education Fast Forward, KU Leuven, Leuven, September 16–20.

Steed, Carol, Dmitry Maslow, and Anna Mazaletskaya. 2005. "The EFQM Excellence Model for Deploying Quality Management: A British-Russian Journey." *Higher Education in Europe* 30 (3–4): 307–319.

Sursock, Andrée. 2002. "Reflection from the Higher Education Institutions' Point of View: Accreditation and Quality Culture." Proceedings of the Working on the European Dimension of Quality: International Conference on Accreditation and Quality Assurance, Amsterdam, March 12–13.

Sursock, Andrée. 2012. *Quality Assurance and the European Transformational Agenda*, 247–265. Dordrecht: Springer. http://dx.doi.org/10.1007/978-94-007-3937-6_14.

van Vught, Frans A., Don F. Westerheijden, and Frank Ziegele. 2012. *Introduction: Towards a New Ranking Approach in Higher Education and Research*, 1–7. Dordrecht: Springer. http://dx.doi.org/10.1007/978-94-007-3005-2_1.

Woodhouse, David. 1999. *Quality and Internationalisation in Higher Education*, 29–44. Paris, France: OECD Publishing. http://dx.doi.org/10.1787/9789264173361-en. ISBN: 9789264173361.