'Knowledge and Knowers' in Engineering Assessment

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Abstract

In multidisciplinary technology-based engineering diploma programmes in South Africa, the curriculum is often structured into distinctly theoretical and practical components, each of which is taught and assessed at different stages by different disciplinary or technical specialists. This separation does not necessarily reflect the complexity of such emerging regions, nor allow for the opportunity to assess multidisciplinary competence relevant to real world practice. Although the Exit Level Outcomes, endorsed by the Engineering Council of South Africa, are intended to provide a holistic framework of achievement in engineering qualifications, it is evident that these outcomes mean different things to the various stakeholders involved in curriculum design, delivery and evaluation. The moment of final academic assessment presents a number of challenges. Who is in a position to assess whether or not a candidate has successfully demonstrated the required level of competence? Legitimation Code Theory, a multi-dimensional conceptual framework for the analysis of knowledge practices and their bases of legitimacy, offers a lens through which to consider the relationship between the epistemic and social aspects of the assessment of complex performance. This paper presents the analysis of a single engineering assessment case study in which the knowledge and knower values that emerged among a group of assessors are interrogated. The findings suggest that in the absence of specific epistemic expertise, the default assessment position relies on knower attributes. This may have implications for the assumption in science-based professions that what you know matters more than who you are.

Keywords: assessment; knowledge and knowers; Legitimation Code Theory; multidisciplinary engineering; outcomes

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Introduction

Higher Education in South Africa is in a state of flux. The nationwide attempt to restructure qualifications according to the new Higher Education Qualifications Sub-Framework (HEQSF, 2013) marks a policy-driven response to urgent educational and socio-economic needs. The attempts to design 'curricula that are appropriate to a supercomplex world' (Barnett, 2000: 262), however, are situated within their own 'super' complexities. The epistemological, ontological and praxis dimensions of the curriculum (ibid.: 258) in South Africa are challenged by the roles and objectives of various stakeholders involved in the design, delivery and evaluation of curricula intended to redress historical inequalities and meet the needs of society. These challenges are all the more significant in qualifications based on a 'regionalisation of knowledge' (Bernstein, 2000: 9), a process by which different 'singulars' (pure disciplines developing in the field of knowledge production) are 'recontextualised', such as in the case of 'medicine, architecture, engineering, information science' (ibid.). 'Regionalisation' has several implications, not the least of which is the fact that it is situated at 'the interface between the field of the production of knowledge and any field of practice' and that what knowledge is selected and how it is viewed may be underpinned by 'ideological bias' (ibid.).

In the case of a region such as engineering, industry's demands 'that graduates can deliver value from their first day in the workplace' (Case, 2011: 3) have meant a shift from traditional curricula designed around singulars (physics, chemistry, mathematics) to a 'coherent curricular selection from the disciplines that underpin the profession and the situated knowledge that enable its practice' (Winberg et al., 2012: 6). The selection of appropriate disciplinary and 'situated' knowledge elements becomes increasingly complex in 21st century technology-based multidisciplinary engineering curricula. Mechatronics engineering, the focus of this paper, is presented as a case study typifying the challenges entailed in the holistic assessment of complex multidisciplinary competency. Firstly, the disciplinary foundations of such regions are drawn from significantly different types of knowledge which require very different acquisition and pedagogic processes. Widespread evidence of student difficulties in integrating knowledge in such regions suggests the complexity of such integration has been underestimated (Wolff and Luckett, 2013). Secondly, the subject range is diverse and often taught by academics with traditional disciplinary backgrounds and little exposure to the requisite technologies or multidisciplinary application. This has implications for how they may view and assess the application of their discipline in

the context of integrated practice. Thirdly, the provision of opportunities for application of relevant technologies in multiple practice/project-based contexts is challenged by the reality that 'much of what we teach our students today is likely to be obsolete or irrelevant' (Felder, 2012: 4), given the rapidity of technological developments. Though these 'application' opportunities may facilitate a stronger practice-based 'know-how', in truth, the 'knowledge condition [required] for exploring alternatives systematically and generating innovation' (Muller, 2008: 18), particularly in fields dependent on technological applications, is in fact 'know-why'. A multidisciplinary engineering curriculum in the 21st century, therefore, not only needs to provide a platform for the development of the requisite 'know-why' and 'know-how', but needs to be evaluated against the achievement of this objective.

At Universities of Technology (UoTs), engineering diploma programmes include explicit opportunities for 'real world' practical application of knowledge: Workplace Learning (WPL). These are periods of 'internship' (6 months – 1 year) provided by willing industry partners, following which (assuming the completion of the 'theoretical' components) the candidates are assessed against criteria (exit level outcomes) established by the Engineering Council of South Africa (ECSA) in order to qualify as a technician. As with the complexity of different types of knowledge taught by different disciplinary specialists, and multiple sites of potential practice (different WPL sites) with a disparate range of technological applications, the ECSA exit level outcomes (ELOs), whilst attempting to provide a broad and generic framework for all engineering qualifications, are similarly complex. The purpose of engineering diploma educational programmes is to build the necessary knowledge, understanding, abilities and skills in order to qualify as an engineering technician who has a working understanding of engineering sciences underlying the techniques used, together with financial, commercial, legal, social and economic, health, safety and environmental methodologies, procedures and best practices (ECSA, 2012).

Such standards clearly assume the availability of expertise to assess complex performance. Whilst this expertise may be available in traditional engineering regions both in and out of the academy, such emerging regions as Mechatronics engineering are not as fortunate. Given the expanding range of knowledges, technologies and practices, it should come as no surprise that there is no readily defined community, one which would serve to establish a common reference framework 'determining important problems [...], defining acceptable theories [...], methods and techniques to solve defined problems' (Usher, 1996:

15). Secondly, the fact that the region crosses disciplinary/regional/knowledge boundaries implies fewer defined methods and techniques to solve multidisciplinary problems, and this challenges the generic modifier that a technician be able to solve well-defined problems.

These complexities pose a particular set of challenges for assessment of complex multidisciplinary performance, which, we would like to suggest, are not limited to engineering. The research site, a Mechatronics Diploma programme at a South African University of Technology (UoT), however, offers an ideal opportunity to interrogate the implications of such challenges with respect to the basis of legitimacy of complex performance assessment. The programme in question has been the site of on-going research into the nature of multidisciplinary knowledge and practice using a social realist conceptual framework based on the work of Basil Bernstein (2000). Of primary interest has been the question of the different forms of knowledge and their integration in practice (Wolff and Luckett, 2013), and the implications for the redesign of the curriculum aligned to the new HEQSF. Observations over a four-year period of markedly different assessments (by a range of assessors) of the same performances against the same criteria warranted examination of multidisciplinary performance evaluation. Initial research into the nature of the different sites of practice revealed differing stakeholder orientations and values as evident in their individual informal and formal assessments of the same performance. It was during this early phase that the Legitimation Code Theory (LCT) specialisation concepts of knowledge and knower codes (Maton, 2014) were employed to analyse at the micro level the evident basis of achievement underpinning assessor decisions. The purpose of this paper is to present one case study which demonstrated an interesting range of assessor orientations, and which calls into question assumptions about what really counts in multidisciplinary engineering performance in the new South Africa.

Multidisciplinary engineering: knowledge and practice

'Regionalised' curricular knowledge

Mechatronics Engineering is the computer-based control of electro-mechanical systems, and we find its application anywhere where a computer controls a process (from the microwave oven to large scale manufacturing). The curriculum is constructed by drawing from the pure disciplines (such as physics and mathematics), different combinations of these in the regions (such as Mechanical, Electrical and Computer Engineering), and subject areas created to

allow for the integration and application of knowledge specific to the emerging region (such as Computer-Aided Manufacturing). Each of the curricular elements (taught in this context by individual disciplinary specialists) implies different knowledge structures and acquisition processes. Physics-based knowledge, for example, is 'hierarchically' structured, a structural type which sees progression through the integration of knowledge 'at lower levels…to create very general propositions and theories' (Bernstein, 2000: 161). Although this characterisation defines progression in the broader field of production (where new knowledge is created), it is evident in formal educational curricula in the sequencing of specific concepts to allow for subsumption and integration over time.

Horizontal knowledge structures, on the other hand, are those in which there are different 'languages' of the same kind of knowledge. Mathematics is an example of a 'horizontal' knowledge structure as 'it consists of a set of discrete languages for particular problems' (Bernstein, 2000: 165). It has what Bernstein terms a 'strong grammar', meaning 'an explicit conceptual syntax' which 'visibly announces what it is' (ibid.). This is in contrast to horizontal knowledge structures with weak 'grammar' (for example, languages themselves, philosophy, computer programmes). The 'discrete languages' in these types of knowledge tend to absorb elements of each other, are modified according to needs or trends, and also quickly become redundant. The proliferation and rapid redundancy of computer programming languages alone supports the view that this is a knowledge structure with weakening 'grammar' (Wolff and Luckett, 2013). In order to acquire these types of knowledge, 'masses of particulars' (Muller, 2008) need to be learnt, and not necessarily in sequence.

The core knowledge elements of the multidisciplinary engineering curriculum in question are, thus, significantly different in that different acquisition processes are implied, as well as different methods of demonstration of understanding and application. By way of example, the demonstration of the understanding and application of physics-based knowledge requires conceptual grasp of subsumptive concept chains (which implies depth), while that of the applicable types of computer-based control systems requires the demonstration of a range of types and awareness of multiple variables affecting solutions (which implies breadth). By the same token, assessment of the application of these 'sciences' by disciplinary experts may be framed by particular orientations to the structural nature of their particular specialisation.

Integrated knowledge practice opportunities

Each of the curriculum knowledge types does not constitute nor reflect the region as a whole. Mechatronics engineering itself only becomes evident in the relationship between the different types of knowledge and practices as integrated in the context of a particular controlled, electro-mechanical system. The broadest opportunity for this integration is offered in the Workplace Learning (WPL) period in industry designed as part of diploma programmes at UoTs. The WPL contexts (real world application sites), however, range from the automation of a manufacturing line to the design of prototypes, or the control of sewerage systems. These imply significantly different combinations of theoretical knowledge as well as context-specific 'financial, commercial, legal, social and economic, health, safety and environmental methodologies, procedures and best practices' (the ECSA profile descriptor characterising an engineering professional).

The opportunity to integrate 'knowledge and practice' during WPL entails selection at two levels. On the one hand, we have the selection of students for particular opportunities based on a company's perception of their needs and values in relation to those they perceive in the student. Certain values are implied when a company is more interested in a student being 'hands-on' and 'motivated' than their academic record (which is by far the norm in this case). On the other hand, in the curriculum itself we have multiple stakeholders translating disciplinary knowledge into pedagogic forms, in the 'field of recontextualisation' (Bernstein, 2000): What needs to be taught and learnt in what manner and for what purpose. This involves selection and interpretation (which may be dictated by particular orientations, values and policies), and leads to what Michael Barnett terms 'reclassificatory recontextualisation' whereby the *what* needs to be taught and learnt is transformed into a 'tool-box of applicable knowledge' (2006: 147). This principle extends to workplace learning, where 'some accommodation [has to be made] with the situated knowledge...associated with particular job tasks... [and which knowledge is] frequently tacit [and] hard to codify' (ibid.: 146). Much of this situated knowledge 'is often trapped within its context of application' (ibid.) and acquired by the student through apprenticeship or modelling. The ability to transfer this knowledge to other contexts either requires experience or conceptual grasp based on a strong foundation in the disciplines, which may not be explicit to the expert practitioner to whom the student is apprenticed. What these complexities effectively mean is that different students are afforded different opportunities in significantly different contexts, but need to be assessed against a standardised set of criteria.

**Theoretical tools for the analysis of knowledge practice assessment**

The Pedagogic Device: evaluative rules

The Pedagogic Device, a Bernsteinian concept to describe the means by which 'society's worthwhile store of knowledge' is regulated and distributed, is governed by three sets of rules, each of which is 'associated with a specific field of activity' (Maton and Muller, 2007: 19). It is through the device that social power and control are manifest through the production, recontextualisation, and reproduction of knowledge in those respective fields. Briefly, the 'distributive rules mark and distribute who may transmit what to whom and under what conditions' (Bernstein, 2000: 31); the recontextualising rules regulate the formation of a specific pedagogic discourse, which is in fact a principle for delocating, relocating, and refocusing a discourse (ibid.: 32). Evaluative rules govern the criteria against which acquisition of the transmitted knowledge is measured. If, in 'regionalised' practice-orientated curricula, the acquisition of 'transmitted knowledge' occurs across multiple types and sites, recontextualised by a range of stakeholders into curricular materials and experiences, and these acquired knowledge practices are then integrated in, yet again, a range of contexts, then the question surely arises of whose 'evaluative rules' are applied in the assessment of multidisciplinary performance?

The assumption in predominantly natural science-based regions (such as engineering or medicine) is that disciplinary knowledge is primarily what counts, and that there exists a commonly agreed core foundation. The reliance on mathematics and natural science grades for entrance into these qualifications supports this assumption. However, by way of example, the relationship between and nature of the physics and mathematics elements underpinning the three core regions (mechanical, electrical and computer engineering) differ significantly in the curriculum on which the qualification in question is based. In order to overcome such differences, another Bernsteinian concept could be relevant: that of a curriculum based on an 'integrated' code, in which all stakeholders ascribe to an explicit 'relational idea' (Bernstein, 1975: 83). And yet, as an emerging and rapidly evolving region, all the current stakeholders do not share a common reference framework. So, how do we measure what counts in the assessment of multidisciplinary engineering performance? Perhaps what is necessary is a language through which to consider the stakeholder orientations in such assessment processes.

LCT knowledge and knowers

In an effort to develop the approaches of Basil Bernstein and Pierre Bourdieu regarding what is recognised as a legitimate knowledge claim or practice, Karl Maton describes 'every practice, belief or knowledge claim' as being 'oriented towards something and by someone, and so sets up an epistemic relation to an object and a social relation to a subject' (Maton and Lamont, 2010: 5). These relations are illustrated as continua on a Cartesian plane (figure 1). A knowledge code or a stronger epistemic relation (ER+) emphasises 'specialised knowledge, skills or procedures' as the basis of achievement, and a knower code or stronger social relation (SR+) emphasises 'attributes' which may be born, cultivated or socially-based (ibid.).
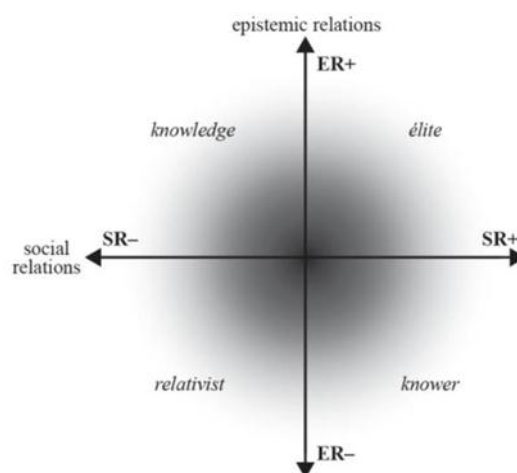
Figure 1: The specialisation plane (Maton, 2014: 30)

Maton uses Bourdieu's concept of 'fields' in describing relations to objects and subjects. Fields in highly differentiated societies, such as ours, are 'relatively autonomous social microcosms' (Bourdieu and Wacquant, 1992: 97) operating with a logic specific to the field. Members of such a field, or 'community of practice', occupy positions determined by the volume and composition of capital, resources valued by the field (education, experience, disciplinary specialisation, status, and so forth), and act in accordance with dispositions (habitus) acquired through conditioning, as well as their position within the field (Stones, 2008). In Maton's terms, a field in which both possessing the right kind of knowledge and being the right kind of knower are the basis for legitimation displays an elite code, and that in which neither is dominant would be classified as displaying a relativist code. Historically, the two relations (epistemic relations and social relations) illustrate the divisions between the natural sciences and the humanities. This paper suggests that no matter what the discipline,

the acceptance by Higher Education of the responsibility to inculcate Graduate Attributes in 21st century curricula firmly establishes the increasing importance of knower code aspects, the traditional focus of the humanities.

Strong classification of the epistemic relations (ER+) is when the specialised skills and procedures applied to a defined or discrete object of study are differentiated and controlled in such a way as not to be applied to other fields or objects. This results in 'relatively little personal discretion in the choice of objects of study, procedures and criteria' (Maton and Moore, 2010: 46). The procedures and criteria that determine the efficacy of a physics-based process in a Mechatronic system bear little relation to that determining control of the system. Physics principles are not dependent on individuals or trends, as the basis is fundamentally the knowledge itself. One's approach to solving a problem of acceleration is not dependent on who one is, rather on laws of motion. Control systems, however, despite being a combination of 'logic', mathematics and programming languages (all horizontally-structured knowledge types) are entirely dependent on choices made by people in relation to budget, feasibility, needs, trends, values, and availability [control system developers advertise and market their products extensively, and are keen to build brand loyalty]. Given that the focus of Mechatronics engineering is 'control', what exactly is the basis of achievement in this region? The intention in this paper is to use the knowledge and knower codes to determine the orientations of stakeholders involved in the assessment of one particular final-year student performance.

Assessment of engineering performance

The assessment process in context

A professional engineering technician is characterised by the ability to apply 'proven, commonly understood techniques, procedures, practices and codes to solve well-defined problems' (ECSA, 2012). The underpinning knowledge, skills, practice and attribute 'competencies' are listed in eleven generic outcome statements. Unlike the traditional universities, where assessment of final-year projects (Shay, 2004) is the preserve of academics, assessment of diploma programme projects is more complex. First of all, the nature of 'academics' at Universities of Technology is 'by no means given, but is a matter of dynamic relationships between social and epistemological interests and structures… Some disciplines could be sets of activity largely distinct from the world of work whereas others

derive their locus from activities in the world of work' (Barnett, 2000: 256). There is only one academic in the research context in question whose activities are actively based in the real world of Mechatronics engineering. The remaining academics are traditional physics-based, mathematics and specific applied technology lecturers, who have little or no experience of Mechatronics engineering as a region in itself. The second difference is that engineering diploma programmes to date have tended to assess the theoretical and practical components of the curriculum separately, the former in traditional examination form by departmental academics, and the latter (WPL period) by Cooperative Education Coordinators in conjunction with industry supervisors. The dilemma with this assessment practice is that it is much like checking a parts list. The 'theoretical' and 'practical' components are seen as discrete entities, and assessed by entirely different individuals, which ignores the fundamental relationship between knowledge and practice in integration.

The final year of the programme in question, however, is structured as two 'project-based' semesters, the first of which is on campus in a simulated industrial environment, and the second one being a period of WPL in industry. Both periods culminate in an oral (30%) and report (40%) presentation before a panel of academic and industry partners. The purpose of assessment at the end of the first final-year semester is to determine the student's preparedness for the WPL period. The assessment process for the second period (WPL) also includes 'project management' (10%) based on weekly electronic log and time sheet submissions to the Work-integrated Learning (WIL) coordinator, as well as technical and professional performance assessment (20%) by the industry supervisor during the course of the WPL period. These two aspects of assessment focus on all the exit level outcomes, whereas the focus of the presentation is the assessment of the first six exit level outcomes (table 1).

The assessment criteria

All engineering diploma graduates are assessed according to eleven core exit level outcomes (ELOs), listed in table 1. Although these are intended to frame the range of aspects that are important to quality assure the nature and level of a qualification, they are also broad enough to allow for considerable degrees of interpretation. The criteria seek to cover the three broad categories (as dictated by national Higher Education policy) that indicate a commitment to graduate development of the requisite 'knowledge, skills and citizenship' (National Planning Commission, 2011) for particular fields, thereby acknowledging the epistemological, praxis and ontological dimensions of the curriculum (Barnett, 2000).

Table 1: ECSA Diploma Exit Level Outcomes

Exit Level Outcome	
1	Apply engineering principles to systematically diagnose and solve well-defined engineering problems.
2	Apply knowledge of mathematics, natural science and engineering sciences to defined and applied engineering procedures, processes, systems and methodologies to solve well-defined engineering problems.
3	Perform procedural and non-procedural design of well-defined components, systems, works, products or processes to meet desired needs normally within applicable standards, codes of practice and legislation.
4	Define and conduct investigations and experiments of well-defined problems.
5	Use appropriate techniques, resources, and modern engineering tools, including information technology, prediction and modelling, for the solution of well-defined engineering problems, with an understanding of the limitations, restrictions, premises, assumptions and constraints.
6	Communicate effectively, both orally and in writing, with engineering audiences and the affected parties.
7	Demonstrate knowledge and understanding of the impact of engineering activity on the society, economy, industrial and physical environment, and address issues by analysis and evaluation and the need to act professionally within own limits of competency.
8	Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member or leader in a diverse team and to manage projects
9	Engage in independent and life-long learning through well-developed learning skills.
10	Comprehend and apply ethical principles and commit to professional ethics, responsibilities and norms of engineering practice within own limits of competence.
11	Demonstrate an understanding of workplace practices to solve engineering problems consistent with academic learning achieved.

Though Engineering lends itself to a psychometric assessment approach, with 'the construction of generalizations across individuals, settings, and tasks, which requires high levels of standardization' (Shay, 2004: 309), Mechatronics, as has been established, covers such a broad range of engineering aspects and offers such variable sites of practice that it has been impossible to specify assessment criteria more explicitly than those listed as the generic exit level outcomes. (Of the first 12 graduates in 2009 and 25 final-year WPL trainees in 2010, there was not a single case of a project or even project site being duplicated.) The use of the generic exit level outcomes as assessment criteria thus clearly relies on interpretation based on the tacit knowledge of those assumed to be insiders (Arnal and Burwood, 2003). However, given that this is an emerging region, with very few multidisciplinary experts in the field, this 'tacit' knowledge relied on by assessors would be applicable to individual specialisations which do not reflect the region as a whole. So, this leaves us with the question

of whether or not the different assessor 'locations' imply different values/orientations as to what counts?

The case study assessment context

The assessment of the performance of one particular student in the first final-year cohort on the programme presented an interesting set of challenges, and, in many ways, served as the impetus for on-going research into how best to facilitate differing orientations in the assessment process. Although the programme industry partners are highly supportive of the cooperative education process, the provision of opportunities for WPL during which the students engage in specific 'projects' is certainly not regarded as an academic exercise. Industry's interest is primarily in the student's potential contribution to their core business. In being assigned a project, the student is expected to demonstrate that a solution to a given problem is feasible and economically viable, the so-called 'value of a product' (the solution), as opposed to the value of a 'process' (how the problem was solved). These are the two different functions served by assessment as an interpretive act (Shay, 2004: 320). The former is aligned to socio-economic or labour market needs, while the latter is an educational need. The student under discussion received a WPL position with his bursar company and was assigned a research task in a heavy current Electrical Engineering field for a very real problem. Firstly, Mechatronics students are not trained in heavy current, and secondly, the student was required to source, collect and analyse data (which no-one in South Africa had previously compiled) so as to enable his supervisor and her team to make solution recommendations, and to which recommendations in his capacity as trainee he was not privy.

The case study assessors

Unlike the Shay (2004) study, where the assessors were all members of the field of Higher Education, the field is slightly more complex at the UoTs.

Table 2: Assessor Profiles and Assessment of Student

Assessor information * Engineering Academic (EA)/ Industry (I)/ Education (Ed)	Assessment

ASSESSOR	Disciplinary Location	Practice Location*	Qualification: NQF level	Years' Experience	ASSESS - OVERALL %	ASSESS – ELO 1 - 5	Based on -	COMMENTS ON PERFORMANCE
1	Mech	EA	7	20	67	80%	Oral	Excellent grasp of technical aspects; Good audience engagement
2	Mech	EA	10	5	60	60%	Rep	'Not equipped to assess' technical content, but good report presentation
3	Elec	EA	8	2	75	80%	Oral	Clearly identified the problem; Good English and clear presentation
4	Elec/ Control	EA	7	15	58	Fail	Rep	More technical, analysed data required;
5	Elec	I	7	10	75	80%	WPL Rep	Knowledge & application of engineering principles exceeds requirements
6	Mech	I/Ed	6	15	67	60%	Oral	Shows good grasp of project aspects; Well-spoken; good audience engagement
7	Humanities	Ed	9	15	70	N/A	Oral Rep	Log sheets demonstrate excellent grasp of problem-solving process
8	Mecha-tronics	All	9	15	Pass	Fail	Rep	No appropriate evidence of ELO2 The report is well written in all aspects. The argument is well structured and logically laid out and professionally presented.

It is quite common on a Diploma programme to have educators ranging in qualification level from Diploma (NQF 6) to a D-Tech or PhD (NQF 10), with varying degrees of experience in industry and/or education, and for the most part with no formal Higher Education training. A profile overview of the eight assessors involved in this case study is presented in table 2. What is summarised is the field location of each assessor, together with information on assessor qualification and experience that might shed light, in particular, on the marks awarded for the technical and disciplinary ELOs (1-5) as assessed in the context of either the Oral presentation and/or the Report. The comments column lists the key comments assessors entered onto the mark sheets.

Four (1, 3, 6, 7) of the eight assessors were on the Oral assessment panel of the student in question. Each completed an assessment form covering the first six ELOs, based on the student's 20-minute oral presentation. In other words, their primary focus was the student's effective communication (ELO 6) of engineering principles (ELO 1), specific sciences (ELO 2), and procedures in relation to the investigation (ELO 4), analysis of and solution to (ELO 3 and 5) a particular technical problem. Two further assessors (2, 4), who had never met the student, were given copies of the student's report for assessment against the same six ELOs. The industry supervisor (5) was not present for the presentation, but had worked with the student for 6 months and had assessed his report and overall performance against all eleven ELOs. Assessor 7, a non-engineering assessor, functioned as Work-

Integrated Learning coordinator and was not formally expected to assess the technical ELOs. The final assessor (8), who knew the student and background, functioned as moderator, based on the report and the overall assessments of the panel.

The final assessment of this student's work saw a clear divide between product and process. All those assessors who came into personal contact with the student during the assessment process (all except 2, 4, 8), as well as those who 'drew on additional sources of evidence that other markers did not have access to' (Shay, 2004: 320) and thus came to understand the process the student had undergone against severe constraints assessed him in a far higher band than those who had only assessed his project report, the product. It is worth mentioning, at this point, that all the assessors agreed the report was well-written and professionally presented. It is also important to note, up front, that the only Mechatronics engineering assessor (8) provided a detailed critique of the project report, and included the following:

> I would expect that the report on such a complex problem would require a considerable amount of data to illustrate or define the problem. A comparison of the actual operating conditions with the specifications of the equipment capabilities would have served this purpose. Numerous references to and statements of physical parameters are made in the text of the report but these are unsupported by references, evidence of measurements or included calculations. (Moderator report)

The awarding of marks between 'fail' and 'distinction' for the first five ELOs, based on collective observation of the same performance clearly demanded further analysis.

Assessment analysis methodology and findings

Based on the assessor profiles, comments and post-assessment discussions, assessors were located on the Specialisation plane (figure 2) according to which aspects they appeared to value.
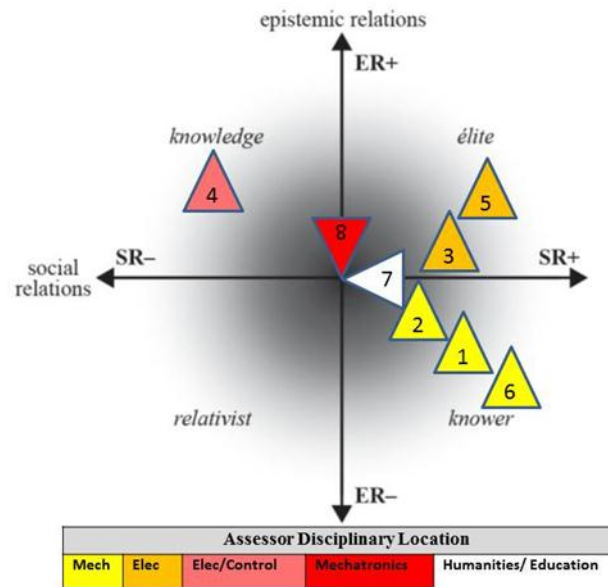
Figure 2: Case Study Assessor Orientations

A number of key elements emerge with respect to the relative presence and strength of the epistemic relations (ER) to the object and the social relations (SR) to the subject in assessing the student's performance.

<u>Epistemic Orientation</u>

• The mechanical engineering oral assessors (1, 6) were impressed (mistakenly so) by the technical content. Their comments, however, focus on the student's excellent 'audience engagement', and post-assessment discussion elicited further comments focusing on student attributes and confidence. The highest qualified mechanical engineering academic (2), who only assessed the report, stated he was not in a position to assess the technical content. This acknowledges the recognition and validity of the requisite knowledge, and he is positioned relatively higher on the ER axis. The fact that he gave the student the benefit of the doubt based on the 'good report presentation' suggests an orientation towards the student's 'communication' attributes. These assessors either incorrectly or were unable to identify the relevant knowledge (ER), and appear to value a stronger SR+ to the subject. They are grouped in the knower quadrant in figure 2.

• The assessors closest to the epistemic nature of the qualification (4, 8) clearly identified the technical inadequacies and awarded a fail mark for ELOs 1-5. Assessor

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4 displays a stronger ER+, with all comments focusing on the knowledge aspects, and he is thus located in the knowledge quadrant. Assessor 8, who acknowledged the validity of assessor 4's comments, but was also privy to broader contextual information affecting the student's performance, did not take a particular final position, and is located at the centre of the plane with a base leaning towards the ER.

•   The assessors located in the project field (3, 5) - electrical engineering - both gave the student distinctions for technical performance, and commented on key 'attributes'. His industry supervisor (5) praised his 'ability to work independently' and gave him an overall 80% mark for the core learning areas. Assessor 3, with the least experience in engineering education, also focused on the student's 'good English'. These assessors have been located in the elite quadrant on the basis of their interpretation of the student's grasp of the epistemic elements, as well as their valuing the right kind of 'dispositions' or character (Maton, 2014).

•   Assessor 7, who functioned as mentor to the student throughout the WPL period, was not required to assess the ELO 1-5, but was aware of the discrepancies in interpretation of the epistemic elements and leaned towards a final SR+ orientation.

Social Orientation

•   A key aspect influencing the oral assessment process, we suggest, was the student's presentation style. The three oral presentation assessors who had no prior knowledge of the student (1, 3, 6) appeared surprised at the student's confidence and praised his 'good English and audience engagement'. The student, a well-spoken young Sotho-speaker, with his private-school English accent, was not a typical student in the institutional context in question. His appropriate use of technical discourse and professional presentation in both oral and written formats were acknowledged by all. What appeared evident, however, was that the assessors from the Mechanical Engineering department were assessing the student as a 'product' of the programme in question, comparing him to students on other engineering programmes. One assessor commented on how 'lucky' the programme was to have 'such' students. Their experience of him in person had a significant impact on their interpretation of his performance, both masking any technical deficiencies, as well as possibly leading to conflation of disposition with relevant epistemic expertise. The

default assessment position was clearly the valuing of a stronger SR+ to the subject, in other words, a knower code.

•   The assessments of assessors 3 and 5 appeared problematic, given that they had the greatest potential insight into the knowledge components of the project itself, both being electrical engineers. As the least experienced engineering academic, but qualified electrical engineer, assessor 3 may well have awarded a distinction for the technical aspects based on recognition of the conceptual leap the student had undergone having to equip himself in the six-month WPL period with heavy current electrical engineering knowledge not covered in the qualification. His assessment suggests a 'process' orientation and a clearly socially-situated/contextualised approach.

•   Assessors 5 and 7 were the only two who had on-going contact with the student throughout the WPL period. What only they knew was that the student had faced major systemic constraints on the project. He had gone to great lengths to establish contact with the international engineer originally responsible for installing the system under investigation, and maintained this contact in such a way as to finally source, analyse and compile crucial data that other project engineers had not managed to collect. Both assessors 5 and 7 were unequivocal in their praise of his performance 'process', clearly valuing 'disposition' (SR+) over explicit technical expertise. That both are women is possibly also relevant.

When the broader contextual aspects were brought to the attention of the moderator (assessor 8), he confirmed that the decontextualised 'product' (the report on the project) fell short of minimum requirements as there was 'no substantive or substantiated technical solution', but that the 'process' (evidence of generic research stages, including independent solution recommendations) exceeded requirements. He qualified a final pass mark by stating the following:

This project is well outside of the qualification objectives in terms of the targeted field of study. From the report it is difficult to determine whether the student acted too far outside of his expertise. It should be noted that the fact that the project was outside of the field of expertise of the assessors made it difficult for the assessors to make judgements or form opinions on the student having met the assessment criteria. (Moderator's report)

Implications for assessment in multidisciplinary fields

These findings make no claim towards generalisability. However, subsequent collaborative assessment processes on the programme in question have consistently revealed disparate and, at times, irreconcilable differences in what exactly is being assessed. At a disciplinary level, where there are strong epistemic relations (ER+) to the object of study, the assumption of a common 'engineering sciences' reference field is clearly called into question in multi/trans-disciplinary emerging regions (of which there are a plethora in the new century). As rapidly as these new regions emerge in the field of practice, the more difficult it becomes to identify the requisite experts (in academic contexts) to assess integrative performance that crosses disciplinary boundaries. In the absence of specific epistemic expertise, the default assessment position appears to be a stronger social relation (SR+) to the subject, in other words, a knower code, informed by perceptions of communicative competence and willingness to engage in independent learning, for example. While this may appear to be a good thing, given the range of criteria in the exit level outcomes for engineering programmes, it does call into question the primary reliance on mathematical and science knowledge underpinning ELO 2 as entrance criteria for such qualifications. On the other hand, the lack of differentiation between significantly different forms of knowledge, and opting for a default SR+ assessment orientation may well threaten the development of the necessary knowledge competence in increasingly complex and rapidly emerging fields reliant on 'know-why', 'the knowledge condition for exploring alternatives systematically and generating innovation' (Muller, 2008: 18).

Furthermore, as engineering diploma qualifications lean increasingly towards socio-economic relevance and sites of practice become more complex, the traditional academic assessment of decontextualised 'theory' and 'well-defined' project briefs may not be achieving the intended holistic competence as suggested by the ELOs collectively. In the research context in question, following an analysis of a series of assessment processes, the programme adopted a pro-active 'community-of-practice' based approach to assessment of final year students. All mentors from the various industries, in addition to a range of academic Engineering Faculty specialists from the sub-disciplines, as well as other HE practitioners are invited to form part of the assessment panel. Although the assessments

consistently reveal a predominant SR+ orientation to the student performances, what has emerged in 'the social process of discursive engagement…in…the transdisciplinary collective' (Jacobs, 2007: 68) is a sensitisation to the complexities inherent in both 21st century engineering and the South African context. This collaborative approach has begun to characterise developments in the Teaching and Learning arenas of HE, notably that between disciplinary and academic development/academic literacy specialists. The challenge in such collaborations is not to lose sight of the nature and value of the different forms of knowledge and practice required in more complex socio-economic and industrial contexts.

Conclusions

This paper has sought to highlight the different stakeholder orientations and values brought to bear on the assessment process in the context of an emerging multidisciplinary engineering region. A single engineering diploma case study is presented in which assessor interpretations of the 'evaluative rules' (Bernstein, 2000) of multidisciplinary performance appear to be influenced by both disciplinary and social locations in the broader South African HE context. This phenomenon supports Soudien's contention that 'the educational experience acknowledges the larger palette of socialities which encompass South Africans' everyday experiences' (2013: 71). Using LCT's specialisation plane (Maton, 2014) to plot assessor orientations, a key finding is the default orientation towards valuing 'disposition', and thus a stronger knower code, in qualification fields assumed to entail stronger disciplinary bases, a knowledge code. The latter is the traditional basis of achievement in engineering regions, and the basis of entry requirements into such qualifications. However, the case study reveals that who you are appears to matter as much, if not more, than what you know.

The authors would like to suggest that the legitimation code in such multidisciplinary regions, given appropriate disciplinary assessment expertise, will be an elite code (ER+/SR+), a 'gentleman scientist' equipped with highly specialised knowledge from a range of fields and having developed the 'human qualities and dispositions, of certain modes of being, appropriate to the twenty first century' (Barnett, 2007: 409). Although the ECSA-endorsed ELOs ambitiously attempt to capture these criteria, there are two key challenges in the assessment of achievement: first of all, such holistic assessment requires the collaboration of multiple stakeholders engaged in theoretically-, socially- and empirically-informed discussion designed to reach a degree of consensus as to the 'relational idea' (Bernstein,

1975: 83) underpinning such emerging regions in our particular South African context. Secondly, the current poor throughput and retention statistics in engineering qualifications (CHE, 2009; Fisher, 2011) suggest that the primary reliance for entry into HE on mathematics and natural science performance at secondary education level may not be sufficient indication of the required competencies, particularly in emerging multidisciplinary engineering regions. The fact that these knowledge areas do not take precedence over 'disposition' in the final assessment of performance may well suggest the need for a review of entrance criteria.

Bionotes

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Francois Hoffman is currently the Manager of the Engineering Project and Innovation Centre at the Cape Peninsula University of Technology (CPUT). As founder of the Mechatronics Engineering Diploma Programme at CPUT, he established an innovative practice- and project-based approach to technician and technologist training, and actively promoted industry engagement. He is the South African World Skills expert assessor in Mechatronics Engineering, and has an international network of collaborations to facilitate engineering training and project development.

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