EXPANDING THE SEMANTIC RANGE TO ENABLE MEANINGFUL REAL-WORLD APPLICATION IN CHEMICAL ENGINEERING

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ABSTRACT

Legitimation Code Theory has proven to be useful in analysing the relationship between theory and practice. *Semantic gravity* can be used to illustrate teaching and learning processes that move between different levels of abstraction and context-dependency. Effective engineering education entails moving both up and down the *semantic range* in a way that enables students to apply concepts to contextual practices. However, students seldom engage at the strongest level of *semantic gravity*. This study investigated the contextualisation of theory in a chemical engineering programme through industrial site visits. Final-year chemical engineering students participated in a voluntary field trip to visit industrial sites. Data obtained through written surveys showed that visits allowed participants to develop a better appreciation for the relevance of taught material to industrial applications and to better understand relationships between different modules and problem solving. Site visits were found to be an effective way of expanding the *semantic range*.

Keywords: chemical engineering, engineering education, Legitimation Code Theory, *semantic range*, Semantics, site visits

INTRODUCTION

The challenge in educating engineers for the complex problems of the 21st century is well-reported, and includes key features relating to the relationship between science, technology, society and nature (UNESCO 2010). This relationship is made more complex in the face of sustainability and optimisation of resources for socioeconomic survival and development. The complexity of the relationship has come under the spotlight by employers worldwide who are increasingly dissatisfied with the ability of higher education systems to adequately equip its graduates. A sector that is particularly challenged is that of chemical and process engineering, in which some have called for a fundamental paradigm shift if education is to successfully impart “fundamental physico-chemical and engineering principles” and “the ability to use technical knowledge ... to construct solutions to new problems” (Molzahn and Wittstock 2002, 234) as well as “professional awareness” (Rugarcia et al. 2000). This implies a necessary bridging between theory and practice. Chemical engineering qualifications are generally aligned to International Engineering Alliance (IEA) standards. These call for outcomes covering knowledge, skills and attributes domains (DHET 2013).

Globally, chemical engineering qualifications follow similar guidelines, including understanding of principles and technologies, awareness of impact, and familiarity with design, operation and management principles (Fletcher, Sharif and Haw 2017). The theoretical and decontextualized practical outcomes are established components of a curriculum intended to contribute towards the development of a graduate engineer. However, the IEA profile (2013) includes the application of “reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems”. The practical limitations of higher education environments to enable the realistic achievement of such an outcome are immense. At best, well-resourced programmes may offer innovative uses of technology to demonstrate contextual application or simulated environments (Schofield 2012). The important role of laboratories (Feisel and Rosa 2005) and practical projects (Pott, Wolff and Goosen 2017) go some way to enabling students to see the links between theory and practice, but these are limited to the confines of the higher education institutional environment.

Theory-practice bridging initiatives are essential given the number of employer surveys which express increasing dissatisfaction with graduate application of theory (Griesel and Parker 2009) as well as a lack of technical abilities (manpowergroup.com 2015) and awareness of business contexts (Fletcher, Sharif and Haw 2017). Mills and Treagust (2003) also argued that the traditional lecture-based teaching style does not adequately equip students to apply good fundamental engineering knowledge in practice or to work in an industry characterised by uncertainty, incomplete data as well as conflicting demands from different stakeholders. In addition, the traditional curriculum and teaching methods offer limited industrial exposure for students to grasp the realities of the social, environmental and economic matters that affect their profession directly and indirectly.

This article hopes to contribute to the development of a more informed perspective on conceptual and contextual nuances between different levels of abstraction as encountered in chemical engineering curricula, teaching, learning and assessment. Using a theoretical tool from the sociology of education – Legitimation Code Theory (LCT) (Maton 2014) – the article presents the analysis of an initiative to extend the theory-practice experience for a group of final year chemical engineering students by way of a range of industrial site visits prior to undertaking their capstone final year research and design projects.

A dimension of LCT called Semantics enables the interrogation and description of conceptual and contextually-dependent meanings which can be plotted on a scale representing a range from abstract to concrete. Semantics is rapidly becoming an effective tool to understand the theory-practice divide in science-based education, and has helped to determine conceptual gaps in physics (Georgiou, Maton and Sharma 2014), chemistry (Blackie 2014) and biology (Kelly-Laubscher and Luckett 2016) teaching and practice in Higher Education. In previous studies at the same institution, the *semantic scale* has evolved to show differences in different engineering sub-sectors. On the one hand, Walls and Wolff (2015) used the *semantic scale* to define the relationship between a structural (physics) principle, its formulaic and mathematical variants, its forms of diagrammatic representation and the real-world structure. On the other hand, the Auret and Wolff (2017) study delved into the middle of this *semantic range* to refine the mathematics and modelling levels of abstraction. In our study, we are focussed on expanding that range from the core theoretical curricular principles all the way into real world sites of chemical engineering practice.

CONTEXT

The BEng (Chemical) degree programme at Stellenbosch University is a four-year degree programme that leads to a professional qualification accredited by the Engineering Council of South Africa, a signatory to the Washington Accord. As such, the undergraduate curriculum is aligned accordingly and contains two capstone modules, namely a final year research project and a design project. All students perform the same design project, which alternates between a classical chemical plant and a processing plant in the mineral processing field annually. The design project involved a classical chemical plant in the year that the site visits were conducted.

The final year research project requires students to conduct an individual research project to develop competence in the planning, execution and reporting of a major engineering investigation through the application of scientific and engineering knowledge. Students are provided with a list of available research projects (and associated lecturers) at the beginning of the year in order for them to indicate their preferred topics. These preferences are then considered together with lecturers' input to assign each student to an academic supervisor with research interests in specific fields. Currently, the five main research themes within the Department of Process Engineering include: bioresource engineering, mineral processing, separations technology, waste valorisation and water technology. This study was conducted with a cohort of students with a final year research project in the field of mineral processing.

Students generally find the capstone modules challenging for various reasons, some of which include: the problems are more ill-defined and open-ended than encountered previously; there is a greater expectation in terms of independent learning; students take more responsibility for time management and scheduling of work; it requires innovative / creative thinking and integration of skills and knowledge from various modules taught during their undergraduate training; and it requires application of theoretical knowledge to solve real engineering problems in a practical, feasible manner. These challenges, in fact, represent the full range of IEA-aligned outcomes. These observations are in agreement with findings reported by Male, Bush and Chapman (2010), who reported the ability to apply knowledge to solve practical engineering problems and to consider engineering business in the broader decision making context as the most common deficiencies of engineering graduates entering the marketplace. Recent graduates also felt that their self management skills (e.g. time management, communication skills, and handling stressful situations) and attitude (e.g. work ethics, impressions and expectations of the working environment, and management of interpersonal relations) were not developed adequately during their undergraduate training.

Although students are taken on site visits during the first semester of their second year, they have had limited teaching on chemical engineering principles at that stage. With this study, final year students were taken on site visits to facilitate improved contextualisation of theory and increased awareness of the interaction between engineering and the environment (natural, social and economic) with the hope that this would better equip students for their capstone modules. Sen (2013) reported that site visits can enhance concepts learned in class and that students generally experience plant visits as an important part of learning that allow them to better understand the role of engineering in specific contexts. Results presented by Markom et al. (2011) support the notion that site visits can be an important learning experience; the fact that site visits can assist in relating theory to practical aspects of unit operations, processes and design concepts was reported as one of the main benefits.

Although much of the literature does not dispute the value of site visits, few studies offer an explicit theoretical understanding of the relationship between contextual experience and the conceptual curriculum. This research study hopes to contribute to a better theorisation of the links between theory and practice.

THEORETICAL FRAMEWORK

Legitimation Code Theory (LCT) has emerged as an evolving framework to consider knowledge and its practices across disciplinary fields, in and beyond education (Maton 2014). It is proving particularly useful in describing and analysing the relationship between theory and practice, and has been employed in a number of engineering studies to enhance educator understanding of teaching, learning and curriculum design (Auret and Wolff 2017; Pott, Wolff and Goosen 2017; Wolff 2015; Wolmarans 2016). The LCT dimension of Semantics foregrounds ways of making meaning, and has two aspects. *Semantic gravity* (SG) demonstrates the strength of the relationship between meaning and its context, from abstract/conceptual forms of meaning which demonstrate weak SG to more concrete, context-dependent forms (strong SG). *Semantic density* captures the complexity of meaning. These two facets can be used in synthesis on a Cartesian plane (called the *semantic plane*) or independently. Taken on its own, *semantic gravity* can enable the tracing of a *semantic wave* over time to illustrate teaching and learning processes that move between different levels of abstraction and context-dependency. In engineering studies to date, Semantics has been used to describe different levels of conceptual to contextual meaning (Table 1), with the weakest form of SG generally representing a principle that can be articulated in words, such as Newton's Laws of Motion, for example. The next level would commonly be that of a mathematical equation which captures the principle, followed by a schematic representation. These two levels are commonly the focus of application in engineering classes: the formulaic and/or representational application of mathematics to demonstrate understanding of a principle.

Table 1: Generic *semantic range* in engineering

Semantic range	**Levels of meaning**	**Example 1 (Walls and Wolff 2015)**	**Example s (Auret and Wolff 2017)**
Weak *semantic gravity* (Context-independent	Principle	Structural forces determining bracing	Conservation of mass and energy
↕	Formula and calculations	$C_r = \emptyset A f_y \, (1 + \lambda^{2n})^{-1/n}$	Mathematical expressions of process control
	Representation	Technical schematic drawings	Block diagram schematic of process control
	Model	3D/simulations of structural behaviour	Software simulation system
Strong *semantic gravity* (Context-bound)	Real	Physical structure (real building)	Physical process control systems

Enabling students to move from one level of meaning to another (including all levels of the *semantic range*) is the aim of "cumulative learning" (Maton 2013). Several studies demonstrate the use of the *semantic wave* in analysing classroom practices, and reveal patterns such as a high or low “flatline” (where the focus is only on one particular level of meaning) or the classic “downward escalator” (which sees a repeat pattern of simplifying complex concepts). Effective engineering education entails moving both up and down the *semantic range* in such a way as to enable students to build on concepts as well as apply these to strongly-bound contextual practices. For the most part, however, students on Bachelor’s programmes seldom engage at the strongest level of SG by actually visiting real world sites where engineering knowledge and practices are actualised.

This article employs Semantics to analyse the impact of real world site visits on students’ engagement with and understanding of material taught in the field of mineral processing within the broader chemical engineering discipline, which they have previously experienced at the upper levels of the *semantic range* during course work. The simplified *semantic range* shown in Table 2 has been created through which to analyse the relationship between students’ perception of coursework and the process engineering site visits. Expansion of the *semantic range* can also be visualised using the *semantic wave,* as shown for a generic case in Figure 1; this figure captures the primary intention of the research project, namely to expand the *semantic range* so as to enable students’ to meaningfully apply their coursework and site visit experiences to their final year design and research projects.

Table 2: *Semantic range* to analyse the relationship between coursework experiences and site visits

Semantic range	**Levels of meaning**	**Course Experience (Pre-Tour)**	**Post-Tour Experience**
Wear *semantic gravity* (Context-independent)	Theory	Lectures	Theory across modules
↕	Application	Tutorials	Research project
		Practicals	Design project
Strong *semantic gravity* (Context bound)	Practice	Problem-based research projects / Decontextualised design projects	Context-embedded real world processes

In the project context section of this article, possible reasons for why students find capstone modules (Design and Final-year project) challenging were presented. In terms of the theoretical framework discussed above, these perceived limitations of the current programme are that the capstone modules are at similar or stronger *semantic gravity* levels than those which students have been exposed to in other undergraduate modules, and secondly, that the movement between different levels of *semantic gravity* is typically limited to individual subjects, with limited stretching of the *semantic range* to illustrate knowledge integration across subject areas.

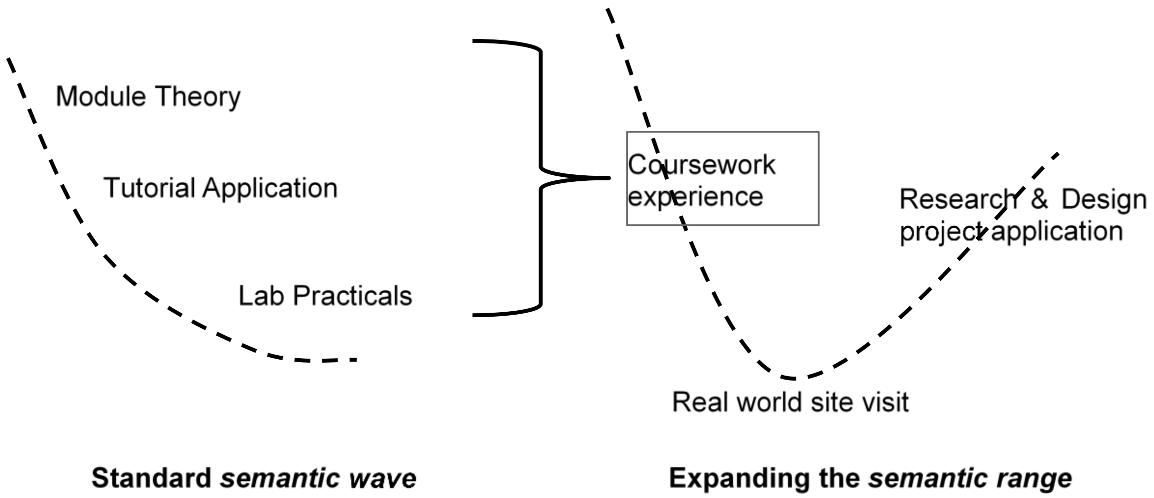

Figure 1: Using the *semantic wave* to illustrate the expansion of the standard *semantic range* typically encountered in final year modules of the chemical engineering programme

METHODOLOGY

The cohort participating in the site visits consisted of 17 final year chemical engineering students with a research project in the field of mineral processing, as all sites visited operate in the mining and metallurgy industry. Participation was voluntary, and there was no assessment or assignment set on the site visits; the intention was simply for students to observe the operations and interact with plant personnel. Six site visits were conducted over a period of 5 days during the mid-semester recess. Two academic staff members accompanied the students. The people leading the site visits were all in senior positions at the respective companies, and had good knowledge about the technical aspects of the plant and processes as well as broader considerations such as business development and the social and environmental impacts of operation.

Data were gathered by means of written surveys which contained open-ended questions as well as questions requiring responses on a five-level Likert-type scale. Two surveys were completed: one before the site visits and one directly after the site visits. Although it was not compulsory for participants to complete the surveys, all participants did complete both surveys. The surveys were not conducted anonymously, but only the authors had access to individual linked data and the appropriate institutional ethical clearance and participant consent were obtained prior to conducting the surveys.

The survey questions focussed on obtaining information about students' undergraduate learning experience. Open ended questions were aimed at obtaining information about which modules students found the most challenging and the most rewarding, about the factors influencing their undergraduate learning experience, and about what they have gained from the site visits. The questions requiring responses on a Likert-type scale were common to both surveys in order to quantitatively evaluate students' learning experience and the change/impact that the site visits had on students' understanding of engineering principles, their engagement with undergraduate modules, and their confidence in their own problem solving and design skills. These questions included the following (where a response of 5 indicated total agreement with the statement and a rating of 1 indicated total disagreement with the statement):

- Q1: "The knowledge and insight that I will gain from the site visits will allow me to better understand and appreciate the material that has been taught in undergraduate mineral processing modules."
- Q2: "The content taught in undergraduate mineral processing modules is appropriate to address the needs of the industry."
- Q3: "I found the content taught in undergraduate mineral processing modules interesting."
- Q4: "The relevance and importance of knowledge gained in the undergraduate mineral processing modules are clear to me."
- Q5: "I understand the relationship between different undergraduate modules and how to integrate knowledge when solving complex problems / performing design tasks."
- Q6: "I have sufficient knowledge and skills to complete my final year project successfully with limited input by my supervisor."

In addition to data obtained from written surveys, students' performance in the final year mineral processing module was also assessed to obtain an indication of whether the site visits affected students' academic performance. The marks of the participants obtained in a major summative assessment prior to the site visits were compared to marks obtained in a second major summative assessment completed at the end of the semester. The participants' results were also compared to the corresponding results of a control group of students who did not volunteer to participate in the site visits.

ANALYSIS AND DISCUSSION

Expanding the semantic range

Table 3**Error! Reference source not found.** shows how Semantics was used to interpret the different levels of conceptual to contextual meaning as currently offered in two undergraduate mineral processing modules in order to illustrate possible theory-practice links bridged by the site visits. Typically, the weakest form of SG in these modules would involve lecturing of theoretical concepts such as mineralogy or principles of comminution, flotation and leaching. At stronger levels of SG, students are expected to complete assignments or tutorials on, for example, modelling of physical separation processes or selection and specification of unit operations; laboratory practicals are also performed on selected topics such as batch solvent extraction and spiral concentration. These practicals, which are usually performed in a simulated or decontextualized environment, are typical of the strongest level of SG at which learning takes place in the existing undergraduate curriculum.

Table 3: Expanding the s*emantic range* of current undergraduate mineral processing modules through site visits

Semantic range	**Levels of meaning**	**Activity**	**3rd Year Mineral Processing**	**4th Year Mineral Processing**
Weak *semantic gravity*	Theory	Taught theory	Mineralogy and principles of liberation; Principles of comminution, flotation, and leaching;	High-temperature metallurgical thermodynamics; material science
↕		Applied theory	Selection of analytical techniques; Population balances and liberation distributions; Particle classification; Mass balance reconciliation; Selection of processing equipment	Analyse processes in terms of phase and reaction equilibria; material selection
	Application	Tutorials	Sizing of flotation cells, estimation of separation efficiencies, identification of suitable operating conditions based on thermodynamic / reaction kinetics data	Selection, specification and characterisation of higher temperature reactors
		Assignments / practicals	Modelling of milling / flotation processes; batch solvent extraction experiments	Design and specify a high temperature reactor
	Simulated / decontextualized practice	Practicals	Mineral identification; solid state analyses; spiral concentrator operation; milling and size classification	
Strong *semantic gravity*	Real practice	Site visits	Appreciate mining and mineralogy and its impact on processing; observe operation of milling, flotation and leaching circuits as well as other physical separation unit operations; appreciate importance of mass balance reconciliation (metal accounting)	Observe operation of industrial scale smelters, furnaces and kilns

The processes observed and learned about during the site visits included physical treatment and separation processes (e.g. milling, crushing, screening, flotation, spiral concentration, thickening, crystallisation, pelletisation), hydrometallurgical treatment processes (leaching, adsorption, precipitation, electrowinning) and pyrometallurgical operations (furnaces, kilns, smelters and converters). The plants are responsible for various aspects of the metal production value chain for several different metals or mining derived products. These are unit operations and processes that students would have been taught explicitly in undergraduate mineral processing modules, as listed in Table 3**Error! Reference source not found.**. In addition, links could be made between the aspects related to, for example, plant design, process profitability, and socio-economic impact of activities and the material taught in several other undergraduate modules.

The extension of the *semantic range* by inclusion of site visits in the curriculum was aimed at achieving two objectives: (1) contextualisation of theory to reduce the level of abstractness so that students can develop a better understanding of the material taught in undergraduate mineral processing modules and (2) bridge the theory-practice gap by exposing students to real industrial applications in order for students to appreciate the relevance of taught material.

Impact on understanding of material

The impact of site visits on students' learning experience and understanding of taught material was assessed as discussed in the Methodology section. The first indicator of student learning was the average marks achieved in two assessments written under examination conditions in a final-year mineral processing module, as shown in Figure 2. In assessment 1, which was written prior to the site visits, the average mark obtained by the cohort of students who participated in the visits was 5.2 and 6.4 percentage points lower than the overall class average and the average mark obtained by the cohort of students who did not participate in the visits, respectively. For the assessment completed after the site visits, the participants on average clearly outperformed the cohort of students who did not participate in the visits. This might suggest that extension of the *semantic range* to better contextualise theory effectively improved students' understanding of taught material. This was confirmed by students' written responses to open-ended surveys questions:

- "I have better understanding about the concepts behind different unit operations and will make it easier when studying for the mineral processing module ..." (Student A)
- "Theoretical ideas become solidified when experiencing first-hand the different units etc. you have learned about ..." (Student B)
- "Actually seeing the equipment allowed me to get a better understanding of processes taught in class ...". (Student C)

Another indicator of student learning was responses to questions on a Likert-type 1–5 scale, with results as shown in Figure 3 (the question numbers correspond to the question numbers listed in the methodology section). After the site visits, all the participants agreed that the knowledge and insight gained from the site visits leads to a better understanding of material taught in undergraduate modules (Q1). This again confirms that that site visits were an effective way of extending the *semantic range*, and that exposure to activities at stronger levels of SG contribute to developing better understanding of taught material.

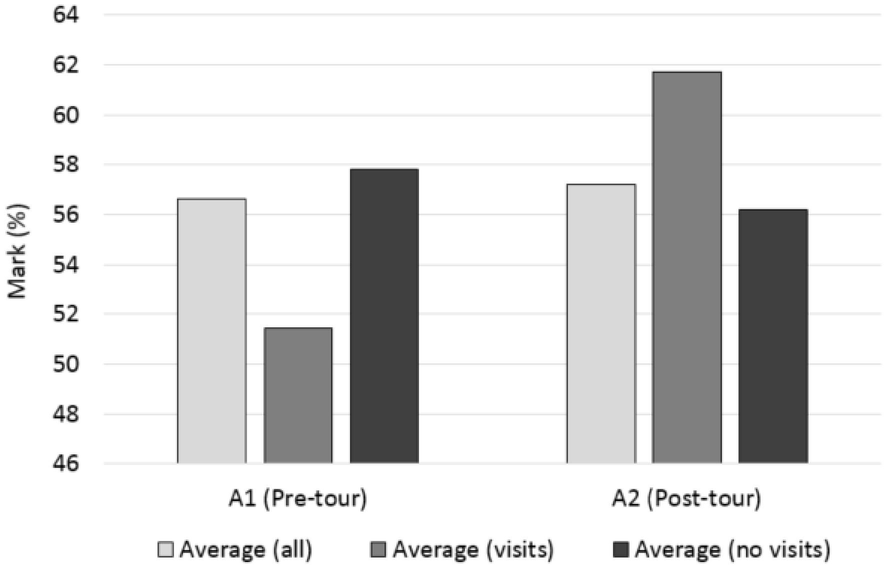

Figure 2: Average marks achieved by tour participants and non-participants in assessment 1 (A1, written before the visits) and assessment 2 (A2, written after the visits) in a final-year mineral processing module

A further significant finding is the fact that students felt that the site visits allowed them to develop a more holistic view of the undergraduate programme with an improved ability to integrate knowledge and skills obtained in different modules (Q5). Apart from learning about process unit operations in the mineral processing industry, even more students felt that they learned about the health and safety of chemical engineering operations (data shown in Figure 4). Process design and process economics were other aspects where students indicated that learning took place during the site visits. By developing an improved understanding of knowledge integration and the broader context within which engineering decisions are made, some of the main deficiencies of engineering graduates as reported by Male, Bush and Chapman (2010) are addressed.

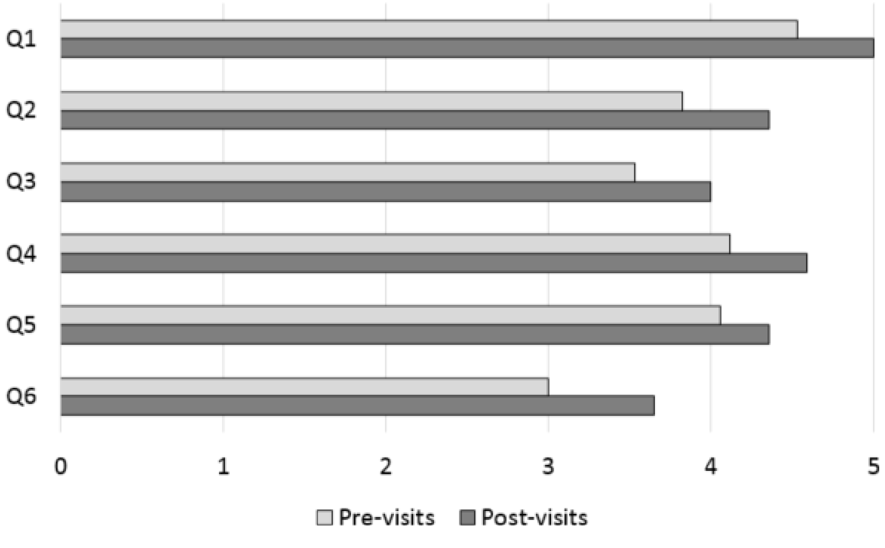

Figure 3: Responses to questions related to undergraduate learning experiences

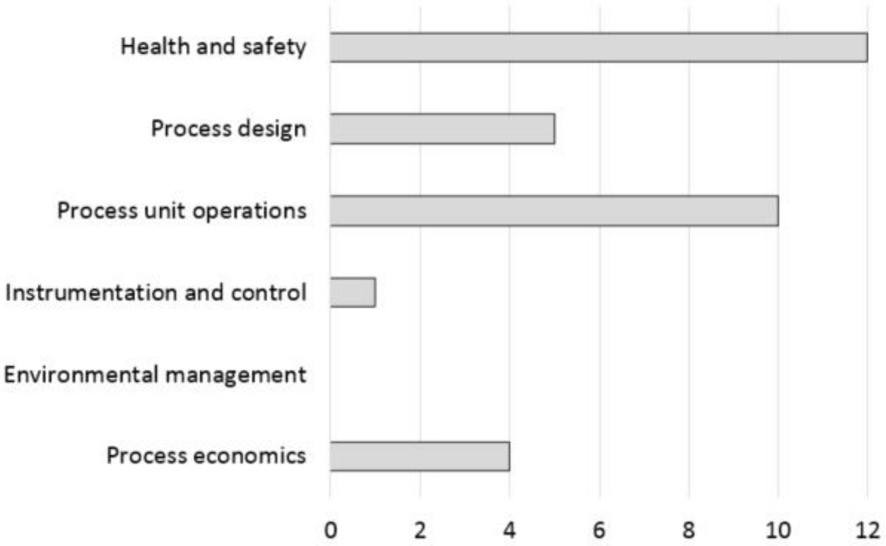

Figure 4: Responses to questions on which aspects of chemical engineering students had learned the most during the visits

Impact on theory-practice links

After the site visits, students agreed more strongly that module content is aligned with industry needs (Figure 3, Q2) and that they have a better appreciation for the relevance of material taught in undergraduate modules (Q4); they also showed a greater interest in module content (Q3). Responses to open-ended questions included statements like “It showed relevance of the course to the industry” (Student D), “... the theory was put into perspective and made the subject relatable and relevant” (Student E), and “Processes such as flotation were taught ... it was really interesting to see the process operating on industrial scale” (Student F). These results support the notion that exposure of students to real industrial applications was effective in bridging the theory-practice gap and developing a better appreciation of the relevance of taught material amongst students.

The site visits generally also increased students’ confidence in their abilities, as evidenced by the response to the statement about completing the final year project with limited input by the supervisor (Q6). It can be argued that exposure to activities at a SG level stronger than encountered before and stronger than that at which students are expected to complete tasks / assignments increases their confidence; this is possibly due to a better understanding of the context in which knowledge should be applied and a more holistic approach to knowledge integration and problem solving, as typically expected in final year research projects. Apart from these benefits, learning about the realities of engineering practice in an industrial environment is not only valuable, but a core focus of the graduate profile as determined by IEA standards. Understanding the importance of adhering to health and safety protocols, for example, sensitises students to the importance of following safe work procedures when performing their final year project and also when starting their careers. This is captured as one of the key exit level outcomes of the bachelor's qualification, which require students to "demonstrate critical awareness of the impact of engineering activity on the social, industrial and physical environment" (SAQA 2014).

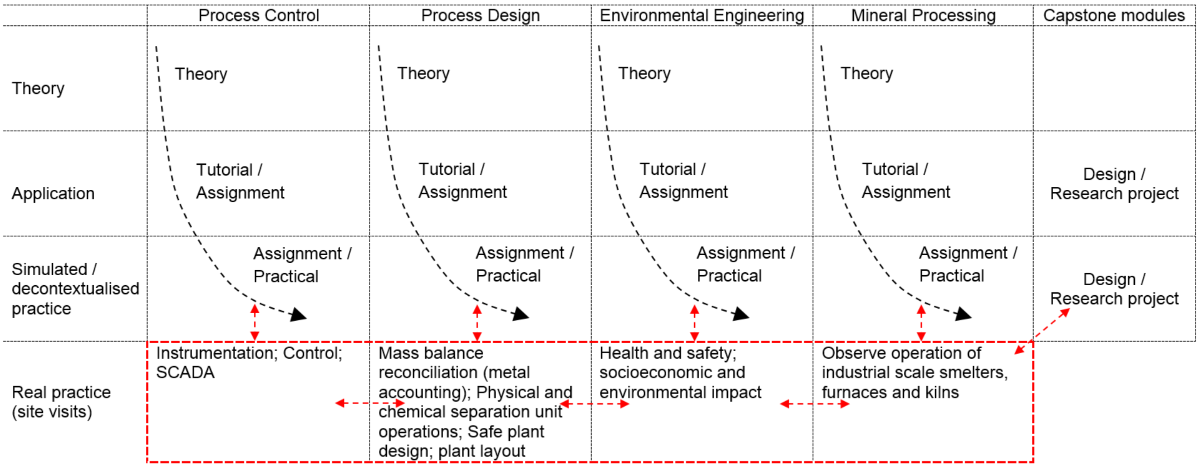

Figure 5: Contribution of site visits to extending the *semantic range* in different final-year modules and the linkage to capstone modules

Considering these results and revisiting the *semantic range* of the typical final year modules in the chemical engineering programme, the impact of site visits on the undergraduate learning experience can be illustrated as shown in Figure 5. There is a clear expansion of the *semantic range* from moderately strong SG levels ("Simulated / decontextualized practice") to strong SG levels ("Real practice") for different modules. From the results presented in this study, it can be argued that this expansion of the *semantic range* through site visits has equipped students to make connections between theory and practice more effectively; this, in turn, would be of benefit when performing their final year design and final year research projects. It can thus be concluded that the site visits did contribute to addressing perceived limitations of the program: the site visits were a learning activity with stronger SG than encountered previously, and allowed effective extension of the *semantic range* in a manner that encouraged knowledge integration and bridging of the theory-practice divide across module boundaries.

CONCLUDING REMARKS

This article has sought to theorise the relationship between the conceptual content of a chemical engineering curriculum and the contextual experience of a volunteering cohort of final year students. Using a theoretical tool from Legitimation Code Theory (Semantics), the impact of a series of site visits to mineral processing plants on student performance and perception of theory-practice links was investigated. The results support anecdotal and descriptive literature evidence of the positive impact on extending students' learning experience to the actual field of practice. This article, however, also contributes to a growing body of literature in presenting a theoretically-informed framework to interrogate and make explicit different levels of conceptual and contextual learning.

Semantic waves were used in this study to assess the movement across the *semantic range* in specific modules. Expanding the use of Semantics to map movement between conceptual and context-bound levels of understanding across the programme as a whole might be a useful tool to aid curriculum development. One of the key questions directly related to this study is at which point during the undergraduate degree programme emphasis should be placed on industrial exposure. By moving the site visits to the second semester of the third year, for example, students would already have sufficient theoretical knowledge to appreciate the technical aspects of site visits, but would also be better prepared for modules such as Process Design offered in the first semester of their final year. Similar questions about the optimal *semantic wave* in individual modules and across the programme still need to be answered, as well as the question of how best to enable academic staff to expand the *semantic range* in the typically theoretical lectures, by way of drawing effectively on contextualised examples.

Despite the potential of site visits to improve the undergraduate learning experience of students, it comes with its own challenges and considerations. The first challenge relates to the feasibility of conducting site visits for large class groups. Conducting site visits is a time consuming and resource intensive process, which require significant logistical coordination. On the one hand, practical as well as health and safety considerations often limit the number of visitors allowed on processing plants while, on the other hand, the undergraduate curriculum is already full with limited scope for scheduling of field trips or site visits. In this particular study, 17 students participated in the site visits. 7 students with a final year research project in mineral processing decided not to participate in the site visits, while a further 60 students performed their final year research project in other research fields and were not offered the opportunity to participate in the site visits. One of the main questions that remains is therefore around the sustainability of the initiative and how the initiative can be expanded to provide equal access for all students in the most practical and resource efficient manner. Other methods of expanding the *semantic range* to strong levels of SG for large classes should therefore be investigated.

A second challenge relates to the role intended by the effective use of technology in engineering education. Although there are several innovative initiatives such as a wealth of video or online material capturing processes in real world sites, much of these do not capture the realities of engineering practice in a developing economy. Utilizing online material is also not the same as meeting plant personnel and seeing real contexts; anecdotal evidence suggests that participants found this interaction with plant personnel to be a very rewarding aspect of the site visits conducted as part of this study. Furthermore, participation in field trips can be a positive experience outside the normal learning environment during which students form bonds with fellow students and develop a feeling of belonging to a caring group. The impact that this could have on students' attitude to and motivation for learning should not be underestimated; this might be one of the factors contributing to the improved performance in an undergraduate module, as was observed in this study.

The third matter arises from the idea that the traditional Bachelor's degree is intended to have a very strong theoretical basis. Codling and Meek (2006) introduced the concept of "vocational drift" to describe the movement of traditional universities to place increasingly more emphasis on applied knowledge and research. If, at the same time, significant "academic drift" occurs at traditional universities of technology, it becomes difficult to differentiate between the mandates of different types of higher education institutions. This would require revisiting and clarifying our mandate as a traditional university within the context of the South African higher education system and the associated policies and socio-economic environment. The reality is that industry expectations globally and the higher education system in South Africa have changed, and we need to adapt in the way we train engineers to better link theory to practice in order to meet industry demands for a broader range of engineering practitioners. The main questions that remain in this regard are (1) to what extent should practical experiences and industry exposure be incorporated in a traditional university's offering (i.e. what extent of "vocational drift" is acceptable and/or desirable), and (2) what are the roles of government and industry in terms of supporting vocational training initiatives by providing funding and opportunities, training graduate engineers, and aligning expectations.

NOTES

All theoretical descriptors are italicised to avoid conflation with everyday use of the terms.

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