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A Workplace Contextualisation of Mathematics: Measuring Workplace Context Complexity

Knowing what you know, as distinct from what you do, can facilitate re-contextualisation for change

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Abstract

Recent research undertaken by the authors (Keogh, 2013; Keogh, Maguire, & O'Donoghue, 2010, 2011, 2012), identified the mathematics activity that underpinned what may be regarded as low-skilled, low paid jobs, and aligned it with the National Framework of Qualifications in Ireland. In the course of this research, it emerged that although the mathematics expertise deployed was modest in terms of complicatedness, it was used by workers in circumstances that were both sophisticated and volatile in varying degrees. To this extent, it was discernable that mastery of routine mathematics alone was a poor indicator of a person's ability to 'do the job'. Furthermore, a National Survey of People at Work in Ireland, while confirming the Mathematics use/denial paradox, revealed that work was not perceived to be 'straightforward' despite widespread adherence to processes, procedures and routines. The authors argue that there exists a spectrum of factors that operate to 'complexify' otherwise routine mathematics, with the possible consequence of concealing the role of mathematics and intensifying its invisibility in the workplace and all that that entails. This paper describes these affective factors

as comprising a workplace contextualization of mathematics which elaborates the complexity of the workplace context in which mathematics at varying levels of complicatedness may be expressed. In this way, workers, employers and providers of learning opportunities may be better informed regarding employability and worker mobility in the long term.

Keywords: complicatedness, complexify, invisibility, employability, mobility

Introduction

A National Survey of People at Work in Ireland, augmented by several case studies, produced strong evidence regarding the character and role of workplace mathematics. It seems that although procedures and routines proliferate in the workplace, and workers adhere to their procedures, they soundly reject the suggestion that their work is straightforward (Keogh, 2013; Keogh et al., 2010, 2011, 2012). The survey substantially confirmed the mathematics use/denial paradox, while the case studies identified hundreds of instances of numerate behaviour in encounter with all Mathematics Domains, but at quite a modest level. The implication is that Mathematics Knowledge Skill and Competence (MKSC) in the workplace was not captured by identifying the level of complicatedness alone, which suggest that all jobs with the same levels of MKSC may not be considered equivalent.

Further analysis of the discourse surrounding the case studies, revealed that work is a social activity, having multiple properties and facets, is performed under pressure of time and accuracy, with attendant materiality, depth, scope and peer to peer accountability, not necessarily aligned with the authority conferred by seniority or role status. These dimensions arise across a range of spectra and combinations such as may differentiate the MKSC required in one job when compared to another, the novice from the expert, between what a worker 'knows' and what s/he 'does', and may not feature in the official accounts of a case study's Standard Operating Procedures (SOP). Whether learnt formally, informally, non-formally, tacitly or through analogical rationality (Gustafsson & Mouwitz, 2010), they are highly valued in the workplace. The descriptor 'work experience' is used as a unitary concept, implying a depth of understanding that is commensurate with the quantity of time served. However, the case studies, and the findings of the National Survey of People at Work in Ireland, provided the basis for a workplace characterization that is rather more profound and may be described more completely in terms of its Complexity (Keogh et al., 2011). The authors now elaborate these themes as a contextualization of the workplace, in 5 dimensions namely, Accountability, Clarity, Familiarity, Stressors and Volatility in which mathematics knowledge skills and competence, regardless of level of complicatedness, are deployed. Each of these characteristics in turn comprises constituent strands as described in the following sections.

Accountability

A common dictionary definition of the term 'accountability' is having to do with taking responsibility or being in some way culpable, connoting a degree of power and control as might be associated with a supervisory or management role. The corollary is that the 'ordinary' worker, for whom there are no official levers of power, is unaccountable and completely free of responsibility. The case studies suggest that accountability is a more immediate and tangible concept, comprising a range of components, each defining part of its context namely *Audit Materiality*, *Decision Making*, *Initiative*, *Concreteness*, *Judgment*, *Planning* and *Responsibility* in degrees of intensity that vary from job to job, as elaborated in the following sub-sections.

Audit Materiality

This facet refers to the impact of error, ranging from the negligible to the catastrophic. For example, a worker in a supermarket may use the same MKSC as a person packing parachutes. This contrast highlights that workers can, by making a simple mistake, compromise the service provided by the employer and expose the organization to embarrassment, loss of business, reputation and the risk of complete failure, despite the presence of appropriate procedures and SOPs.

Decision making

Whether the worker is permitted or expected to make decisions, to what extent, and under what conditions, extends the remit of that worker beyond simply executing a sequence of tasks. This may be further nuanced by the influence of other stressors which may produce both formal and informal interpretations of the decision-making rules or guidelines.

Initiative

A worker may have complete latitude to assess a novel situation and respond accordingly, or be required to apply the SOPs to the letter. There may be a 'fuzzy' understanding of when the worker is expected to use his/her initiative and when not. A worker who assumes responsibility for having acted *ultra vires*, adds an extra tier to the dimension of Initiative component of a job, with a possible consequence of placing his/her continued employment at risk.

Concreteness

It is plain that the lowest level of manual work e.g. digging soil, comprises elements that are fully recognisable, physically present and few, whereas, at the opposite end, some or many work components may be abstract, theoretical or imagined. In the central range of concreteness, a tradesperson may handle elements that are concrete and specific, but expected to take into account other factors such as the appearance of the finished product and its aesthetic fit with work accomplished by other people.

Judgment

From time to time, a worker may have resolve conflicting variables. Such an intervention may form part of the job specification, may be conditioned or may require knowledge and expertise from elsewhere. In this way, the exercise of judgement, in what circumstances and to what extent, adds to the fabric of the context in which MKSC are deployed in work.

Planning

Planning, as a component of context at the highest end of the spectrum, is typically associated with optimising the likelihood of a satisfactory outcome. Low-grade jobs may have little or no involvement in planning, although this may not be the case in the strictest sense. The authors argue that every job contains some element of sequencing tasks with the benefit of local knowledge, keeping in mind tasks that follow, for example, loading goods on a truck while being conscious of the delivery sequence and / or load stability. In this way, the planning

dimension of a job may be learned explicitly or tacitly, and may be subject to rules and guidelines that vary in specificity.

Responsibility

Responsibility has become synonymous with guilt and the definition of who pays compensation when something goes wrong. While it is associated with high status and the power to command resources, the authors suggest that it trickles down through the hierarchy, depositing degrees of responsibility at every identifiable level, including those at the lowest level. Each worker has some degree of responsibility to his/her peers, regardless of their principal activities, to produce work on time and in line with specifications.

Each of these sub-dimensions of Accountability interacts in unique combinations and may be influenced by the degree of *clarity* with which the context is perceived by the worker and his/her colleagues.

Clarity

Clarity around the aims and objectives is a desirable feature of the workplace, and one that is obtained in varying degrees. It is a difficult concept to describe succinctly, as its meaning is dependent on the situation it intends to describe, particularly so in a rapidly changing workplace. At every level in an organization, it is critical that everybody has a clear understanding of their purpose, whether in anticipation of an outcome in the near-, mid- or long-term. The authors suggest that the extent of clarity in the workplace is a combination of the interaction of several factors namely, *Distracters, Priorities, Reflectivity, Information Sources, Vision* and *Information Completeness*.

Distracters

This refers to the likely presence of elements that may distract the worker from their purpose, or add the potential for confusion and error. Simple, tightly defined jobs, involving one or few elements would seem to be free of distracters, except perhaps boredom born of narrow, repetitive cycles. Other distracters may be explicit and easily identified and discarded. Towards the upper end, it may become more difficult to discriminate between pertinent factors and distracters that are embedded and plausible.

Priorities

The setting of priorities is a function of the control and command structure in organisations, but not exclusively so. In the more project-mature organizations, such milestones are agreed amongst the individuals with the relevant expertise, each of whom must juggle their local resources. Discretion regarding priorities is not necessarily aligned with job status, especially in global enterprises that commission very specific outcomes from their plants spread across the World. To this extent, the exposure to competing priorities, however set, is another descriptor of workplace context.

Reflectivity

Reflective practice in industry is common, although it may be realised as project review, strategic planning, periodic reports, performance review, and systems and financial audits. It is pervasive and hierarchical insofar as the outcomes tend to flow upstream. It may be initiated in reaction to a costly error, to identify a systemic flaw, in which case the remedies flow downstream. Reflection, in pursuit of continuous improvement may inject a force for change in the metrics and methods employed in, and therefore, constituting, work practice.

Information Sources

The sources of work information may range from single, simple source, expressed in job specific terms at the lower end, to multiple sources in various formats, referencing concrete, abstract and theoretical data on familiar and unfamiliar topics. It may be verbal and non-specific, requiring interpretation and locally-attuned inference. It may be deduced from dialogue and rumour, or adduced from relevant experience and may vary in reliability. Dealing with multiple information sources would seem to describe a crucial element of any job, and could impinge on other context strands such as clarity, and accountability.

Vision

Vision, in this sense, has to do with the meaningfulness of the job to the individual. It alludes to the sense of purpose, beyond the boundaries of the job and how the output of the job integrates with surrounding activity to produce something that is whole in itself. For example, the collection of meter readings for input to a spreadsheet is a limited experience in the absence of further explanation. In contrast, acquiring a broad view of an organisation's aims and position within the market can influence the way in which work is done and the utility of the supporting artefacts, including MKSC.

Information Completeness

Work information is likely to be complete in circumstances that are tightly controlled and closely monitored, although not necessarily so. Incomplete or imprecise information, imports guesswork and uncertainty, however informed, and tends to increase the risk of error. At the leading edge of industrial research and development, complete information is the object being pursued. Creative and innovative activities feature aspects that are known and unknown in extent, and the recognition that there may be other unknown-unknowns, and perhaps even the unknowable. That this is a facet in the workplace that varies in impact on how work is done is another workplace context attribute.

Exposure over time may contribute to the extent to which the characteristics and properties of the workplace become familiar.

Familiarity

Familiarity is a gauge of what has become known as the 'comfort zone'. This is a concept rooted in Adventure Education which indicates an anxiety-neutral, risk-free environment conducive to steady performance (White, 2009). It may be realised in the workplace as a state in which the worker is well practiced in the performance of a sequence of tasks, in unchanging

surroundings, in encounter with stable, recognised components. Beyond the 'comfort zone', lies the 'stretch zone' in which it is thought there exists a fundamental disequilibrium which promotes intellectual development and personal growth (Panicucci, 2007). Such a workplace presents challenges to the worker that are nonetheless within their capacity to achieve.

An overall sense of familiarity, or otherwise, may be the product of *Specificity*, the nature of the *Principal Activity*, the range of job-related *Elements,* their associated *Facets,* the impact of *Groups* in work and *Routine*.

Specificity

This refers to the extent to which components of a job are specific, recognised and unvarying at one extreme, in contrast with the abstract, theoretical, and widely varying at the other, with gradations in between to account for degrees of transformation from one to the other. The implications for the context in which the experience of work occurs are clear, encapsulating a factor which presents more challenges as specificity diminishes in proportion to the advance towards the abstract.

Principal Activity

The worker's principal activity adds a determining context characteristic. A single, closely defined and monitored, solitary activity has a simplifying effect on the worker's job. In contrast, a professional person, at the leading edge of his/her discipline is likely to encounter a wide variety of familiar and unfamiliar situations, diagnose problems, develop creative solutions and implement them, in multiple interacting activities. In the interim, individuals may switch between increasingly varied activities in response to workplace demands.

Elements

A job may comprise a single element at the basic level, or progress through an unvarying sequence of tasks, to one that is moderately, or extensively influenced by internal or external factors, some of which may be unfamiliar. This reflects complexity in the sense of the number of elements and ways in which the elements can be combined. As these quantities increase so too does the degree of complexity.

Facets

Not to be confused with Elements, Facets, in this case, deals with the extent to which elements may be nuanced, and not solely an empirical count. This connotes a capacity to detect and interpret a particular instance of an element and to act accordingly. Facets may become familiar over time, but that may not preclude the emergence of a novel occurrence, all of which conjures up an influential consideration of the workplace context. For example, the job's SOP addresses each *Element* i.e. work order, delivery address, delivery type (document, computer media, property deed etc.), related security and operating principles. However, each individual client may have formal and informal preferences or *Facets*, to which the worker must adhere to retain their custom,

Group

Solitary activity can be challenging to those unsuited to working alone, but may be appropriate to a person unsuited to working in a group. Engaging with a small group, becoming familiar over time, may present less challenges than belonging to a larger group that is mainly co-located. The ability to participate in an unfamiliar group, which may be large and partially or substantially distributed across a number of locations in geography, time and culture, implies a maturing set of knowledge skills and competence, and confidence in one's mathematics and other capabilities at their point of use.

Routine

Following a familiar set of tasks in the same sequence, repeatedly, may be a product of the constraints imposed by procedure or a set of procedures, conditioned by internal or external factors. However, as the survey findings have shown, procedure accounts for just over half of workplace activity, the balance being evoked by unspecified factors such as this present workplace contextualization is seeking to capture. Routine is a ubiquitous dimension in work, and is not completely positive in its implications, but is worth regarding for its descriptive qualities.

However, many workplaces may differ in the range of factors, including routine, that could contribute to stress experienced by workers.

Stressors

The uniqueness of the individual makes it impossible to be definitive about the causes and effects of stress in the workplace. The authors do not presume to comment on the possible effect of 'distress' in the workplace, but rather to introduce a range of factors that either singly or in combination, may change the experience of work, while using the same level of MKSC or other skills. The suggested factors are: *Constraints, Pressure, Problem-potential range, Solutions, Sources of stress*, and *Structure* of the workplace.

Constraints

In the unlikely event of limitless resources, constraints are imposed to optimize output minimize the input, in terms of time, materials and labour. Ranging from the clear and simple at one end of the spectrum, to those which are broad, imprecisely defined and inferred from internal and external conditions at the other, constraints have the potential to simplify or complexify work. The presence of a few clear and fixed constraints is characteristic of a job at the lower end of the scale, whereas, multiple, flexible, interrelated and mutually regulating constraints may add substantially to the performance of work towards a specific outcome.

Pressure

Workplace pressures come in many guises including the cultural, temporal, personal, professional, philosophical and political. Most common of these has to do with priority, urgency, accuracy and expectations. For example, completing a set of calculations under

extreme and continuous time pressure is quite a different proposition to performing the same mathematical activity at leisure. In this way, the experience of work may be described by levels of pressure ranging from none, through loosely defined expectations, to issues of volume throughput targets, compliance, quality, accuracy, culminating in extreme pressure as may feature in cases of emergency.

Problem - potential range

Simple jobs exhibit little or no potential for problems, excepting equipment breakdown. Even then, the worker may be required, or permitted only, to report the situation by triggering a call for attention. Jobs may increase in complexity in line with the number and possible range of familiar problems, through to levels of expertise needed to deal with multiple, mutually dependent, independent and/or novel problems.

Solutions

Similarly, the range of available responses to problem situations escalate from there being one response to all problems, through a continuum of the application of familiar solutions to familiar problems, progressing to mainly unfamiliar problems to that requiring novel responses and creative solutions to unfamiliar problems. Each of these levels of expertise, adds to the palette with which to discriminate between the experience value of different jobs, and the selection of the appropriate mathematics-based response.

Sources of Stress

There may be few or many centres from which workplace stress may arise. They may be internal or external to which the individual is exposed partially, moderately or broadly. They may be avoidable, or an integral part of the work, having a relentless and cumulative effect. A more complete treatment of stress in the workplace is beyond the scope of this document, however, dealing with multiple sources of stress in work, is, potentially, very challenging to the individual, and may affect deeply, the environment in which MKSC finds expression.

Structure

Working in a highly structured, tightly defined organization, lends simplicity to its functions, albeit at the cost of flexibility, which itself might cause stress. Clarity concerning demarcation, rules, accountability and so on, may cause lower levels of stress. Loosely structured, broadly defined, matrix-configured organizations, may give rise to increased levels of stress as a result of their fluid, inherently unstable nature, which could be described in terms of volatility.

Volatility

Volatility is the property of frequent and unanticipated change that may be short-lived. The extent of volatility in the workplace necessitates the capacity to respond to sudden and new developments in the market or the customers' demands. It may be characterized as occurring over 5 transitions namely, completely stable, mainly stable, moderately unstable, mainly unstable, and totally unstable.

Organizations and their embedded jobs are subject to change with varying degrees of need and urgency, as may be profiled by *Conditionality, Demands, Diversity, Predictability, Range and Risk.*

Conditionality

The performance of work may be subject to a variety of conditions, the state of which may be determined by known or unknown, internal or external factors, themselves being influenced by other conditions. The range of affective conditions may differ in quantity and power. Other jobs may be immune to conditions, requiring the same response every time. The recognition of conditionality and the extent to which it pertains to a job, reflects the set of appropriate knowledge and skills and the competence, in the broadest sense, that it develops.

Demands

The demands on a job justify its existence insofar as it has been created to fill a perceived need. Simple jobs have few demands that are clearly defined and relatively easily met. More complex jobs feature multiple demands that may not easily coalesce and may compete for resources. At this extreme, the worker sequences his/her activities, and may deploy innovative methods to cope. The effect of multiple, competing demands, may de-stabilize the job to an extent that is unlikely in a job profiled by one or few demands.

Diversity

Diversity is the property of difference, rather than breadth. In the workplace, it refers to the extent of heterogeneity, and coherence of the tasks. While it makes sense to gather together mutually dependent tasks, requiring elaborations of related sets of knowledge, skills and competence, there are jobs that occupy the boundaries of other specialities enabling cooperation and communication. For example, a change-management specialist may need to communicate with engineers, accountants and computer software developers, in order to ensure cohesion and the desired outcome. In contrast, a completely homogenous workplace implies little scope for diversity that may not be accounted for otherwise.

Predictability

Complete predictability in a job engenders familiarity, stability, clarity, and the establishment of routine. Complete unpredictability adds depth to many of the other factors including stress, accountability, familiarity and the absence of clarity. The majority of jobs probably lie between these two poles, as evidenced by the survey findings and case studies.

Range

The breadth of components associated with a job confers the potential for complexity commensurate with its range. Single-issue jobs are simpler and more straightforward when compared to those encompassing several issues distributed a broad, yet coherent, landscape.

Risk

In this context, risk alludes to certainty of outcome and the extent to which it is confined. Jobs for which the outcome is almost certain e.g. attending a machine that cuts metal forms with a die, have quite a different character from stock-broking. The risk associated with the former has more to do with the wellbeing of the machine operator rather than whether the die will produce the expected form. The activities of the latter risk the organization's resources in the expectation of substantial gain, while at the same time exposing it to potentially catastrophic loss. Risk may be classified as that component of a decision-making process for which there is insufficient information. It may not be permanent and pervasive and may be conditioned and limited. Most jobs are located along a continuum between these extremes, exerting concomitant influence on the context in which Mathematics and other knowledge, skills and competence are used.

Workplace Context-Complexity Protocol

The Workplace Contextualization of Mathematics described in preceding paragraphs, represents an extensive range of parameters with which to differentiate between jobs, regardless of the level of complicatedness of their mathematics knowledge skills and competence. The unique nature of each job may be reflected by the extent to which these parameters are present in the job specification and profile. That these workplace characteristics shaped the context in which MKSC were used, inspired the authors to develop an appropriate framework to capture the essence of the workplace namely a Workplace Context-Complexity Protocol, to enable the context in which MKSC are used in the workplace to be more fully reported.

Protocol Structure

Each of the main context headings, Accountability, Clarity, Familiarity, Stressors and Volatility, is listed with its attendant properties as sub-headings, in the attached Appendix 6.1. Each property of the protocol is scaled and described across 5 transition states, and assigned a two-step scoring range to permit interpretation toward the lower or upper end of the scale. For example, The Volatility property, Predictability, may be scored at 5 or 6 to indicate that a job may feature moderate unpredictability that is more than the lower adjacent category (4) but somewhat less than would justify the next higher category (7), i.e. mainly unpredictable. This scoring system recognizes that there is no empirical scale to measure these things yet, and that the boundaries are not sharp and clear cut. Nevertheless, guided by the evidence available and by working through each heading and sub-heading in turn, it is possible to produce a detailed profile of the workplace context. In this way, the Workplace Contextualisation of Mathematics can be used as a protocol for profiling the Context-Complexity of a workplace. The idea is that it is possible to capture the complex circumstances in which fairly routine mathematics knowledge skills and competence are used in many workplaces. The possibility that an individual may deny their use of mathematics, or dismiss it as common sense, argues in favour of a mechanism that is capable of making the mathematics more visible and more fully accounted for. The structure and application of the National Framework of Qualifications in Ireland (NFQ)(QQI, 2012) and its alignment with formally established complicatedness of mathematics at different levels is reported elsewhere (Keogh et al., 2010).

This present work suggests an augmentation to the NFQ to facilitate the recognition of, and communication about, mathematics activity in work for the benefit of mathematics teaching,

learning and assessment.

Extended NFQ Illustrated

The provisions and structure of the of the NFQ reflect its provenance and purpose namely to set and maintain the standards expected as learning outcomes, formally acquired, across 10 levels, and detailed in terms of Knowledge, Skills and Competence. In contrast, the learning outcomes required in the workplace are dynamic, in reaction to change to meet its own needs, regardless of domain, and untrammelled by the depth and breadth necessary for progression in formal learning environment. Competence in the workplace is a concept that bears little resemblance to that accounted for in the NFQ, and presents a more 'spikey' profile that is tuned to local conditions rather than conformance with a remote, generalized description. In this way, it seems that mathematics in the workplace may not be accounted for fully in terms of complicatedness alone.

The Workplace Contextualization of Mathematics, described herein, and the Context-Complexity Protocol which it underpins, are the products of in-depth case studies comprising doctoral research. At the time of writing, no comparable frameworks had been located to capture similar facets of the modern workplace. Nevertheless, these tools offer the prospect of extending the provisions of the NFQ, to enhance mathematics visibility, and to recognize the sophisticated circumstances in which MKSC is used in the workplace. The application of the Context-Complexity Protocol to a sample case study discussed in the next section, demonstrates the added power to communicate an extended NFQ would offer for the benefit of the individual, employer, recruiter and curriculum developer.

Sample Case Study

'R' is a Warehouse Picker. He is required to retrieve 60 items per hour from a warehouse that stores approximately 3 million separate documents, files, deeds, legal briefs, and computer media. He is guided by a 'work order', one for each customer, issued by his line manager. The 'picks' are distributed across 2 buildings, each of 4 floors, fitted with up to 26 storage racks on each floor, each with 52 bays, each with 3 shelves, each of which may contain 27-30 boxes of documents. There are several fireproof safes and secure vaults to contain sensitive documents and electronic media. Each 'pick' is tagged with a barcode which indicates its location by referencing building, floor, row, bay and shelf, but no more. R is provided with a scanning device which lists the barcodes in alphabetical sequence – not by optimal route. It is not feasible to accumulate picks as his work progresses from beginning to end. Instead, he deposits parts of the pick at strategic locations around the warehouse to be gathered at the end of the session. The pick route is planned by his taking account of the locations of cargo lifts, stairs and access points between buildings, and the next 'nearest neighbour'. He must decide how much time to devote to a pick that is not in its reported location, bearing in mind the need to complete his work within the time allotted and the impact on the delivery person and customer service of omitting the requested document.

This warehouse picker has little formal education. The level of mathematics he actually displays in the performance of his job scarcely meets the learning outcomes at level 1. He has the lowest status in the workforce, yet he bears ultimate responsibility for picking the correct item and making it available for delivery to the correct customer. The work instructions he is provided with are clear in general, but surrounded by distracters, competing priorities, and moderately incomplete information. He reflects on his work and introduces unauthorised 'work-

arounds' to compensate for the shortcomings in the warehouses' design. He is informed by different but familiar information sources, although constrained, partially, by the preceding and following picks. Several years of experience has resulted in mid-range familiarity and subject to stressors generally in the middle range. In arriving at complexity level indicators, each item of the protocol was considered in turn and matched to the band that most closely described his work.

The outcome of this matching process is shown in the next section.

Extended NFQ – Sample Case Study

The standard NFQ approach to the accreditation of learning when applied to a sample case study, represents the identified mathematics knowledge and skills at level 1, having met the criteria detailed in the relevant Significant Learning Outcomes (SLO) set out in the assessment criteria. In keeping with standard custom and practice, the same level is credited to the four Competence sub-strands, namely Context, Role, Learning to Learn and Insight, each shown separately in Figure 1.1 on the assumption that these properties are somehow embedded in the learning process.

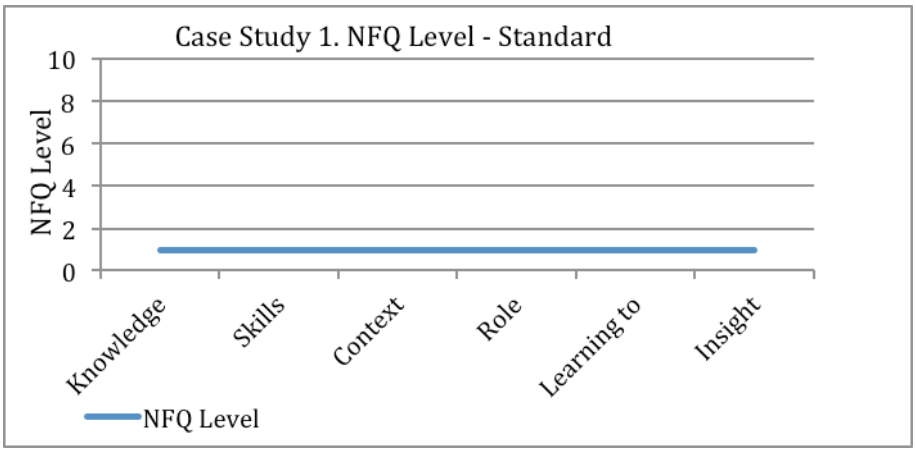

Figure 1.1. Company A, Case Study 1, Mathematics Knowledge, Skills and the Competence Strands of Context, Role, Learning to Learn and Insight - standard interpretation.

However, an evaluation of the Competence in Context and Role, based on the evidence of observations and on interpreting the formal provisions of the NFQ, exceed that of the Mathematics Knowledge and Skills levels identified in the Case Study – Job Shadowing phase. Figure 1.2.

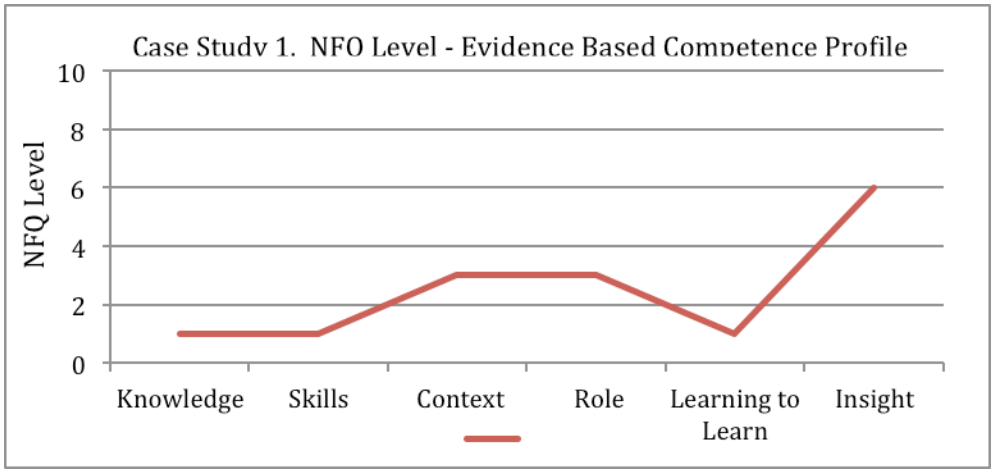

Figure 1.2. Company A Case Study 1, Evidence-based interpretation of the NFQ provisions to represent the Competence Observed in the workplace.

The scale of Learning to Learn-recognition is biased in favour of the formal learning structures, leaving no scope for the recognition of tacit, informal and non-formal learning. The apparently extreme score recorded for Insight, reflects intelligent exposure to the workplace and its capacity to promote tacit rationality and analogical thinking.

The impact of having applied the Context-Complexity Protocol to Case Study 1, is shown in Figure 1.3. While a separate trace is shown for each mathematics domain for consistency with the broad aims of the research, their confluence would seem to indicate their interdependence rather than distinct and discrete behaviour. The plots shown represent the mean score of the factors comprising each dimension of workplace context-complexity.

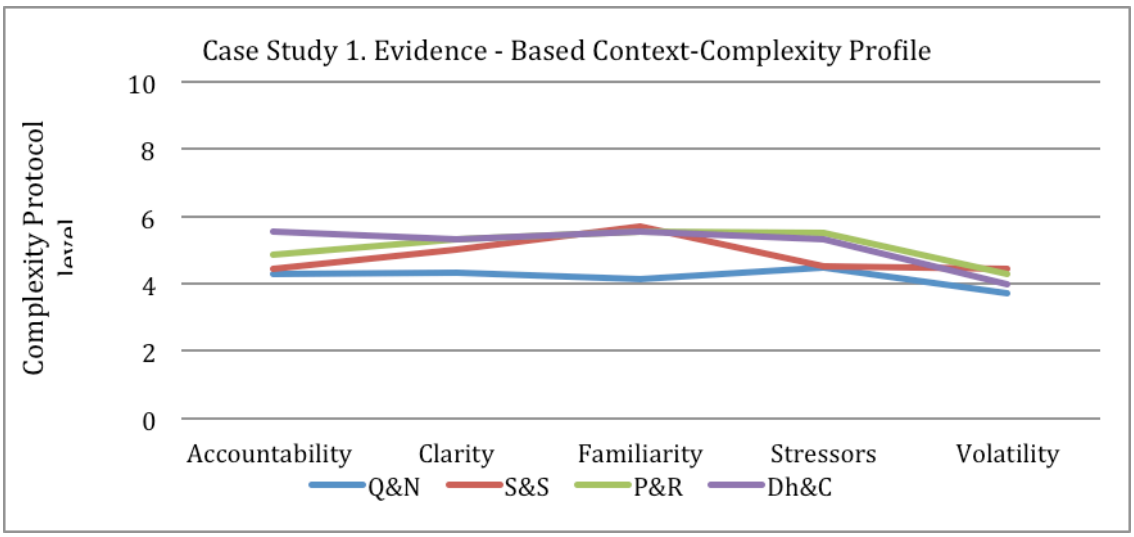

Figure 1.3. Context Complexity Dimensions for 4 Mathematics Domains

When these data are combined, the resultant graphic, Figure 1.4, captures not only how complicated the Mathematics Knowledge and Skills deployed in this particular workplace are, (plotted at NFQ level 1), it also shows the observed, rather than assumed, levels of competence in Context, Role, Learning to Learn and Insight, appropriate to each Mathematics Domain. The

key additional job profile information reports Context-Complexity dimensions which effective performance in the workplace demands.

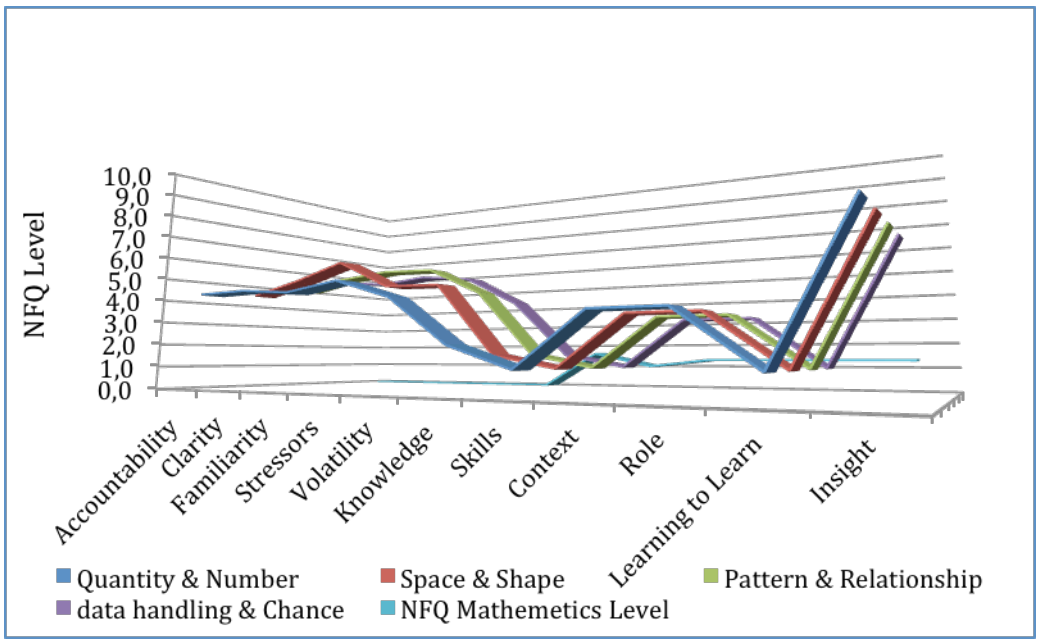

Figure 1.4. NFQ extended to account for Context-Complexity.

The profile of the context-complexity communicates new information about the workplace and a sense of what the individual 'knows' in addition to what s/he 'does'. While the complicatedness of the MKSC at NFQ level 1 may be characterized as routine, the circumstances under which they are used requires their deep understanding, in support of thinking and as a guide to action.

Implications for Mathematics Teaching & Learning

The implications for mathematics teaching and learning for and by adults, may be profound, especially when considered in tandem with other outcomes of this research. The findings of the national survey associated with this research tended to confirm the importance of the context in which mathematics knowledge, skills and competence are realised. While this is not new information, it contributed to the formation of the Workplace Contextualisation of Mathematics detailed in the attached appendix, 6.1. By embracing this contextualisation of the workplace, teachers of mathematics have the opportunity to mould the learning environment accordingly. For example, a problem could be posed that, while requiring the application of mathematics techniques, might invite an answer expressed in terms of the 'least-worse' outcome. While this strategy may challenge the teacher's imagination, it could highlight the idea that mathematics can support strategic thinking and need not be an end it itself. In a forthcoming companion document, the authors introduce the concept of a subject-centric perspective of cultural historical activity theory as a possible explanation of mathematics invisibility in the workplace and suggest a mechanism by which it may be measured. Taken together, these devices may offer an holistic approach to establishing a realistic starting point for adults learning mathematics, and a road map for future action.

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