On the use of semantics for curriculum development of new Engineering Technology Programme

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***Abstract*—Engineering technology education has undergone many changes over the past few decades, with the most recent one being the establishment of a new qualification for engineering technologists. This qualification is intended to decouple the engineering technology qualification from the engineering technician qualification. The establishment of a new degree for engineering technologists poses challenges for curriculum developers who need to ensure that the new curriculum will serve to shape graduates as envisaged by the new qualification standards. This is especially challenging because engineering technologists have always followed the same curriculum as engineering technicians for the initial phase of their education. This work focuses the particular challenge of planning of the curriculum knowledge that will shape the intended knower. In this paper, we present some preliminary thoughts on an outcomes-led approach toward determining how the new graduate attributes affect selection, sequencing and pacing. We use legitimation code theory to conceptualise the relationship between knowledge and outcomes.**

***Index Terms*—Engineering education, curriculum development, graduate attributes, semantics, legitimation code theory**

I. Introduction

Recently, higher education in South African has seen the development of a new degree qualification – i.e. Bachelor of Engineering Technology. This new qualification is intended to replace the current qualification for engineering technologists. The existing articulation path for engineering technologists is through firstly earning a National Diploma in Engineering (NDipEng) and then a Bachelor of Technology in Engineering (BTech). There are specific reasons for the establishment of the new qualification which are discussed in this paper. A key implication of the new qualification is that the new exit-level outcomes, or graduate attributes, stipulated by the Engineering Council of South Africa (ECSA) ultimately points to the development of a different knower than was intended to be developed by previous qualifications. Essentially, this shift in the knower to be developed translates to various curriculum development considerations. Curriculum developers are faced with many challenges in determining the knowledge components, teaching and learning activities, and assessments etc. that will shape students into the graduates or knowers envisaged in the new qualification standard.

In this study, we focus on how selection, sequencing and pacing for the new curriculum, in relation to the intended outcomes, affect epistemological transitions to more advanced levels of study and determine strategies on how to assist students to navigate these transitions. We use Blooms taxonomy, and Legitimation Code Theory to analyse how these transitions should be affected in the curriculum in relation to the new qualification standard and intended programme outcomes. The concepts of semantic gravity and density are used to perform a preliminary analysis and better understand the knowledge structuring in the new curriculum. We study the case of the Electrical Engineering Technology programme at the University of Johannesburg, and use the data collected during the prior curriculum planning and implementation for the first year with particular focus on the first-year Electrotechnology module.

II. New Bachelor of Engineering Technology Programme

A. Background

There is a need in South Africa to align education and registration models for engineering technicians, engineering technologists and engineers that corresponds to the roles of these professionals in practice [5]. In higher education, the engineering technologists' articulation model followed the same route as engineering technicians – i.e. NDipEng. After becoming a technician, one would enter the BTech(Eng) programme and then qualify to become an engineering technologist. Upon promulgation of the Higher Education Qualification Framework (HEQF), this articulation model was deemed to be uncompliant by ECSA [2]. Hence, the new BEngTech qualification was created for engineering technologists so that there could be a decoupling of technicians and technologists in engineering education. A new set of exit-level outcomes to distinctly define the knower to be developed was then established in a new qualification standard.

One of the major challenges in engineering education now lies in realising the decoupling of engineering technicians and engineering technologist through the new curriculum. In South African higher education, the educational goals of the engineering technologist programmes have been the same as with the engineering technician – i.e. for the initial NDipEng phase. The new qualification sets out the goal of defining a completely separate graduate to be developed that is distinctly a technologist.

B. Comparison to existing qualifications

The credit allocations according to different knowledge areas for the BEngTech and NDipEng are given in Figure 1. The total credits are different for each qualification – i.e. 480 credits for BEngTech and 360 credits for NDipEng. The percentages however do give some indication of the difference in the focus on various knowledge components and highlight the type of knower to be developed in each case. There is an incremental shift in engineering sciences, design and synthesis as well as complementary studies for the BEngTech. Engineering practice constitutes the major shift between the two programmes. Work Integrated Learning (WIL) is a significant component of the NDipEng programme does feature in the BEngTech programme. Additionally, a larger number of credits is allocated for redistribution in the BEngTech qualification. This is a discretionary allocation for curriculum designers which is a typical feature engineering degree programmes [2].

There are also 10 graduate attributes in the BEngTech qualification standard [3]. These attributes are the same as the exit-level outcomes stipulated in the NDipEng qualification standard [4]. These attributes or outcomes pertain to problem solving; application; design; investigation; methods; communication; activity impacts; individual and teamwork; independent learning; and professionalism. Although the attributes of the BEngTech matches that of the NDipEng, there is a key difference in the level descriptor at which most of these outcomes must be met. For the BEngTech, the level descriptor stipulates a "broadly-defined problem" and for the NDipEng, the level descriptor stipulates a "well-defined problem". The type of problems that an NDipEng graduate must be able to solve, as envisaged by the NDipEng qualification standard, are problems that are mostly defined and routine in a familiar context [6]. In engineering, these types of problems can be solved in a standard or prescribed way and requires practical engineering knowledge with some theoretical foundation. On the other hand, the BEngTech qualification standard envisages that a graduate must be capable of solving ill-posed, under- or over-specified problems. This requires more coherent and detailed engineering knowledge with greater theoretical underpinnings [7].

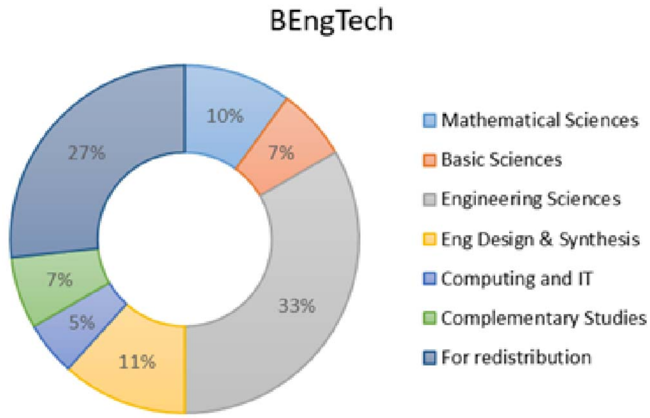
III. Curriculum Development Issue

ECSA have developed a specific set of outcomes against which the compliance of an engineering curriculum/programme is measured. Curriculum development – in the case of engineering education in South Africa – is therefore outcomes-led which may be classified into the category of "rational curriculum planning" [1]. In [1], Knight argues that the choice of goals is problematic and producing detailed outcomes is fraught. For example, evaluation of compliance typically focuses on the stipulated outcomes. Therefore, there is much complexity to developing the curriculum in the case of the new BEngTech and planned curriculum can only be measured against the standards. One of the core curriculum development issues with the new BEngTech program is determining how to adopt knowledge components so that the knower, as envisaged by the standard, is developed.

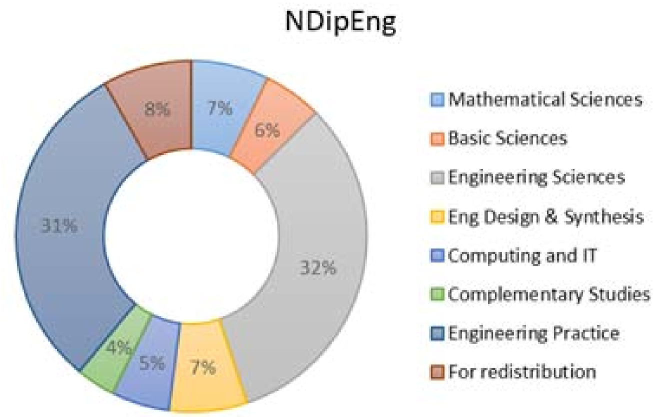
As illustrated previously, the qualification standard does give us guidance on the knowledge components to be adopted in the new curriculum. However, the challenge is understanding how these components need to be converted into the curriculum to ensure that the intended knower is developed. This curriculum development problem therefore relates to the structuring of knowledge. One avenue of disentangling the problem is via the pedagagogic device. The pedagogic device can be described as the ordering and disordering principles of the pedagogising of knowledge [8]. Essentially, this device constitutes the principles or set of rules by which knowledge is converted into pedagogic communication. In [9], Roberts describes the device as the 'grammar' of pedagogy in a metaphorical sense. The pedagogic device arose from earlier work by Bernstein in which he proposed the concept of pedagogic identity for the purpose of classification and framing of educational knowledge. The actual device provides the aforementioned principles through interdependent rules categorised into distributive, recontextualising and evaluative. In a nutshell, distributive rules deal with the regulation of power relationships between social groups via distribution of different forms of knowledge, recontextualising rules deal with formation of specific discourse and evaluative rule deal with specific pedagogic practices. This pedagogic device provides a means of understanding the dynamics and influences of factors affecting knowledge in curriculum [10] and processes by which knowledge is pedagogised for curriculum [8].While the pedagogic device does give us a sense of the presented problem at a macro level, the framework developed by Bernstein is complex and does not give us a pragmatic tool with which to begin to address the problem at a micro level.

As the BEngTech qualification standards provide a starting point for addressing the knowledge problem, the outcomes-led curriculum planning approach inherently requires a better understanding of the relationship between knowledge and outcomes. In [11], Barnett provides some coherency to this relationship through prompting thinking about curriculum as encounters with knowledge for affecting change and describes the profound relationship between knowing and being, and how knowledge can influence being. In this case, the ECSA graduate attributes or outcomes constitute the change. The questions of knowledge in the new curriculum pertain to not only what should be taught – i.e. what the student should know, but also to how it should be taught – i.e. how the student will know.

These are curriculum questions relating to recontextualisation or selection, sequencing and pacing. Maton offers some insight into how the nature of knowledge practices could be captured via Legitimation Code Theory (LCT) or, more specifically, the semantics framework [14]. However, these questions require further exploration particularly for the engineering discipline. The work presented in [12] and [13] are supportive towards answering these questions. In [12], Shay



(a)



(b)

Fig. 1: Comparison of credit allocation per knowledge area for (a) BEngTech, and (b) NDipEng.

conceptualises knowledge differentiation for professionally-oriented curricula. The previously mentioned differences in the knowledge components and graduate attributes level-descriptor can provide a means of differentiating the knowledge for the curriculum. Winberb et al builds on this knowledge differentiation for the specific case of electrical engineering by analysing the role of selection and sequencing of knowledge in the curriculum [13]. This work utilises the semantics framework to conceptualise the how knowledge is differentiated in the curriculum.

Maton proposes an alternative theory in [14] – i.e. LCT, which focuses on the knowledge component of curriculum and offers a means with which to transform pedagogic practice through enabling us to analyse how we facilitate knowledge-building. This "semantic" theory component of LCT offers a qualitative (and perhaps somewhat quantitative) means of analysis. There are essentially two major components (or measures) within the framework – i.e. semantic gravity (SG) and semantic density (SD). The framework presents the idea of "quantifying" the degree to which meaning relates to its context – i.e. SG and the degree of condensation of meaning – i.e SD. Although the application of these measures are highly subjective and therefore contestable, it does provide a more pragmatic and functional approach to addressing the presented curriculum challenge.

IV. Semantic Analysis

A. Overall Program

As mentioned, ECSA has produced the same outcomes as the existing engineering qualification with the key change made only to the range description – i.e. in the type of problems to be solved. In outcomes-led curriculum development, this change in range description must be translated into the curriculum knowledge.

A generalized conceptual model can be ascertained with basic analysis of the curriculum knowledge components for the new program. For example, mathematical and basic sciences such as chemistry and physics do display a relatively higher SD. This subjects generally have a stronger condensation of meaning. The engineering sciences are applied forms of this basic sciences and mathematics and therefore have both stronger SD and SG [13]. This means that these subjects are often the most challenging for students.

Relatively, the conceptual depth of what is required for the BEngTech graduate as compared with the NDipEng graduate can be said to be greater. This is expected because of the emphasis on the sciences and mitigation of certain practical or more contextual knowledge components. Additionally, this aligns with the envisaged attributes of the BEngTech graduate. They are expected to solve ill-posed problems with unfamiliar context and should therefore be equipped with knowledge of greater conceptual depth. A simple illustration of this is given in Figure 2.

B. Case of Electrotechnology Module

Electrotechnology is a first year electrical engineering course. This course serves as an introduction to the basic principles of electrical engineering that will serve students throughout the program. The concepts studied in this course

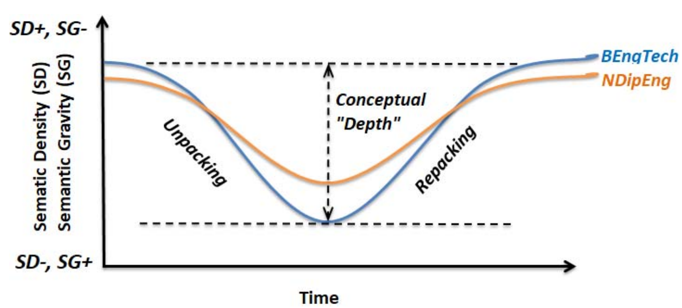


Fig. 2: Example of conceptual "depth" comparison for NDipEng and BEngTech knowledge components

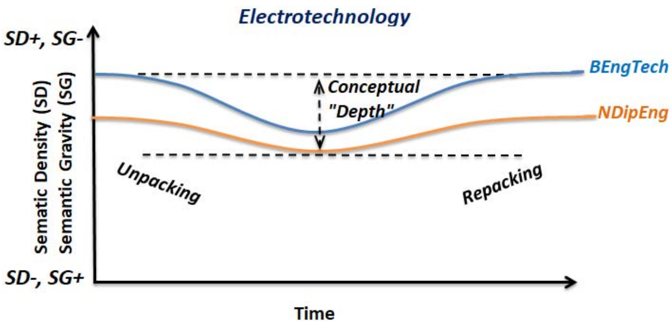


Fig. 3: Example of conceptual "depth" comparison for NDipEng and BEngTech knowledge components for a particular first-year course

will be used in various other courses with stronger SG. Once again, a relative comparison between NDipEng version of this course with the BEngTech version can be carried out using semantic analysis.

We can take a particular example in the course to begin to formulate the comparison. If we take the simple example of electromagnetism. For the BEngTech Electrotechnology course, emphasis is placed on understanding of the concepts of self and mutual inductance, mutually coupled coils then circuits, eventually leading to the ideal transformer. With NDipEng, basic electromagnetism principles taught before directly leading into the ideal transformer. This is because engineering technicians are not expected to deal with unfamiliar engineering problems and therefore the emphasis is placed on the technology in practice. This is not to say that engineering technicians have a greater density in the applied engineering aspects. The semantic density here will also be higher for the BEngTech course because, as presented in [13], that abstract knowledge is not made simpler through contextualization in engineering. In fact, contextualization can be made more complex. A good example of this is engineering projects found at the final year of the program. These projects have very high semantic density and very high semantic gravity, and are the culmination of the different knowledge components of the program.

In terms of selection, there is the need for greater emphasis on conceptual depth. Sequencing, also plays an important role as this will determine where the SG or context features in the curriculum. Pacing will therefore be dependent on both selection and sequencing. This will essentially determine how the density and gravity are changing through the curriculum. From this preliminary analysis, the unpacking and repacking of concepts for example will be done at a greater "pace" in the BEngTech curriculum purely because the depth is greater over the same period of time.

V. Conclusion

The establishment of the new BEngTech programme presents many curriculum challenges. One such challenge is account for the shift in graduate attributes through the knowledge component of the curriculum. This is challenging because the relationship between knowledge and outcomes need to be understood to the extent of how the different knowledge components are adopted in the curriculum to elicit the envisaged graduate attributes. The differences between the NDipEng and BEngTech qualifications are found in the emphasis on knowledge components and the level descriptors for the graduate attributes.

Answering the question of how these knowledge components should be adopted began with its relation to the pedagogic device. The concept of redistributive rules and pedagogising of knowledge unpacked the main question into more specific questions relating to selection, sequencing and pacing. We found that the semantics framework of LCT could be potentially used as a tool for analysing how the adoption of knowledge in the curriculum could elicit graduate attributes. Although, the preliminary analysis offered in this paper has been carried out in hindsight to the implementation of the new program, it does provide a powerful means of reviewing the suitability of our curriculum development specifically with respect to knowledge.

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