Quantitative literacy practices in civil engineering study: designs for teaching and learning

By ROBERT PRINCE[1] and ZACH SIMPSON[2]

[1] University of Cape Town, South Africa

[2] University of Johannesburg, South Africa

Higher education needs to produce increasing numbers of good quality graduates. Included herein is the need for graduates that can engage in high level quantitative literacy practices, which requires designs for learning that understand how texts are constructed through language, images and mathematical notation, which together form the meaning-making repertoire of quantitative literacy. This paper applies a framework for quantitative literacy events in the analysis of a particular graphical procedure used during undergraduate civil engineering courses throughout South Africa. The framework draws on the New Literacies Studies' view of literacy as social practice and examines the specific practices that students need to engage with during individual quantitative literacy events. Application of the framework demonstrates that such graphical procedures constitute quantitative literacy events in which students engage in various quantitative practices, the implications of which inform designs for learning in civil engineering in several key respects.

Keywords: quantitative literacy; higher education studies; multimodal social semiotics; new literacy studies; engineering education;

INTRODUCTION: QUANTITATIVE LITERACY AND HIGHER EDUCATION IN SOUTH AFRICA

Higher education needs to produce increasing numbers of good quality graduates, but South African higher education's graduate output rate is low and the drop-out rate is high (Council on Higher Education 2013: 15). The South African school system is characterized by significant inequalities and does not adequately prepare many students for higher education. It has been pointed out that "the educational factor to which poor performance is perhaps most commonly ascribed across the higher education sector is student underpreparedness for standard undergraduate programmes" (Scott, Yeld & Hendry, 2007: 42). This underpreparedness arises not only from content knowledge in the various school subjects that may not have been adequately taught and learned, but even more crucially from difficulties in the area of academic literacies. McKenna (2009: 8) argues that the real key to whether students will succeed is related to the literacy practices they bring with them to the University from the school and home environments, and the extent to which these are related to the literacy practices of the chosen discipline.

Quantitative literacy is an aspect of academic literacies in which students experience particular difficulties. This can be seen in results from the South African National Benchmark Tests (NBTs) Project. For example, in 2014, 76 693 candidates wrote the NBT quantitative literacy test as prospective applicants to higher education in 2015. In this case only 11% of the candidates were classified as 'Proficient' in quantitative literacy and the remaining 89% of candidates were expected to experience academic challenges due to their low levels of proficiency (Centre for Educational Testing for Access and Placement, 2015: 26). The notion of 'underpreparedness' often implies deficiency in the students only and does not recognise that higher education institutions themselves are underprepared to meet the needs of the students that they admit (Boughey, 2009: 4). However, university teaching and learning needs to take into account the strengths and weaknesses of the students and make changes to the curriculum to address the "articulation gap" (Scott, Yeld & Hendry, 2007: 42) between the demands of curricula and the level of many students' quantitative (and other) literacies. Furthermore, Selander (2008) argues that formal learning sites have generally struggled to get to grips with the possibilities and challenges of the new information structure that has resulted from the rise of digital communication and information technologies. In order to design a more responsive curriculum, lecturers and curriculum developers in higher education need information about the capabilities of students.

In this paper, we apply a quantitative literacy framework initially developed as part of the NBT project (Frith & Prince, 2006: 28), but later adapted for more general application (Frith & Prince, 2009: 89). The framework is used to explicate the quantitative literacy practices associated with a quantitative literacy event in civil engineering. The importance of quantitative literacy for higher education in general and engineering in particular is widely recognised (see, for example, Steen, 2004), and there is also an increasing awareness that many academic disciplines make complex quantitative demands that are often very different from those that are the focus of traditional mathematics courses.

THEORY: A FRAMEWORK FOR UNDERSTANDING QUANTITATIVE LITERACY

The nature and definition of quantitative literacy are actively debated, particularly in Australia and England (where it is often called 'numeracy') and in the United States (where it is most often called 'quantitative literacy'). This debate concerns itself not only with the definition of the concept, but also with its relationship to mathematics itself. Hughes-Hallet (2001: 94) expresses the distinction between quantitative literacy and mathematics as follows: "Mathematics focuses on climbing the ladder of abstraction while quantitative literacy clings to context... Mathematics is about general principles that can be applied in a range of contexts; quantitative literacy is about seeing every context through a quantitative lens".

In this paper, we adopt a *designs for learning* approach that ties the social semiotic concern with sign-making practice to the institutional framing for learning activities (Selander, 2008). We identify quantitative literacy as a social practice in which people engage in formal and informal learning activities so as to identify some kind of problem and arrive at some kind of solution by using and transforming, in this case, quantitative information (Selander, 2008). Street and Baker have written a number of articles (Street, 2005; Street & Baker, 2006) in which they develop the idea of quantitative literacy as social practice. Johnston (2007) and Yasukawa (2007) also conceptualise quantitative literacy as social practice, and focus on an individual's critical awareness. Within such a view, quantitative literacy is 'a critical awareness that builds bridges between mathematics and the real world' (Johnston, 2007: 54). This definition arises from work in basic adult education as well as with students in higher education. It is desirable for students to develop the ability to ask critical questions about the use of data and mathematics, questions pertaining to the appropriateness and limits of the mathematical models applied to real situations and questions that ask in whose interest these mathematical models work (Johnston, 2007: 53).

The definition of quantitative literacy that underpins the framework below is as follows:

> Quantitative literacy is the ability to manage situations or solve problems in practice, and involves responding to quantitative (mathematical and statistical) information that may be presented verbally, graphically, in tabular or symbolic form; it requires the activation of a range of enabling knowledge, behaviours and processes and it can be observed when it is expressed in the form of a communication, in written, oral or visual mode
>
> (Frith & Prince, 2006: 30).

In higher education, there are different quantitative literacy practices associated with different academic disciplines. These practices are often tacit (Collins, 2001) and are embedded within curricula that often remain implicit, regardless of which students in those disciplines need to become competent practitioners. Yet, these practices involve the transformation of signs and the formation of new signs and, in so doing, act as traces of learning and support the development of new capabilities (Selander, 2008). In Prince and Archer (2014) the notion of academic voice is used to facilitate the awareness and analysis of multimodal texts in order to "enable student access to the invisible norms and conventions of quantitative disciplines."

The quantitative literacy framework is designed to work across all higher education disciplines and contexts. This framework is presented in Table 1. As can be seen, it divides quantitative literacy into six broad competences.

Table 1: Framework for analyzing the quantitative literacy demands of higher education (Frith & Prince, 2009: 89)

Competence	
1 Knowing the conventions	1.1 Understanding verbal representations of quantitative concepts
	1.2 Understanding symbolic representations of quantitative concepts
	1.3 Understanding visual representations of quantitative concepts
2 Identifying and distinguishing	2.1 Identifying connections and distinctions between different representations of quantitative concepts
	2.2 Identifying the mathematics to be done and strategies to do it
	2.3 Identifying relevant and irrelevant information in representations
3 Deriving meaning	3.1 Making meaning from representations
4 Doing mathematics	4.1 Using mathematical methods.
5 Higher order thinking	5.1 Synthesising
	5.2 Logical Reasoning
	5.3 Conjecturing
	5.4 Interpreting and reflecting or evaluating
6 Expressing quantitative concepts	6.1 Representing quantitative information using appropriate representational conventions
	6.2 Describing quantitative ideas and relationships using appropriate language

QUANTITATIVE LITERACY EVENTS IN UNDERGRADUATE CIVIL ENGINEERING STUDY

The work of the civil engineer can be conceived of as a series of meaningful re-presentations. This series begins with a systematized representation of a real world phenomenon, object or process, which usually entails a process of data gathering. Thereafter, the gathered data is manipulated often through further representations or through manipulation of the initial representation, which culminates in a plan for a re-designed phenomenon, object or process. The manipulation of the gathered data and its attendant representations occurs through any number, possibly hundreds, of interim representations and draws on multiple sets of data. In combination, these interim representations constitute what can be termed engineering design work. The final step is construction, where the designed plan is put into effect back in the real world context. Learning to become a civil engineer is thus a process "of interpretation and identity construction [in which learning is] an activity where signs in different media (information) are elaborated, and where the forming of new signs in new media (re-configuration and re-contextualisation) takes place" (Selander, 2008: 12). This re-configuration and re-contextualisation of meaning occurs in numerous forms which have in common two important aspects. First, each re-presentation takes place through the deployment of meaning-making practices. Because of the nature of engineering, these practices often involve quantitative literacy. Second, the deployment of these meaning-making practices is interest-laden. That is to say, each re-presentation is partial in the sense that it foregrounds aspects of the real world that are of particular interest to the civil engineering practitioner, and backgrounds aspects of secondary or limited significance.

In this paper, we examine one such civil engineering practice, and locate it within the transformation of meanings described above. The aim of this analysis is to apply the quantitative literacy framework described to these engineering practices so as to explicate the quantitative literacy demands involved in the teaching and learning thereof. In this particular practice, civil engineering students use a graphical procedure to depict information and then transform this information so as to construct new knowledge about the physical environment. The graphical depiction is underpinned by a calculation mechanism, that is, it deploys the spatial resources of graphics in service of undertaking and completing calculation tasks.

In this civil engineering practice, the strength parameters of a soil are determined by applying Mohr's circle to the results of a triaxial test undertaken on a sample of that soil. The triaxial test is used to determine the mechanical properties of a soil. The results of the test can be interpreted through the graphical procedure developed by Christian Mohr in the late 19th century, Mohr's circle, which relates the geometric properties of a circle to the shear strength of soils. The procedure and calculations involved in conducting a triaxial test are beyond the scope of this paper, but it suffices to say that the outcome of these procedures and calculations is the major and minor principal stresses at which each of three samples of a soil fail (dependent on different loading conditions). The test is thus an exercise in data gathering, the results of which are represented by being plotted to scale on an axis. The difference between the two stresses are taken to represent the diameter of a circle. Once the three circles are drawn, a tangent to all three circles is found, and the geometric properties of this line (its intercept with the y-axis and its gradient) are determined. These properties are, respectively, the cohesion and angle of resistance of the soil which, in turn, are the two parameters required to calculate a soil's shear strength. An instance of this practice, as produced by a civil engineering diploma student, can be found as Figure 1.

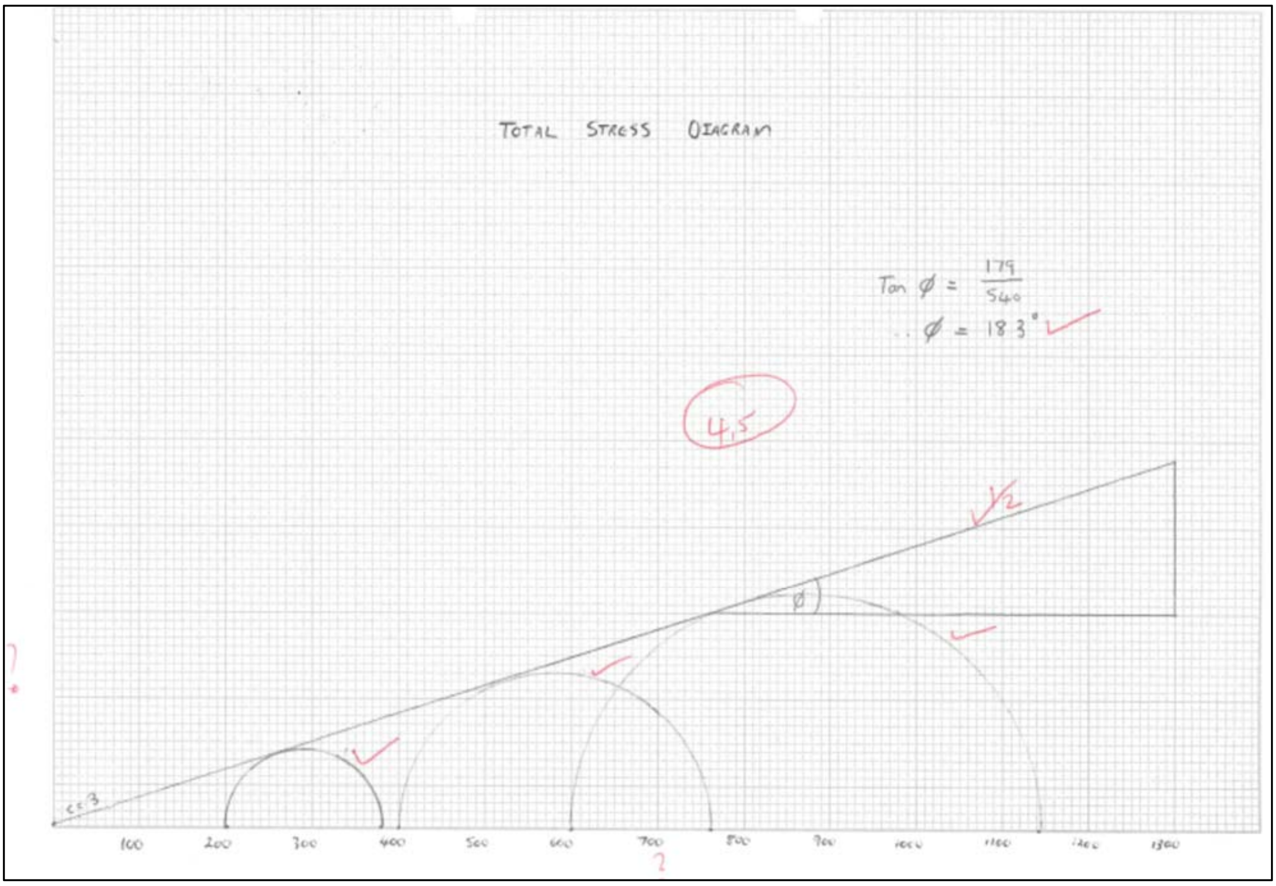

Figure 1: Student's determination of stress parameters of a soil based on triaxial test results

QUANTITATIVE LITERACY DEMAND IN CIVIL ENGINEERING PRACTICES

The first competence included in the quantitative literacy framework involves knowing the conventions for the visual and verbal representation of quantitative concepts. Successful undertaking of the Mohr circle analysis is heavily reliant on such competence. It requires, for example, that students understand the conventions for symbolizing unknown angles (the Greek letter, ϕ). It also depends on knowledge of the conventions of the Cartesian plane, where two axes are used to represent the relations between two variables: in the case of Mohr's circle, the x-axis represents the principal stresses and the y-axis the cohesion of the soil, both of which are stresses and both are measured in kPa (kiloPascals), though the student does not indicate this in the Figure.

The competence of identifying and distinguishing is also evident in this civil engineering practice. In particular, included in this quantitative competence is the need to be able to identify the mathematics to be done and strategies for doing it. In this regard, the practice represented in Figure 1 requires students to calculate a scale that is appropriate to the dimensions of that which is being represented, taking into account the need for accuracy and the limitation of the size of the paper available. The mathematical problem at stake is, put simply, akin to: given I have a paper sized at X centimetres and given I need to represent an object which has a largest dimension of Y kiloPascals, what scale should I use to represent this object? In the example of Mohr's circle, it is the results of the triaxial test that need to be represented to scale. Here, students' knowledge of ratio and proportion is indirectly tested. Students are also expected to identify that the use of the trigonometric function TAN can be used to calculate the unknown angle, ϕ. The student must identify that an equation involving TAN ϕ must be formulated, using the dimensions of any right-angled triangle including angle ϕ. Of course, the unknown angle can be measured using a protractor, but the decision to use the trigonometric function is informed by the need for a greater degree of specificity and exactness that is not afforded by the use of a protractor.

A third quantitative competence comprises deriving meaning from representations. Figure 1 illustrates this competence well in that it requires the students to use their own visual judgment to construct a line that is tangential to the three Mohr's circles, to use the axes to determine the lengths of the lines of the right-angled triangle that are adjacent and opposite to the unknown angle ϕ so that these values can be placed into the TAN ϕ equation, and to determine the value of C, using the y-axis. Indeed, this competence is of utmost importance, given that the goal of this representation is not to simply represent pre-existent data, but to use graphical procedures to derive new knowledge about the physical world, that is, to determine the strength of a particular soil so as to ascertain its suitability for a particular construction application.

The fourth quantitative competence included in the quantitative literacy framework involves doing mathematics. This has already largely been addressed. In the example, students must use trigonometric relations to model the situation algebraically in the form of the TAN ϕ equation so as to solve for ϕ. There are also instances where students must undertake basic operations such as subtraction. It is thus evident that this practice involves using the required mathematical methods to undertake meaning-making work.

The penultimate quantitative competence demanded of students in higher education is higher-order thinking, which comprises synthesis, reasoning, conjecture, and interpretation, reflection and evaluation. This is a crucial component of the meaning-making process, but largely takes place outside of the graphical procedure described in this paper. In the case of Mohr's circle, students demonstrate these higher-order thinking skills when they synthesis the results of the procedure with other data and reason out the overall viability of the use of the soil for a particular construction application. This higher order thinking is hinted at in the context of the graphical procedures, but does not take place therein. For example, the fact that the student whose work is given in Figure 1 does not include axis labels indicates that this student may be too focused on determining values for C and ϕ, without due consideration to both the pedagogical context for the event, but also the real-word context, which relates these circles and lines to the kilopascals of stress that soils can bear (which the axis label would indicate). Higher order thinking is the means by which the meaning-making transformations of civil engineering activity, described above, move forward. As students move from one interim representation to another, they exercise reasoning, evaluation and synthesis in determining how to move forward and which representations to deploy so as to ultimately arrive at a workable design for a civil engineering service or structure.

A final quantitative literacy demand is expressing quantitative concepts. This has largely been addressed already. It requires that students use the verbal, symbolic, graphic and diagrammatic meaning-making repertoire so as to make meaning for others. This ranges from tasks as simple as using a curved line and greek symbol to indicate an unknown angle (see Figure 1), to providing axis labels that assist viewers in understanding the context for a graphical representation (not done in Figure 1), to having the mathematical, statistical and quantitative vocabulary with which to discuss diameters, line segments, samples and so on, and to being able to use representations in subsequent texts (spoken, written or visual) to explain the reasoning that has informed one's own design and analysis work.

DISCUSSION AND CONCLUSIONS: QUANTITATIVE LITERACY AND DESIGN FOR LEARNING

Analysis of the quantitative literacy demands of, in this case, civil engineering practices allows for an understanding of points of disconnection or confusion in the texts that students produce which, in turn, can inform the design of pedagogy that seeks to minimize these points of disconnection. This is evident in the data reported upon here in four key respects, each of which is discussed below.

First, quantitative literacy events such as that described here often serve to mathematize space, that is, they use the spatial resources of graphics to undertake calculative tasks. This is particularly common within civil engineering practices. The mathematization of spatial resources introduces a level of semiotic complexity that has not yet been well understood in the literature, or in pedagogical practice. The potential confusions that it may introduce are evident in Figure 1 where the student fails to label the axes of the graphical construction because of a focus on the QL event as an attempt to calculate the stress parameters of the soil and not as an attempt to produce a Cartesian graphic. In so doing, the student does not recognize the 'semiotic economy' of the graphic, that is, the social norms for organizing information in routine and recognizable ways (Selander, 2008). The fact that the assessor notes the absence of axis labels, through the use of question marks, and awards marks (or not, as is the case here) for these axis labels, indicates that, from the perspective of the assessor, the exercise is as important as a graphical representation as it is as a calculative task. That is to say, the representation of the procedure in accordance with the conventions of such graphical procedures, the form, is as important as the content of the answer. It is evident that further research needs to be undertaken into the mathematization of space in graphical procedures such as these.

Second, the data reported upon here problematizes notions of context and abstraction. Hughes-Hallet (2001: 94) argues that "mathematics focuses on climbing the ladder of abstraction while quantitative literacy clings to context... Mathematics is about general principles that can be applied in a range of contexts; quantitative literacy is about seeing every context through a quantitative lens". The absence of axis labels is relevant again here. Axis labels provide a semiotic bridge between the abstracted nature of the Cartesian plane, and the real world context of the variables it represents. When these are not provided, they remove one of the key contextual indicators within such texts, making it difficult to tie the meanings generated to specific real life contexts. In this context, the axis labels are a generic convention associated with the use of the Cartesian plane. Their non-use violates a social agreement aimed at lessening meaning-making effort for both the reader and author (Selander, 2008).

Third, the example provided here also demonstrates the extent to which it is possible that the use of tools and technologies, however mundane, impacts upon text-making. Whether texts are produced using computer software applications, pens, pencils or, as the case may be in this example, compass, protractor and ruler, their production relies upon knowledge of these tools, and how to use them to achieve the representational requirements of the event. In these events, students do not express their understanding of quantitative concepts using language: they do so using the tools present in their stationery sets. These tools and technologies coordinate the ways in which individuals (can) construct knowledge (O'Halloran, 2007): as Gee (2000: 192) argues, "you can't just do anything you want with a hammer... and the hammer has certain affordances that make it easier to use in some ways than others". In our particular example, it can be seen that the student obtains c = 3 (in small print in the bottom left of the Figure; c represents the cohesion of the soil). However, the correct answer which was supposed to be obtained is c = 0. When one examines the student's answer to the question, it is evident that the participant understands the procedure involved in using the Mohr Circle to interpret triaxial test results and determine the total stress parameters of the soil. However, the student nonetheless obtains an incorrect answer due to the inaccuracies introduced through inexperienced use of the procedure and of the tools involved in its undertaking. The evidence of this is subtle: the line, which is meant to be a tangent to all three circles, does not actually touch the middle circle and acts almost as an arc to the largest circle, for example.

Tool usage, and quantitative literacy demand, are also built into the decision to use graph paper, as opposed to plain paper. Graph paper is a tool that is utilized in order to assist with accurate scaling in the production and/or reading/viewing of scaled diagrams. But, this is not self-evident: in fact, anecdotal evidence suggests that many students have no experience using graph paper and do not understand how it works. The use of graph paper is intricately tied to the QL competence of identifying the mathematics required and identifying strategies for doing it. As discussed above, choosing an appropriate scale for the graphic is one of the tasks facing the student. In this respect, strategic use of the graph paper can assist in the mathematics involved herein, and poor use can complicate the mathematics involved. This is because the nature of graph paper is such that it makes sense to work in a scale that is easily divisible by 2, 5 and 10, as the paper is made up of 2mmx2mm blocks grouped into squares of size 2cmx2cm (or 10 blocks x 10 blocks). In Figure 2, the student has strategically opted to use a scale where 2cm represents 100 KPa (Kilopascals, a unit for pressure). This significantly lessens the mathematical effort required in using trigonometric identities to calculate ϕ, as compared to a scale where 2cm represents 80 or 90 KPa, where each 2mm block would then represent 8 or 9 KPa and each mm represents 4 or 4.5 KPa. Although not evident in this example, such uninformed use of graph paper is common amongst students. It is thus evident that use of tools and technologies is perhaps a competence that is lacking from the QL framework used here and consideration could be given to adding this dimension. The deployment of tools and technologies in service of representing quantitative information is crucial to the meaning-making success of students in civil engineering, specifically, and higher education more generally, and curricula may do well to take greater cognizance of the fact the tools associated with mathematics, science and engineering have allowed their users to understand, control and manipulate the physical landscape (O'Halloran, 2009).

Finally, discussion of how graphical procedures such as this work, not only draws greater attention to the QL demands embedded therein, but also facilitates enhanced critical questioning on the part of students. As Johnston (2007: 54) argues, such critical questioning establishes a bridge between the mathematization undertaken within the event, and the real world context for which it has implications. Students need to not only understand how such graphical procedures work, but also how they arise, and how they serve the particular interests of the civil engineering community. In so doing, their learning becomes "a complex process of transformations of signs, by way of modes and media in different institutional settings"

(Selander, 2008: 10). For example, the use of three samples in the triaxial test serves the interest of the discipline of civil engineering in that it provides for accuracy and reduces the chance of error. This can feed back into a deeper understanding of the procedure itself. A discipline can only progress if its practitioners routinely question the appropriateness and possible improvement of the mathematical models and quantitative techniques it uses to achieve its aims. Indeed, as Selander (2008) argues, the ability to search, select, critically evaluate and present information are crucial incidents in the design of learning.

REFERENCES

Boughey, C. (2009). Understanding Teaching and Learning at Foundation Level: A 'Critical' Imperative?. In: Hutchins, C. & Garraway, J. (eds). *Beyond the University Gates: Provision of Extended Curriculum Programmes in South Africa. Proceedings of the January 2009 Rhodes University Foundation Seminar,* Grahamstown: Rhodes University. [Available online:] http://www.cput.ac.za/storage/services/fundani/beyond_the_university_gates.pdf#page=9. [Date of Access: February 24, 2015], 4 – 7.

Centre for Educational Testing for Access and Placement. (2015). *National Benchmark Tests Project National Report: 2015 Intake Cycle,* Cape Town, Centre for Educational Testing for Access and Placement. [Available online:] http://tinyurl.com/onhjqdk. [Date of Access: February 24, 2015].

Council on Higher Education. (2013). *A Proposal for Undergraduate Curriculum Reform in South Africa: The Case for a Flexible Curriculum Structure*, Pretoria, Council on Higher Education. [Available online:] http://www.che.ac.za/sites/default/files/publications/Full_Report.pdf. [Date of Access: June 2, 2015].

Collins, H. M. (2001). What is Tacit Knowledge?. In: Schatzki, T. R., Knorr Cetina, K. & von Savigny, E. (eds). *The Practice Turn in Contemporary Theory*, Oxon, Routledge, 107 – 119.

Frith, V. & Prince, R. (2006). Quantitative Literacy. In: Griesel, H. (ed). *Access and Entry Level Benchmarks: The National Benchmark Tests Project*, Pretoria, Higher Education South Africa. [Available online:] http://www.hesa.org.za/sites/hesa.org.za/files/2006_HESA_Access and Entry Level Benchmarks.pdf. [Date of Access: February 24, 2015], 28 – 34, 47 – 54.

Frith, V. & Prince, R. (2009). A Framework for Understanding the Quantitative Literacy Demands of Higher Education. *South African Journal of Higher Education,* 23(1), 83 – 97.

Gee, J. P. (2000). The New Literacy Studies: From Socially-Situated to the Work of the Social. In: Barton, D., Hamilton, M. & Ivanic, R. (eds). *Situated Literacies: Reading and Writing in Context*, London, Routledge, 180 - 196.

Hughes-Halett, D. (2001). Achieving Numeracy: The Challenge of Implementation. In: Steen, L. A. (ed). *Mathematics and Democracy: The Case for Quantitative Literacy,* USA, The National Council on Education and the Disciplines, 93 – 98.

Johnston, B. (2007). Critical Numeracy?. In: Kelly, S., Johnston, B, & Yasukawa, K. (eds). *The Adult Numeracy Handbook: Reframing Adult Numeracy in Australia,* Sydney, NSW, Adult Literacy and Numeracy Australian Research Consortium, 50 – 56.

McKenna, S. (2009). Cracking the Code of Academic Literacy: An Ideological Task. In: Hutchins, C. & Garraway, J. (eds). *Beyond the University Gates: Provision of Extended Curriculum Programmes in South Africa. Proceedings of the January 2009 Rhodes University Foundation Seminar,* Grahamstown, Rhodes University. [Available online:] http://www.cput.ac.za/storage/services/fundani/beyond_the_university_gates.pdf#page=9. [Date of Access: February 24, 2015], 4 – 7.

O' Halloran, K. (2007). Mathematics and Scientific Forms of Knowledge: A Systemic Functional Multimodal Grammatical Approach. In: Christie, F. & Martin, J. R. (eds). *Language, Knowledge and Pedagogy: Functional Linguistic and Sociological Perspectives,* London, Continuum, 205 - 237.

O'Halloran, K. (2009). Historical Changes in the Semiotic Landscape. From Calculation to Computation. In: Jewitt, C. (ed). *Routledge Handbook of Multimodal Analysis*, Oxon, Routledge, 98 – 113.

Prince, R. & Archer, A. (2014). Exploring Academic Voice in Multimodal Quantitative Texts. *Literacy and Numeracy Studies*, 22(1), 41 – 78.

Scott, I., Yeld, N. & Hendry, J. (2007). *Higher Education Monitor No. 6: A Case for Improving Teaching and Learning in South African Higher Education*. Pretoria: The Council on Higher Education. [Available online:] http://www.che.ac.za/sites/default/files/publications/HE_Monitor_6_ITLS_Oct2007_0.pdf. [Date of Access: February 24, 2015].

Selander, S. (2008). Designs for Learning: A Theoretical Perspective. *Designs for Learning*, 1(1), 10 – 22.

Steen, L.A. (2004). *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education,* Washington D.C., The Mathematical Association of America.

Street, B. (2005). Applying New Literacy Studies to Numeracy as Social Practice. In: Rogers, A. (ed). *Urban Literacy: Communication, Identity and Learning in Development Contexts,* Hamburg, UNESCO Institute for Education, 87 – 96.

Street, B., & Baker, D. (2006). So, What about Multimodal Numeracies?. In: Pahl, K. & Rowsell, J. (eds). *Travel Notes from the New Literacy Studies,* Clevedon, Multilingual Matters, 219 – 233.

Yasukawa, K. (2007). Teaching Critical Mathematics: Some Reflections from a Teacher. In: Kelly, S., Johnston, B, & Yasukawa, K. (eds). *The Adult Numeracy Handbook: Reframing Adult Numeracy in Australia,* Sydney, NSW, Adult Literacy and Numeracy Australian Research Consortium, 228 – 232.