NOVA

University of Newcastle Research Online

nova.newcastle.edu.au

Prieto, Elena, Holbrook, Allyson & Bourke, Sid. "An analysis of Ph.D. examiners' reports in engineering" Published in *European of Journal Engineering Education*, Vol. 41, Issue 2, Pages 192-203, (2016).

Available from: <http://dx.doi.org/10.1080/03043797.2015.1056096>

This is an Accepted Manuscript of an article published by Taylor & Francis in the *European of Journal Engineering Education* on 16/06/2015, available online:

<https://www.tandfonline.com/doi/full/10.1080/03043797.2015.1056096>

Accessed from: <http://hdl.handle.net/1959.13/1319733>

An analysis of Ph.D. examiners' reports in engineering

Elena Prieto*, Allyson Holbrook and Sid Bourke

Faculty of Education & Arts, Centre for the Study of Research Training & Impact, The University of Newcastle, Callaghan, Australia

In recent years, there have been increasing calls for an overall transformation of the nature of engineering Ph.D. programs and the way theses are assessed. There exists a need to understand the examination process to ensure the best quality outcome for candidates in engineering. The work we present in this paper uses data collected between 2003 and 2010 for a total of 1220 Australian Ph.D. theses by analysing examiner reports. Our analysis indicates that Ph.D. theses in engineering, $N = 106$, differ considerably from those in other fields in areas such as gender of candidates and examiners and the examiners' geographical location. We also found that assessment areas such as *significance and contribution of the thesis, publications arising from the thesis, breadth, depth and recency of the literature review and communication and editorial correctness* are areas in which the proportion of text of engineering examiners' comments differs significantly from other fields.

Keywords: Ph.D.s in engineering; engineering doctorates; Ph.D. examination

1. Introduction

The landscapes in which modern engineering doctorates are constructed and shaped are diverse. Engineering doctorates can comprise a portfolio of related publications or the single monograph (Moodie and Hapgood 2012); they can stand-alone or be integrated in larger team projects (Borrell-Damian et al. 2010); and can take the form of a traditional Ph.D. or be increasingly conceived as work-integrated higher degree studies in the form of the Professional doctorate (Evans, Evans, and Marsh 2005; Stewart and Chen 2009). There can be little question that in the past two decades, the changes in doctoral provision have been profound, while by contrast, examination at the doctoral level in engineering has varied little. There are essentially two approaches. In the first and least common, the assessment consists solely of the thesis examination by a number of internal and external examiners (usually two or three). This is the model in Australia. In addition, Australian institutions draw almost entirely on external anonymous examiners independently evaluating the thesis and this is seen to be a particular strength of that system (King 2012). The second approach includes an oral examination, commonly referred to as viva-voce or viva. In the USA, the UK and most countries in continental Europe, an oral examination of the candidate is generally conducted in addition to examination of the thesis. The viva typically takes place on site with the student presenting to a panel of internal and external examiners.

*Corresponding author. Email: elena.prieto@newcastle.edu.au

Whereas it is difficult to gain access to oral examinations, examiners in many countries including Australia, write individual reports that include a range of comments and recommendations about the thesis. With particular reference to engineering, these documents provide valuable insights into what examiners expect from a Ph.D. thesis. In turn, they provide a foundation on which to explore more fully the relative contribution of other forms of doctorate, and to gain a sense of what, if anything, is unique about such expectations in engineering compared to examiner expectations in other disciplines. With current calls to reassess the value of doctorates in the sciences and engineering (Cyranoski et al. 2011; Godfrey 2012), an analysis of the issues raised by experts in the field in their Ph.D. examination reports, is not only timely but necessary. In order to learn what engineering examiners expect of Ph.D. research and ascertain the strengths of the Ph.D. assessment system for the particular case of engineering doctorates, this paper explores in detail 282 examiner reports and examiner recommendations on 106 engineering Ph.D. theses from 10 Australian Universities. While acknowledging that the study is restricted to the Australian doctoral landscape, we believe that parallels can be drawn with written feedback in other doctoral examination settings and to the peer review process for novice researchers in general. Our research questions are:

In the examination of Australian Ph.D. theses

- (1) Is there a difference in thesis performance between local and international engineering candidates by country of origin or gender?
- (2) Are nationality and gender of examiners related to their assessment of thesis quality?
- (3) What do engineering examiners focus on in their reports and how does it differ from examiners in other broad fields of education (BFOE)?
- (4) How do the emphasis in the report relate to examiners' final judgements of the thesis?

Grouping some disciplines together into larger BFOE was needed to ensure no student/examiner could be identified in areas where there were only small numbers enrolled nationally.

2. Methodology

The work draws on data obtained in the course of two different, consecutive, Australian Research Council funded Discovery Projects: 'PhD Assessment: An investigation of examination process, examiner consistency and factors that identify Thesis quality across disciplines' (2003–2005) and 'Modelling and validating an approach to maximise consistency in research thesis examination' (2008–2010). In broad terms, the projects aimed to gain a better understanding of the Ph.D. examination process in Australia across institutions and disciplines, to identify standards in use by examiners, and the characteristics of quality.

Table 1. Number of PhD candidates and examiner reports.

	2003–2005 study		2008–2010 study		Total	
	All BFOE	Engineering	All BFOE	Engineering	All BFOE	Engineering
Candidates	801	66	323	40	1124	106
Reports	2121	168	743	95	2864	263
Institutions ^a	8	7	5	4	10	9

^aThree universities were in both studies.

The universities were selected to represent the range of institutions in Australia with respect to research intensiveness. The candidate and examiner data were collected by asking each university involved to select the most recently completed candidates, up to 100 candidates in both studies. In this way, the data represented approximately the university's proportions of candidates across all BFOE. In both projects, the same text coding framework was used, but until this point, the data from both projects have never been integrated, nor has there been a specific focus on the engineering reports. The material constitutes the largest data set of examiner reports on engineering to be analysed in depth, and constitutes a unique resource.

The number of candidates, examiners and institutions in both studies is summarised in Table 1.

Table 2. Coding categories.

Assessable areas		
<i>Scope and significance</i>		
1	Scope	Examiner reference to the candidate's research questions and aims
2	Significance and contribution	Examiner view of relative strength of thesis in the field
3	Publications arising	Comments about the possibility of publishing to be anticipated from the thesis work
4	Existing publications	Comments about publications already arising from the thesis and referenced in the thesis
<i>Review of the literature</i>		
5	Coverage	Depth, breadth, recency, and adequacy of the literature
6	Inaccuracy	Misreporting or inconsistent reporting of the literature
7	Utilisation	Reference to the candidate's immersion in, depth of understanding and use of the literature
<i>Approach</i>		
8	Approach and methodology	Candidate's approach to the research methods and design such as nature of the experiments, instruments and mechanics of approaches to analysis
<i>Subject matter and findings</i>		
9	Analysis and reporting	Comments about analysis and interpretation of results as well as the examiner's response to the candidate's endeavours
10	Topic related issues	Examiner provides atypical, extended detail or reflection on specific topics
<i>Communicative competence</i>		
11	Substantive issues	Holistic appraisal and/or summary of communication skills
12	Editorial	Comments on typographical, basic mechanical, clerical or technical errors
<i>Evaluative elements</i>		
<i>Summative</i>		
1	Positive	Evaluation that is succinct, comprising comment that pinpoints the qualities of the thesis, including general statements of the thesis as a whole. It may be positive, negative or neutral
2	Neutral	
3	Negative	
<i>Formative instruction</i>		
		Formative instruction requires a combination of information, action, and involvement
<i>Other instruction</i>		
4	Commentary	Instructional commentary with no specific action required
5	Prescription	Very specific action with minimal or no commentary, considered negative in tone
<i>Other judgement</i>		
6	Positive	Captures dimensions such as satisfaction (or not), worth (or not), effort (or not), through to interest, displeasure, frustration, etc. It contains no clear action
7	Neither	
8	Negative	

All examiner reports used in the combined studies were translated into standardised line and page lengths and entered into *QSR N6* text analysis software (the precursor to *QSR NVivo*). This process of coding to categories line-by-line enabled proportions of text by category to be calculated and thus reveal ‘emphasis’ in comment (see Lovat, Holbrook, and Bourke 2008). The categories capture various elements of comment. The first of these elements picks up the broad content areas of a thesis, referred to as *assessable areas* (described in Table 2). The second element is the nature of evaluative or judgemental comment (*evaluative elements*). Typically a line of text coded at one of the assessable areas is also coded with an evaluative code.

Two other elements identify more about the examiner. They are the aspects of the report where examiners provide information about themselves and their expectations of the process (*examiner and process*); and specific features of examiner discourse that reflect on the nature of academic communication, in particular active dialogue, including engagement with, and consciousness of, communicating personally with the reader(s) (*dialogic elements*). These two elements, while evident in reports across all disciplines, were not significantly related to recommendation in engineering reports.

The QSR N6 text analysis software allowed for comments to be coded under multiple categories. During the coding process certain comments were coded simultaneously in assessable areas, such as literature review, and evaluative elements, such as formative assessment. This overlap occurred between categories, but rarely within categories, that is, not many times a comment would appear coded both under methodology and literature review. Inter-rater agreement of 90% between two coders across a range of coding categories was achieved through trial coding, and the development and use of detailed coding notes (Lovat, Holbrook, and Bourke 2008). Table 2 lists the coding categories and sub-categories for all the different elements coded in the assessable areas, the analyses of which are presented in Section 3 of this paper.

3. Results

The results have been categorised into the two broad areas identified in relation to the questions: Demographic inferences and assessment of thesis. The assessment of thesis is further divided into two separate areas, the analysis of different categories of the assessable elements and how they reflect on the final outcome of the thesis, and the analysis of the summative and evaluative elements contained in the examiners’ reports. For all of these we present the results for engineering as well as a comparison with other broad fields of study.

3.1. Demographic inferences

The country of origin of Ph.D. students in engineering fields has been subject to recent investigation in the USA. In a study of factors influencing engagement in engineering postgraduate programmes, there were statistically significant differences in nationality groups’ satisfaction with: project ownership; their own development; meeting expectations; and with international diversity (Crede and Borrego 2012). Such comparisons are rare. Of the two datasets we report in this article only the first of the two studies collected information about engineering candidates’ nationality with 75.4% of them being local (from Australia or New Zealand). This proportion is much higher in other fields of education, where local students comprise 83.2% of the total number of candidates. However, like in other BFOE, no statistical difference was found when comparing engineering candidates’ nationality and their final Ph.D. outcome.

In the case of the nationality of examiners, most of the engineering examiners in the study came from countries other than Australia. This is not the case in other fields of study in the two datasets analysed in this paper (see Table 3). It is to be noted that whether the Ph.D. thesis was

Table 3. Examiners by region and BFOE.

Examiner region	Engineering (%)	Other BFOE (%)
Australia and NZ	42.8	53.7
USA and Canada	23.8	21.6
Europe	21.4	17.0
Asia	7.3	3.6
Other	5.0	3.1

examined in Australia or overseas had no statistically significant influence on the outcome of the thesis. The data on nationality of candidates and examiners were obtained from the Office of Graduate Studies in each participating university. The Office of Graduate Studies is the legal custodian of the information and consequently anonymised the data before passing it to the research team.

It is often reported that engineering as a field provides less opportunities for female professionals. In the USA, for instance, it is reported that 25% of engineering college graduates are women, but women make up only 11% of the engineering workforce (Fouad, Fitzpatrick, and Liu 2011). The UK has the lowest percentage of female engineers in the European Union with women accounting for 8.7% of the total engineering workforce (Kiwana, Kumar, and Rander-son 2011). In Australia, these proportions are even lower, with the number of female students engaged in tertiary engineering education being 15.5% and the total number of female engineers in the professional workforce 9.6% (Kaspura 2008). The datasets we analyse in this paper show that the percentage of female Ph.D. candidates is significantly lower than other BFOE; however, the most striking comparison came from data about the examiners: notably only 7% of all examiners were female, as opposed to 27% in other BFOE.

3.2. *Assessment of thesis – final outcome*

In engineering a great deal of controversy surrounds the issue of Ph.D. examination and is raising calls for its reform (Zhu, Cox, and Adams 2011). For instance, it is argued that the examination process in certain countries in Europe is too academic and narrow and does not seek attributes such as key professional skills, effective collaboration, team-work, organisational and managerial skills, appreciation of applied problems, and knowledge and awareness of other fields. Furthermore ‘it seems that all PhD candidates successfully complete their PhDs in engineering with, more or less, the same skills, style and training of their supervisor’ (Saleh 2009). Others argue that Ph.D. candidates do not possess an adequate balance of breadth and depth (Akay 2008). It is interesting to note, however, that a review conducted in the UK acknowledged that the focus of White Papers into the quality of Science and Engineering doctorates in the late 1990s and early 2000s often focused on the aforementioned nature and purpose of the Ph.D. and the Ph.D. candidate but rarely (or never) on its assessment (Morley, Leonard, and David 2002). In the USA, some authors argue that the final outcome and recommendations of the thesis are in fact the only measure of ‘quality’ for Ph.D. dissertations (Lovitts 2007, 3) and thus analysing these outcomes for consistency at many levels becomes essential to appraise the robustness, and to an extent the fairness, of the Ph.D. assessment paradigm.

In Australia, doctoral theses are assessed by two or three examiners and in most institutions each examiner selects an outcome between five different possibilities ranging from (1) ‘accept the thesis as submitted’, through (2) minor correction (invited or required), (3) requiring more substantial correction, (4) requiring the thesis to be revised and resubmitted for further examination, to (5) ‘fail’, the latter without the possibility of resubmission for further examination. In some cases, in the Australian universities that constitute the sample for this work, there were

Table 4. Final recommendation by BFOE.

Recommendation	Engineering (%)	Other BFOE (%)
Accept ('top box')	37	31
Invite or request changes	59	61
Resubmit or fail	4	8

additional categories that could be readily collapsed into these five categories. Predicting the outcome of the Australian thesis with the datasets analysed in this paper has been the focus of a previous paper (Bourke, Hattie, and Anderson 2004).

When examining the data in this study, it was noted that engineering examiners seemed to give more 'top box' results (see Table 4), that is, final recommendation in category (1). A further analysis showed that this difference was in fact statistically significant. It was also noted that engineering examiners were more likely to be chosen overseas, and that these overseas examiners were not more inclined to produce 'top box' results than their local counterparts. This also was the case for other BFOE.

In this model issues of consistency in examination results may potentially arise. In a previous paper, this issue was analysed across disciplines (Holbrook et al. 2008) showing that the comments of only a small minority of examiners were inconsistent with each other or with the committee decision in a significant way. Other research has been undertaken in the UK examining the impact of consistencies in the doctoral examination across and within institutions (Tinkler and Jackson 2000). Analysis of the data pertaining to engineering disciplines found that examiners were overwhelmingly consistent when evaluating theses. The variance between the three examiner outcomes using the 5-point scale was used as a measure of consistency. Overall, this variance ranged from 0 ($N = 33$) to 4.5 ($N = 7$), the differences between engineering and other BFOE are depicted in Figure 1. Engineering examiners did not differ in consistency from those in other BFOE.

In terms of gender differences related to assessment outcome, the studies we are reporting in this paper show no statistically significant difference in the outcome of the thesis between male and female candidates. Examiner gender was also not related to final outcome for the examined thesis.

Figure 1. Consistency measure for engineering and other BFOE.

Table 5. Assessment area emphasis as a percentage of text.

Assessment area % of text	Engineering $N = 235$	Other BFOE $N = 2485$
Scope	8.47 _a	8.34 _a
Significance and contribution	12.36 _b	9.44 _a
Publications (existing and arising)	1.38 _b	3.18 _a
Literature review	5.18 _b	7.18 _a
Approach and methodology	10.39 _b	12.93 _a
Analysis of findings	39.17 _a	37.82 _a
Communication and reporting	5.99 _a	6.48 _a

Note: Values in the same row not sharing the same subscript are significantly different at $p < .05$ in the two-sided test of equality for column means. Tests assume equal variances. The difference in sample size between this table and Table 1 is due to the fact that incomplete data were received from some examiners.

The issue of how the age or experience of the examiner affects the final outcome has also been the object of scrutiny in recent years (Mullins and Kiley 2002; Lawson, Marsh, and Tansley 2003; Kiley and Mullins 2004; Kiley 2009; Taylor 2012). The data from engineering collected in the second study showed that there was a statistically significant difference between novice and experienced examiners. While 40% of novice examiners recommended that changes had to be made to the final thesis before it could be passed; only 22% of experienced examiners nominated the same outcome. This is an interesting result which corroborates findings by Kiley and Mullins (2004) suggesting that this group tends to be more cautious especially in regard to marginal theses. These differences were not evident for other BFOE.

3.3. Assessment of thesis – examiner comments

When coding the written reports of examiners, the assessable areas were divided into 12 different categories. The makeup of the categories are summarised in Table 2 in the Methodology section of this paper. The analysis of the datasets considered in this paper showed that scope, significance, publications arising from thesis, review of the literature, approach, analysis of findings, and communicative competence, were significant for the assessment provided by engineering examiners. One interesting fact when comparing engineering assessment reports with other BFOE is the emphasis, as evidenced by the amount of text written, that examiners placed in some of these issues. The differences have been summarised in Table 5.

It is often argued that examiner's reports consist of at least two components,

firstly, summative assessment where a judgement is made about whether the thesis has met the standards established by the discipline for the award of the degree, and, secondly, the developmental and formative component, where examiners provide feedback to assist the candidate to revise the thesis. (Stracke and Kumar 2010, 1)

As outlined in the Methodology section, when analysing and coding examiner reports, evaluative elements were taken into consideration. These were (1) Summative judgements, (2) Formative instruction, (3) Prescription, and (4) Other judgement. In the subsections below we will focus on the first, summative judgement. An analysis of the formative comments found in examiners' reports in the fields of Education and Science was the focus of a previous publication by Holbrook et al. (2014).

Due to the fact that the judgement that the examiners made could be either positive or negative in nature, an intersection of these was performed with the assessable areas to obtain an overview of the type of the 'tone' of the evaluation in each of them. The tone could be either positive or negative depending on whether the examiner praised or otherwise emphasised problems or issues in a particular area of the thesis. Examples are provided in Table 6.

Table 6. Examples of engineering examiners' comments.

Summative positive	Summative negative
This thesis addresses an interesting topic which is very current. The thesis is well written and has an overall good presentation. It is very informative and provides ample referencing to previous work in the field. Critical insight is demonstrated throughout the thesis when the candidate evaluates existing methods and algorithms, compares them and decides on a strategy for proposing a novel algorithm that outperforms existing methods. One particular example is provided where the author proposes three strategies to improve classification performance using contextual information, bootstrapping and classifier combination. Originality is best demonstrated by three of X's publications which show him as first author	A big problem with this thesis is that clear statements of results are rarely given (and sometimes when they are, there are several errors). Often as not, long calculations are performed and some conclusion is given with no clear hypothesis. This style is accentuated by the sections or subsections having no introduction indicating what is going to be discussed or proved . . . there is not always a clear delineation between new and known results and that there is, at times, a sloppy attitude to explaining notation, then you get a thesis from which it is difficult to establish exactly what is proved. I would like to see clear, self-contained statements of results with precise hypotheses, followed by clearly labelled proofs

The next section contains an analysis of the proportions of text and their correlation with the quality of the thesis, as evidenced by the examiner's final recommendation in the ranking categories of (1)–(5) explained above. A summary of the proportion of text devoted to each of the different assessable areas that included some form of assessment or judgment can be found in Table 7.

3.3.1. *Scope*

Scope comprised close to 4% of the summative judgment in engineering examiners' reports and the total proportion of text written about this assessable area had a small but significant positive correlation with the quality of the thesis as evidenced by the final outcome. There were no significant differences in terms of proportion of text in the way the scope of the thesis was treated, compared to other BFOE. In terms of quantity of writing, engineering examiners wrote approximately the same amount of text as examiners in other fields, and in terms of the correlation with the quality of thesis (as measured by their final recommendation) there was no statistically significant difference with other BFOE.

3.3.2. *Significance and contribution*

Issues of significance and contribution of the thesis comprised 10% of the summative judgment in engineering examiners' reports and the total proportion of text written about this assessable area correlated positively with the final outcome awarded to the thesis. There was a difference in

Table 7. Judgement proportions in engineering doctorates.

Assessment area:	Positive (%)	Negative (%)	Correlation with quality (overall)
Scope	3	< 1	0.107**
Significance and contribution	8	< 1	0.321**
Publications (arising only)	1	< 1	0.225**
Literature review	2	< 1	– 0.028
Approach and methodology	4	< 1	– 0.011
Analysis of findings	6	> 1	0.123**
Communication and reporting	3	< 1	– 0.014

**Correlation is significant at the 0.01 level (2-tailed).

the proportion of text examiners used in relation to this area of assessment. Engineering examiners wrote significantly more about Significance than examiners in other areas, and they ranked its importance higher than other fields, showing a strong positive correlation with the final recommendation. This may be due to the fact that traditionally the engineering field is a practical one and concrete applications of research work are expected and encouraged.

3.3.3. *Publications arising from thesis*

Even though engineering examiners wrote significantly less about the publications arising from the theses than their non-engineering counterparts, the correlation with quality of theses (as evidenced by final outcome) was not significant. A very small proportion of text was devoted to this area in engineering examiners' reports (2%), and even less (to the point of being statistically negligible) to existing publications, however the inclusion of comments about publications correlated significantly with the final assessment of the thesis granted by the examiner. A possible explanation for this could be that at the time of the study Australian theses in engineering were monographs and journal publications were not expected of candidates before they submitted.

3.3.4. *Literature review*

The literature review, as it pertains to its accuracy, breadth, depth, or recency, occupied slightly over 2% of engineering examiners' reports. These examiners wrote significantly less than examiners in other BFOE. This significance was in general not transferred to a correlation with thesis quality. However, if we were to look only at negative comments made about the literature review (e.g. references were obsolete or lacking necessary breadth or depth), the correlation was significant.

3.3.5. *Approach and methodology and analysis of findings*

Examiners in engineering and other areas devoted a large amount of text to Approach, Methodology (4%) and Analysis of findings (7%). No differences were found between engineering and other BFOE in terms of examiners' emphasis on this area, however, in the case of engineering the total proportion of text devoted to this area correlated with the final outcome awarded to the thesis.

3.3.6. *Communicative competence*

Even though engineering examiners devoted approximately the same amount of text to evaluation and assessment of issues of communication within the thesis (approx. 4%), the correlation with quality of theses (as evidenced by final outcome) was significantly higher than other BFOE. This fact seems to demonstrate that within the engineering research environment clear communication is highly valued.

4. **Conclusions**

The traditional engineering doctorate is under scrutiny. There are questions about its usefulness for the future careers of the candidates as well as the quality and consistency of its assessment across nations (Cyranoski et al. 2011). In this paper, we examined different aspects of the assessment of engineering doctorates, focusing on areas which have been previously identified as worthy of note, ranging from its soundness (King 2012, 14) to its contribution when compared to other disciplines (Lovitts 2007).

Our analysis found that, in fact, with regard to the final outcome of the thesis, engineering examiners differed significantly from examiners in other disciplines in a number of respects. The most notable one, which also answers our first research question, is that they were more likely to judge Australian engineering dissertations highly and recommend ‘top box’ results. We also found differences in the gender composition of both examiner and candidate cohorts compared to other BFOE and it is not a surprise, given global trends, to find more males than females among them. However, and answering our second research question, we found no significant differences in the proportion of ‘top box’ results given by male and female examiners compared to other BFOE, no differences in the final assessment outcome when comparing the gender of the candidates within engineering, and no differences in outcomes by examiners’ country of origin.

To answer our third research question, it is to be highlighted that examiners in engineering favoured theses they considered were strong in terms of *scope, significance and contribution*, and a thorough *analysis of findings*. This was evidenced by how the emphasis placed on these areas in their reports correlated positively with the final outcome of the thesis. A special mention needs to be made about *Publications arising from the thesis*: while examiners devoted relatively little of text to this area, it was a clear indicator of thesis quality.

There were also notable differences in emphasis between engineering and other BFOE (as evidenced by the number of units of text written) in the assessable areas of the examiner reports such as significance and contribution of the thesis; publications arising from the thesis; breadth, depth and recency of the literature review; and communication and editorial correctness of the thesis. Finally, and to answer our last research question, it was found that when correlated with thesis quality (as measured by the examiner’s final recommendation), *significance and contribution* of the thesis and *communication and editorial correctness* of results were significantly more valued in engineering than other BFOE.

In summary, our analysis shows remarkable consistency in examiners’ reports in engineering. We found certain unique characteristics which are perhaps not surprising to engineering educators in the higher education sector such as the emphasis placed by engineering examiners on the *significance and contribution* of theses. Our analysis would indicate that the examination system in Australia is robust and future research should be conducted in how to best use such evidence if proposed new ways of conducting doctoral research in conjunction with industry are to be undertaken.

Doctoral degrees in engineering, as argued earlier, are undergoing a transformation and institutions in different countries are opting for other forms of training (e.g. professional degrees) and assessment (e.g. thesis by publication). Areas that would benefit from further research would be direct comparison between different systems of doctoral training and assessment to establish impact of variation in examination processes in different countries may affect doctoral outcomes. Also, traditions such as submitting the thesis as a monograph or publishing papers based on the thesis research could be explored. With respect to the training of researchers in engineering, those areas emphasised by examiners would be worthy of further exploration in relation to supervision.

References

- Akay, A. 2008. “A Renaissance in Engineering PhD Education.” *European Journal of Engineering Education* 33 (4): 403–413. doi:10.1080/03043790802253475.
- Borrell-Damian, L., T. Brown, A. Dearing, J. Font, S. Hagen, J. Metcalfe, and J. Smith. 2010. “Collaborative Doctoral Education: University–Industry Partnerships for Enhancing Knowledge Exchange.” *Higher Education Policy* 23 (4): 493–514. doi:10.1057/hep.2010.20.
- Bourke, S., J. Hattie, and L. Anderson. 2004. “Predicting Examiner Recommendations on Ph.D. Theses.” *International Journal of Educational Research* 41 (2): 178–194. doi:10.1016/j.ijer.2005.04.012.
- Crede, E., and M. Borrego. 2012. “International Diversity and Student Engagement in Graduate Engineering Research Groups.” *Procedia-Social and Behavioral Sciences* 56: 141–152. doi:10.1016/j.sbspro.2012.09.641.

- Cyranoski, D., N. Gilbert, H. Ledford, A. Nayar, and M. Yahia. 2011. "Education: The PhD Factory." *Nature* 472: 276–279. doi:10.1038/472276a.
- Evans, T., B. Evans, and H. Marsh. 2005. "International Doctoral Conference Commissioned Paper: Australia." Paper presented at the Forces and Forms of Change in Doctoral Education Internationally, University of Washington, Seattle, WA, September 6–10.
- Fouad, N., M. Fitzpatrick, and J. P. Liu. 2011. "Persistence of Women in Engineering Careers: A Qualitative Study of Current and Former Female Engineers." *Journal of Women and Minorities in Science and Engineering* 17 (1): 69–96. doi:10.1615/JWomenMinorScienEng.v17.i1.60.
- Godfrey, P. 2012. "The Engineering Doctorate (EngD) Developing Leaders for Tomorrow with Industry." Paper presented at the CLAIU-EU Conference on the Engineering Doctorate. Madrid, Spain, February 9–10.
- Holbrook, A., S. Bourke, H. Fairbairn, and T. Lovat. 2014. "The Focus and Substance of Formative Comment Provided by PhD Examiners." *Studies in Higher Education*: 1–18. doi:10.1080/03075079.2012.750289.
- Holbrook, A., S. Bourke, T. Lovat, and H. Fairbairn. 2008. "Consistency and Inconsistency in PhD Thesis Examination." *Australian Journal of Education* 52 (1): 36–48. <http://search.informit.com.au/fullText;dn=058613048601328;res=IELHSS>.
- Kaspara, A. 2008. *Engineering Profession: A Statistical Overview*. 5th ed. Australia: Engineers Australia, Barton, A.C.T. <http://search.informit.com.au/fullText;dn=944834427118175;res=IELENG>
- Kiley, M. 2009. "'You Don't Want a Smart Alec': Selecting Examiners to Assess Doctoral Dissertations." *Studies in Higher Education* 34 (8): 889–903. doi:10.1080/03075070802713112.
- Kiley, M., and G. Mullins. 2004. "Examining the Examiners: How Inexperienced Examiners Approach the Assessment of Research Theses." *International Journal of Educational Research* 41 (2): 121–135. doi:10.1016/j.ijer.2005.04.009.
- King, R. W. 2012. "Engineering Doctorates in Australia." Invited paper presented at the CLAIU-EU Conference on the Engineering Doctorate. Madrid, Spain, February 9–10.
- Kiwana, L., A. Kumar, and N. Randerson. 2011. *An Investigation into Why the UK has the Lowest Proportion of Female Engineers in the EU*. Engineering UK, London, UK. http://www.engineeringuk.com/_resources/documents/Int_Gender_summary_EngineeringUK_04_11_.pdf.
- Lawson, A., H. Marsh, and T. Tansley. 2003. "Examining the Examiners." *Australian Universities Review* 46 (1): 32–36.
- Lovat, T., A. Holbrook, and S. Bourke. 2008. "Ways of knowing in doctoral examination: How well is the doctoral regime?" *Educational Research Review* 3 (1): 66–76.
- Lovitts, B. 2007. *Making the implicit explicit: Creating performance expectations for the dissertation*. Sterling, VA: Stylus Publishing.
- Moodie, J., and K. Hapgood. 2012. "The PhD thesis by Publication in Engineering: Insights for Supervisors." Paper presented at the Australasian Association for Engineering Education (AAEE) Annual Conference, Melbourne, Australia, December 3–5. <http://www.aeee.com.au/conferences/2012/documents/abstracts/aeee2012-submission-124.pdf>.
- Morley, L., D. Leonard, and M. David. 2002. "Variations in Vivas: Quality and Equality in British PhD Assessments." *Studies in Higher Education* 27 (3): 263–273. doi:10.1080/03075070220000653
- Mullins, G., and M. Kiley. 2002. "'It's a PhD, not a Nobel Prize': How Experienced Examiners Assess Research Theses." *Studies in Higher Education* 27 (4): 369–386. doi:10.1080/0307507022000011507
- Saleh, M. 2009. "Challenges in Engineering Education: A View Towards the Future." Paper presented at the E-Learning in Industrial Electronics 2009, ICELIE'09, 3rd IEEE International Conference on. Porto, Portugal, November 3–5.
- Stewart, R. A., and L. Chen. 2009. "Developing a Framework for Work Integrated Research Higher Degree Studies in an Australian Engineering Context." *European Journal of Engineering Education* 34 (2): 155–169. doi:10.1080/03043790902833325.
- Stracke, E., and V. Kumar. 2010. "Feedback and Self-Regulated Learning: Insights from Supervisors' and PhD Examiners' Reports." *Reflective Practice* 11 (1): 19–32. doi:10.1080/14623940903525140.
- Taylor, S. E. 2012. "Changes in Doctoral Education: Implications for Supervisors in Developing Early Career Researchers." *International Journal for Researcher Development* 3 (2): 118–138. doi:10.1108/17597511311316973.
- Tinkler, P., and C. Jackson. 2000. "Examining the Doctorate: Institutional Policy and the PhD Examination Process in Britain." *Studies in Higher Education* 25 (2): 167–180. doi:10.1080/713696136.
- Zhu, J., M. F. Cox, and S. Adams. 2011. "Alternative Models of Assessment for 21st Century Engineering Doctoral Students." Proceedings of the 2011 Australasian Association for Engineering Education (AAEE) Conference, Fremantle, Western Australia. <http://www.aeee.com.au/conferences/2011/papers/AAEE2011/PDF/AUTHOR/AE110194.PDF>.