Towards a Realistic Description of Competence for New Radiology Graduates in South Africa

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Abstract

In this article, we trouble the notion of competence in current use to describe new radiological graduates. Against the backdrop of inequalities, a diverse set of experiences and scarce human and clinical resources alongside a lack of criterion-referenced descriptions, we argue that 'competence' is open to various interpretations and may unrealistically, include skills that an incumbent may not have acquired but is assumed to have. In this position piece, we suggest that a model to clarify radiological competence is possible by rearticulating Dreyfus and Dreyfus' model of skills development. We posit that a re-articulated model could be useful to distinguish the nature of expert from novice radiological competence, using perceptual skill as an example. We conclude with an invitation to engage in a conversation with a wider audience to arrive at a consensual framework for a realistic description of competence for new radiologists.

Keywords: Dreyfus and Dreyfus Model; novice and expert radiologist; radiological competence; tacit knowledge

Introduction

This position piece reviews the notion of competence, identifies the complications and contextual complexities faced by novice radiologists and, based on an analysis thereof, offers a re-articulation of an existing model to

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lead a discussion towards a realistic description of radiological competence for new graduates. The article's intention is to trigger deep discussion about the need to formulate and describe the competencies (explicit and tacit) that specialist radiologists should acquire, as they evolve professionally from novice (beginner specialist) to expert (experienced specialist) levels of proficiency.

Current debates around professional competence for medical practitioners can be traced to a seminal paper written more than a decade ago by Epstein and Hundert (2002). They defined medical competence as 'the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values and reflections in daily practice for the benefit of the individuals and the community being served'. Epstein and Hundert's broad description suggested that competence is closely aligned to wisdom and application – qualities that are undoubtedly, essential for all medical professions (Epstein & Pacini 1999). In the specialist fields, temporal specifications and content knowledge are foregrounded in a qualification, rather than wisdom and utility.

Whilst content knowledge is specified in sufficient detail, indicators of the aspects of competence, e.g. perception, have not been adequately unpacked to reduce the ambiguity of meaning, interpretation or practice. This lack of clarity arises because skill competence differs from one specialist to another in terms of acquired professional learning, role functions and performance. Furthermore, although Epstein and Hundert's notion of competence suggests what it is, the specifics of some aspects of radiological competence are implied, and therefore, remain tacit. In disciplines that are grounded in the interpretation of visual images, practitioners encounter additional challenges in that the level of professional expertise is tempered by the degree to which the embodiment of tacit knowledge (such as human visualisation) is exercised (Nodine, Kundel *et al*. 1999). However, it is common knowledge that a tacit skill like visualisation is inherently fallible (Tuddenham 1962; Renfrew, Franken *et al*. 1992) and consequently, unreliable for diagnostic purposes by novitiates. Nevertheless, it is true that, in practice, the application of tacit skills separates a novice from an expert. From Eraut's (2000) perspective, tacit knowledge epitomises professional performance. Eraut (2000) identified three types of tacit knowledge, namely, people and situations, routinised actions and intuitive decision-making, which together constitute professional performance. In the case of radiologists whose work is image analysis, routine actions and intuitive decision-making are crucial. We argue that, if tacit knowledge is made explicit (to the extent that it can be), the fallibility of intuitive decision-making could be reduced.

The medico-legal perspective currently provides an alternative route to interpret the notion of competence by understanding what it is not: an 'unreasonable lack of skill' (Berlin 2007) or, as 'nonconformity to the general opinion of experts in the field' (Robinson 1997), highlighting the fluid nature of the definition of medical competency.

In view of the number of complex factors that can obfuscate a realistic perception of a specialist in radiology by lay, academic and professional persons, we contend that, efforts should be made to question, deliberate and to solve the issues related to clarifying the notion of professional competence for mentors and supervisors of new radiologists. Irrespective of their area of practice, the establishment of parameters for and descriptions of novice and expert practitioners, and identification of the relevant knowledge and skills that should be acquired, is crucial. Hence, the questions we pose in this article are twofold. Can appropriate descriptions of discipline specific competence serve to capture the reality of actual and competent radiological practices? Can we suggest a framework that describes and prescribes the relevant competencies expected of qualified radiologists?

We begin by tracing the qualification pathway and contextual background.

The Regulation and Certification of Radiological Professionals in South Africa

At present, the education, certification, professional development, and specialisation processes of the medical profession are split amongst three different organs under the auspices of the Health Professionals Council of South Africa (HPCSA). The HPCSA determines initial and continued registration for specialists (i.e. permission to practice as a professional). In addition, it monitors medical academia through regular accreditation visits and assessments. The HPCSA relies on universities to provide structured teaching for health care professionals and on the Department of Health to offer opportunities for service-based learning in provincial health facilities while the Colleges of Medicine of South Africa benchmark and assess for competence.

The quality of the curriculum and the production of radiologists is a shared responsibility of individual national universities and their associated Departments of Health. These responsibilities include overseeing a curriculum with clearly prescribed outcomes, explicitly-stated programme expectations, the use of appropriate learning tools and relevant learning methods in suitable working environments. However, at times, the learning outcomes of national programmes may not be aligned to a distinctive local clinical context. In South Africa, for instance, the quest for restitutive justice has led to a national curriculum that provides access to those excluded by the racial policies of the past (Benatar 2013), resulting in the maginalisation of local disease prevalence and demographic profiles. A critical complication of this arrangement is that while each programme may be internally coherent within a university and ethically practiced locally, the multiplicity of locally relevant programmes may be too diverse for a coherent curriculum from a macro standpoint.

Furthermore, it is important to remember that medical teachers are more likely to be qualified medical specialists without being qualified educationalists and, as such, teaching strategies and assessment standards are probably intuitive or experientially directed rather than pedagogically informed. An understanding of adult education, the challenges of university massification and the ability to address student diversity are often beyond the grasp of medical teachers without a teaching credential, especially as learning to teach may not feature on the list of priorities of overburdened medical specialists in higher education and public service institutions.

Furthermore, despite the integrated approaches to oversee and regulate the quality of the programmes, the South African specialist qualification is not recognised in some international arenas. For example, South African medical graduates who seek employment in Australia, Canada and the United States cannot do so without an assessment of competency through enforced probation and professional practice with subsequent assessments and re-examination before full registration is granted. An unexpected boon for the country is that conditional recognition by the aforementioned countries could staunch the ‘brain drain’ of trained South African doctors and specialists. While we may celebrate the retention of medical professionals, there is cause for concern if it means that there may be professionals in the country who cannot provide appropriate quality care for South African citizens (see e.g. Health 24 2016; PPS 2014). This suggests that it might be worthwhile to examine aspects of quality when considering the pathway from novice to expert. Good quality may be possible by establishing parameters and descriptions of competence for beginner and experienced radiologists and for identifying the relevant knowledge and skills that should be acquired, commensurate with their stage of professional development.

The focus on competence should not be read as an agenda that counters the efforts made by South African health service providers to address challenges and needs. Indeed, competence is critical to improve healthcare provisioning and, simultaneously, to ensure the effectiveness of the curriculum for specialist radiologists in both the local and international arenas. We begin with an elucidation of the context in which radiologists are expected to hone their radiology skills.

The Radiology Learning Environment in South Africa

The learning site for a radiologist is predominately the state hospital. During the process of specialisation, the radiology trainee (a qualified medical doctor) is exposed to postgraduate teaching programmes and practical apprenticeship-like training in the state health sector over a minimum of four years. Working in state hospitals offers numerous opportunities to hone practical skills and to acquire advanced specialist knowledge and problem solving techniques in two ways: working alongside many experienced specialists and exposure to a large number and variety of cases. One would surmise that while the hospital experience can be intense, it also has the potential to be an ideal space for on-the-job learning opportunities. In reality, for many South African radiology specialists-to-be, a state hospital is often not experienced as an ideal learning environment (Health 24 2016; PPS 2014). Teaching hospitals, especially for radiological trainees, are currently unequally resourced, lack cutting-edge equipment and facilities, and are financially constrained and lack skilled human resources both for service provisioning and teaching (Mail & Guardian 2009).

The overstrained health care system (Govender 2016) means that new graduates and radiologist trainees may have to function independently at a premature stage of professional development and without the benefit of post-qualification vocational training. They are, therefore, less likely to correct poor diagnostic habits and may establish and reinforce diagnostic misinterpretations during the crucial acquisition of useful experience. Furthermore, trainees are often exposed to patients who present at more complex levels of a disease, obliging a trainee or new graduate to provide clinical services that are beyond their level of expertise and experience. Whilst experience is gained through time-on-task for a prolonged period, expertise is an expression of both explicit and tacit proficiencies. A clear idea of the criteria that characterise expertise would enable it to be pursued and obtained by professionals.

To exemplify the issue at hand, we discuss the skills of visualisation and pattern recognition for diagnostic purposes.

Visualisation, Pattern Recognition and Analysis for Diagnostic Competence

Diagnostic competence for a specialist radiologist includes core abilities to visualise and to recognise patterns. In practice, a new radiologist is expected to identify, triage and interpret imaging signs for clinical usefulness and to convey that interpretation in an accessible form to the referring clinician.

The skills that exemplify radiological performance, an adaptation by Morita of the Blesser model (1972), are a combination of integrated (cited in Morita, Miwa *et al*. 2008) and interdependent steps: visualisation (sensory awareness) and autonomous pattern recognition using long-term visual memories, and analytical skills (Blesser & Ozonoff 1972). The model provides a broad, fundamental overview of practice in visually-based disciplines.

New radiologists, therefore, have to demonstrate practical and clinical diagnostic competencies which arise from two sources; first, a complex process of integrating growing formal knowledge with increasing embodiment of tacit knowledge (Heiberg Engel 2008) and second, by gathering useful experience through experiential learning (Anderson 1982). The ability to create, process and manipulate mental images (i.e. visualisation) is one such tacit skill. Tacit skill is a form of non-analytic reasoning and is an invisible but vital component of professional expertise at all levels of development (Norman, Young *et al.* 2007) that contributes effectively to overall competence (Talbot 2004). Since there is a continuum of increasing complexity aligned to professional development from novice to expert, tacit knowledge needs to be made explicit. Eraut (2000) reminds us that tacit knowledge is unstable, dynamic and contextually situated and, more importantly, distinctive and individual. Deploying an iceberg metaphor, Eraut explains that professional knowledge that is learnt is that part of the iceberg, which is visible. Tacit knowledge which is invisible acts as a barrier to personal mastery and competence unless it is made obvious.

We therefore, conclude that the attainment of radiological competence depends on lucid guidelines and descriptions of tacit knowing to develop expertise. By clearly stating descriptors of skill competence for perceptual skill, we may isolate indicators of its maturation during training, and ensure that such changes are effected and that ultimately, the curriculum is rendered more efficient. However, despite growing evidence that novice and experts image readers gather, process and retrieve stored mental images differently (Brazeau-Lamontagne, Charlin *et al*. 2004), two assumptions have persisted since 1962. The first is that the mental image is faithful to the external image and the second, that every person gathers visual data in exactly the same manner regardless of the level of expertise (Tuddenham 1962). Based on these assumptions, teaching practices that view the cultivation of analytic skill as incidental learning endorse the traditional preference for nurturing analytical reasoning. Furthermore, excessive promotion of the embodiment of perceptive skill effectively fails to consider the substantive role of perceptual skill in the diagnostic process (Norman, Coblentz *et al*. 1992; Morita, Miwa *et al*. 2008). In order to address this issue, we focus on the characteristics of radiological perceptual skill at extreme ends of the continuum of professional development, that is, the novice and the expert image reader (see fig. 2) as an exemplar of how it may be possible to clarify skill competence. This focus on the extremities is in line with the agenda to begin a conversation about radiological competence.

Towards a Clarification of Radiological Competence

As noted earlier, a concept like 'competence' is open to numerous interpretations which are often subjective and context dependent, leading to divergent and, perhaps, contradictory outcomes. One way to obviate this fuzziness is to restrict the multiplicity of interpretations through the use of criterion referenced descriptions for each identified skill. Dreyfus and Dreyfus' (1980) model of skill development provides a useful idea of how clarification may be accomplished. The Dreyfus model is a five-stage typology used to identify the characteristics of skills attained at each level of professional development (see figure 1). A more detailed description of each category is discussed extensively in the literature (see e.g. Carraccio, Benson, Nixon & Derstine 2008; Dreyfus 2004; Dreyfus & Dreyfus 1980).

While, at first glance, the model appears to be an insightful approach to tracking expertise and competence, Atherton (2013) draws attention some limitations. In particular, Atherton (2013), argues that the Dreyfus and Dreyfus model is one-dimensional as it makes explicit those skills, knowledge and practices that are measureable and underplays immeasurable aspects of practice such as interpersonal skills, professional development, lifelong learning and by extension, human skills such as visual perception.

1 Novice	○ Sees what is most important in a situation ○ Rigid adherence to taught rules or plans ○ Little situational perception ○ No discretionary judgment
2 Advanced Beginner	○ Guidelines for action based on attributes or aspects ○ Situational perception still limited ○ All attributes and aspects are treated separately and given equal importance
3 Competent	○ Coping with 'crowdedness' ○ Now sees actions at least partly in terms of longer-term goals ○ Conscious deliberate planning ○ Standardised and routinised procedures
4 Proficient	○ Sees situations holistically rather than in terms of aspects ○ Perceives deviations from the normal pattern ○ Decision-making less laboured ○ Uses maxims for guidance, whose meaning varies according to the situation
5 Expert	○ No longer relies on rules, guidelines or maxims ○ Intuitive grasp of situations based on deep tacit understanding ○ Analytic approaches used only in novel situations or when problems occur ○ Vision of what is possible

Figure 1. University of Michigan adaptation of the Dreyfus and Dreyfus model (Source: Dreyfus & Dreyfus 1980)

Writing from the perspective of clinical skill acquisition, Peña (2010) is far more critical of the Dreyfus and Dreyfus approach and disapproves of its phenomenological roots. In similar vein, Selinger and Crease (2002) lay bare its limitations. Despite its philosophical weaknesses, this framework is widely applied in medical education (see e.g. Batalden, Leach, Swing, Dreyfus & Dreyfus 2002; Carraccio, Benson, Nixon & Derstine 2008; Benner 2001; Selinger & Crease 2002). We reason that an approach that relies on personal experiences is apposite for understanding and application in local contexts that are disproportionately resourced, unpredictable, and diverse.

Despite claims that the Dreyfus and Dreyfus model reflects skills acquisition (Dreyfus 2004; Dreyfus & Dreyfus 1980) we argue that it while it interprets the characteristics of competence, it cannot explain the acquisition thereof (Peña 2010). It is, nonetheless, useful to describe the skills and to rank them along a continuum of competency from novice to expert for two reasons: it can clarify differences and can make explicit those skills that can be elusive because of their tacit nature.

Despite its limitations, the Dreyfus and Dreyfus model offers three uses: a continuum of development expertise stages that range from novice to expert; identification of the commensurate skills associated with each stage of development; and a common language of description which exemplifies each developmental stage. Applied as a template, a reworked Dreyfus and Dreyfus model for radiological competence could make explicit the differences between the perceptive practices of radiology experts and novices as delineated in figure 2.

	VISUALISATION	PATTERN RECOGNITION

Novice	**Less useful hypothesis generated/ inferior quality of mental image**
	
	• Visual working memory predominately data gathering rather than internal information processing
	  ○ Overburdened and irrelevant data gathering
	• Untrained information preprocessing
		Analysis predominates over pattern recognition
		
		• Smaller and disorganised long term visual memory - pattern recognition less likely
		  ○ Relies more on analysis of image features and individual signs
		• Decontextualised general depictive mental images

	• Limited confidence ○ Less experience with natural bias and psychological perceptual traps ○ Adaptation of mental images rather than assimilation of new information • Mental images are generalised; systematic but atomistic gathering of visual information	○ Cannot easily narrow differential diagnoses • Has yet to nurture useful practice habits ○ More false positive/ false negative diagnoses
Expert	**Superior quality of mental image, more useful and organised hypothesis generation** • Visual working memory predominately internal information processing rather than data gathering • Perceptual learning - superior information gathering and preprocessing abilities • Greater confidence ○ More experience with natural bias, psychological perceptual traps ○ Assimilation of new information into existing mental images rather than adaptation of mental images • Holistic image data gathering	**Pattern recognition predominates over analysis** • More intuitive • Holistic image retrieval from expansive organised long term memory (useful, specific) • Contextualised focused details, descriptive mental images • Can make specific diagnoses more easily • Displays discernible professional habits

Figure 2 Proposed table for clarifying radiological competency for perception skill

For this article, we focus only on the first two processes that together exemplify visual perception to extol the potential of a model for radiological competence. It should be noted that this table is work in progress and requires refinement by many minds. We do this in the context of the Blesser model of the radiological process that identifies three meta-skills: visualisation and visual information processing, pattern recognition and visual data analysis skills (Blesser & Ozonoff 1972). Figure 2, therefore, seeks to synthesise the differences between the perception meta-skills of novice and expert image readers, where the act of 'visualisation' refers to a visuospatial coherence of the mental image (the 'what' and the 'where'), while pattern recognition is the ability to match new mental images with consolidated and organised long-term memories (Gunderman, Williamson *et al*. 2001). In other words, visualisation engages the sensory system and internal image processing such that spatial processing and pattern recognition become non-analytical and subjective comparisons of exemplars with new mental images (Hofman & Hicks 2010). Pattern recognition, it must be remembered, has been shown to be the easier and preferred method of human behavior (Leape 1994) and, in addition to visualisation, extends beyond appreciation of the individual physical attributes of sensory information (Sabih, Sabih *et al*. 2011) without necessarily engaging higher cognitive functioning at that particular time (Evans & Stanovich 2013).

In radiology, the novice practice of assigning equal importance to all image parts in a systematic and bottom-up manner when gathering information (Kundel, Nodine *et al*. 2007) is not useful as it could detract novices from establishing diagnoses by drowning vital information in a sea of irrelevant details. By contrast, the expert internalises images in a more successful and intuitively holistic manner through a search pattern (Kundel, Nodine *et al*. 2007) that is shaped by a visual concept (Kundel & Nodine 1983; Manning, Ethell *et al*. 2014). Considering the appropriate weighting to the clinical scenario, the expert collects and stores information in a holistic rather than in a piecemeal way (Kundel & Nodine 1983). Indeed, as expertise develops, the mental representation inspected for pattern recognition and its final interpretation becomes more situationally relevant and coherent to the requirements of a task rather than being faithful to the external image (Tuddenham 1962). The skilled radiologist does this by refining how he or she focuses attention such that expert visualisation of patterns allows access to exemplars of visual memories by modifying new or stored mental images.

Pattern recognition is critical to the diagnostic process and, arguably, even a dedicated systematic scanning of images cannot compensate for its inadequacy (Oestmann, Greene *et al*. 1988). These exemplars are easily accessed through simple recall but it is the quality of the exemplar rather than the mere act of recall that epitomises expert pattern recognition. However, the internalisation of quality mental images requires internal manipulation of such images through modification of raw sensory information. The modified mental image plays a crucial role in the efficient analysis of visual data when there is failure to recognise a pattern in problematic or novel situations. Quality mental images allow the visual working memory to be redirected to further internal image manipulation if required, especially when the new mental images differ visuospatially from stored exemplars. Memory redirection is particularly relevant to the radiological process as images are virtually irreproducible even for the same person and more so for those dynamic tasks that require subconscious and instantaneous interpretation.

In visually oriented disciplines such as radiology, the sensory system (in this case, the peripheral eye brain system) evolves anatomically and functionally and becomes more proficient to the task at hand (Goldstone 1998). The bi-directional advancement of perceptive skill and discipline specific knowledge means that the subsequent mental images are distorted via sensory pre-processing[1] rather than solely through growing discipline specific knowledge or the influence of cognitive skill (Hertzog & Fahle 1997). There may be differences in the quality of the mental image in terms of visuospatial coherence between experts and novice radiology readers, lending doubt to the presumption that all readers perceive external visual information in exactly the same way.

Externally, this manifests as a radiology reader's ability to transition from using steadfast maxims (such as pictorial images) to being capable of visualising novel possibilities outside of such rules and regulations aligning with Dreyfus and Dreyfus' descriptors of skill development. The outcome is that improved discretionary judgment and contextual perception is honed with

[1] Structural and functional neuronal plasticity suggests that both early and late changes contribute to perceptual learning i.e. through changes in the receptive field structure as early as the primary visual cortex (Fahle 2004) and improvements in signal selection (Fahle 2004) through modifications of central neural loci in the parietal cortex (Karni, Weisberg *et al*. 1996)

concomitant ability to cope with dense information and the deployment of deep, tacit understanding.

The final interpretation of an image, therefore, coheres with individual discipline specific understanding of the visual data gathered; the readers' own perceptive ability and their ability to recognise and overcome the limitations in their own psychological, perceptive and analytical skills. Expert visualisation is consequent to the integrated development of perceptual, higher cognitive skill and growing self-confidence, enabling the student to exploit all routes of learning. By recognising that tacit knowledge is central to competent diagnosis and is a presupposer to radiological interpretation, we can surmise that creation of the adequate mental image[2] is a driver of the early learning process and would benefit from practice early in training (Norman, Coblentz *et al*. 1992; Taylor 2007).

This article sought to understand perceptive skill holistically to make explicit and extract the various skills that separate novice and expert radiological competence, and more importantly, to demonstrate the relevance of developing a model based on common, core competencies and outcomes during the training period. In elucidating the differences between expert and novice perception and its determinants, we have attempted to show how perceptive practices, regardless of their developmental influences, manifest in an observable manner during training. Simply described, one could argue that, the trainee should be able to demonstrate the ability to intuitively and confidently contextualise their interpretation of the image, discard situational non-specific, irrelevant imaging details, and support their intuitive conclusions through analysis if required while being dependent on an internalised image that is increasingly visuospatially coherent. It is, therefore, clear that it is not only cognitive processes that have the potential to evolve positively with training.

Analysis may be assessed in the structure of the written radiological report. The challenge relates to assessing tacit perceptual skill in work-placed based assessment and summative assessments. Based on the aforementioned range of differences between novice and expert radiological competence, the issue at hand is how we work collectively to design and implement a

[2] Mental images can be created either through the reader's own skillful perception (Woodman, Vogel *et al*. 2001) or the supervisor's explicit demonstration of imaging signs (Crowley, Naus *et al*. 2003)

curriculum to inform realistic assessments and prepare for sufficiently competent radiology graduates.

Conclusion: Beginning a Conversation about Radiological Competence

New radiologists are not without competence. However, it is not apparent what we mean by the description, ‘a competent radiologist’ because currently, the notion of ‘competence’ can be regarded as an incomplete signifier (Laclau 2000), which is open to multiple interpretations. Although competence is explicitly pursued in the training of new radiologists, it lacks definition, is difficult to describe, and in practice, is subjective and poorly criterion-referenced. Thus, it is imperative to begin a conversation about radiological competence, skills and learning outcomes that are explicit and acceptable to the profession. On a more critical note, it is difficult to be certain that the notion of competence in radiology specialist training is reflective of craft competence. It seems apparent that the two steps of the radiology process, although integrated, can be thought of as different skills and may be nurtured and assessed differently. We have sought to show how perceptive skill is different for expert radiologist and novice functioning and suggested that an isolated attempt to nurture theoretical knowledge and analytical problem solving skills without explicitly observing its positive influence on perceptual skill and learning means that such learning is inefficient in the quest for realistic competency. We therefore, need to consider the importance of including and assessing for both perceptive and analytic skills during the period of training for new radiologists. We believe that, a Dreyfus and Dreyfus-like model to clarify competence holds promise as a tool for radiological education for the embodiment and assessment of the tacit skill of perception.

In order to be useful, the conversation about the training should consider at least three issues: aligning local specialist care with internationally acceptable standards; producing specialists who address local health requirements within the available health care resources; and identifying the unique skills of each discipline for incorporation into training programmes. The outcome, in our opinion, increases the possibility of efficiently producing qualified specialists who are competent in all relevant areas within the relatively short training period and the suboptimal hospital training environment.

As work in progress, we invite comment and continuation of the conversation to explore the possibilities for a realistic description of radiological competence that is founded on the basis of consensus. Ideally, this will populate the proposed Dreyfus and Dreyfus-like model with explicit criteria that have been inadvertently omitted and refine those that have been included.

References

Anderson, J.R. 1982. Acquisition of Cognitive Skill. *Psychological Review* 89,4:369.

Atherton, J.S. 2013. Doceo: Competence, Proficiency and Beyond. Available at: http://www.doceo.co.uk/background/expertise.htm#DREYFUS (Accessed on 16 October 2017.)

Batalden, P., D. Leach, S. Swing, H. Dreyfus & S. Dreyfus 2002. General Competencies and Accreditation in Graduate Medical Education. *Health Affairs* 21:103–11.

Benatar, S. 2013. The Challenges of Health Disparities in South Africa. *South African Medical Journal* 103,3:154-155. Doi:10.7196/SAMJ.6622.

Benner, P. 2001. *From Novice to Expert: Excellence and Power in Clinical Nursing Practice*, *Commemorative Edition*. Upper Saddle River, NJ: Prentice-Hall.

Berlin, L. 2007. Radiologic Errors and Malpractice: A Blurry Distinction. *American Journal of Roentgenology* 189,3:517-522.

Blesser, B. & D. Ozonoff 1972. A Model for the Radiologic Process 1. *Radiology* 103,3:515-521.

Brazeau-Lamontagne, L.B., R. Charlin, L.S. Gagnon & C. van der Vleuten 2004. Measurement of Perception and Interpretation Skills During Radiology Training: Utility of the Script Concordance Approach. *Med Teach* 26,4:326-332. https://doi.org/10.1080/01421590410001679000

Carraccio, C.L., B.J. Benson, L.J. Nixon & P.L. Derstine 2008. From the Educational Bench to the Clinical Bedside: Translating the Dreyfus Developmental Model to the Learning of Clinical Skills. *Academic Medicine* 83:761–7.

Crowley, R.S., G.J. Naus, J. Stewart & C.P. Friedman 2003. Development of Visual Diagnostic Expertise in Pathology: An Information-processing Study. *Journal of the American Medical Informatics Association* 10,1:39-51.

Dreyfus, S.E. 2004. The Five-stage Model of Adult Skill Acquisition. *Bulletin of Science, Technology and Society* 24,3:177-181. Doi: 10.1177/0274067604264992.

Dreyfus, S. & H. Dreyfus 1980. *A Five-stage Model of the Mental Activities Involved in Directed Skill Acquisition.* California University Berkeley Operations Research Center [monograph on the Internet]; Available at: http://www.dtic.mil/dtic/index.html. (Accessed on 21 September 2017.)

Epstein, R.M. & E.M. Hundert 2002. Defining and Assessing Professional Competence. *JAMA* 287,2:226-235.

Epstein, S. & R. Pacini 1999. Some Basic Issues Regarding Dual-process Theories from the Perspective of Cognitive-experiential Self-theory. In S. Chaiken & Y. Trope (eds.): *Dual-process Theories in Social Psychology*. New York: Guilford Press.

Eraut, M. 2000. Non-formal Learning and Tacit Knowledge in Professional Work. *British Journal of Educational Psychology* 70:113-136.

Evans, J.S.B.T. & K.E. Stanovich 2013. Dual-process Theories of Higher Cognition: Advancing the Debate. *Perspectives on Psychological Science* 8,3:223-241.

Fahle, M. 2004. Perceptual Learning: A case for Early Selection. *Journal of Vision* 4,10:4.

Goldstone, R.L. 1998. Perceptual Learning. *Annual Review of Psychology* 49,1:585-612.

Govender, K. 2016. South Africa's Adoption of the World Health Organization's 'Test and Treat' Guidelines: Are we Too Ambitious? *South African Medical Journal* 106,10:952.

Gunderman, R., K. Williamson, R. Fraley & J. Steele 2001. Expertise: Implications for Radiological Education. *Academic Radiology* 8,12:1252-1256.

Health 24, 21 October 2016. *South African Medics Worried about Poor Training, Doctor Shortages*. Available at: http://www.health24.com/Medical/HIV-AIDS/News/SA-medics-worried-about-poor-training-doctor-shortages-20140604. (Accessed on 16 October 2017.)

Heiberg Engel, P.J. 2008. Tacit Knowledge and Visual Expertise in Medical

Diagnostic Reasoning: Implications for Medical Education. *Med Teach* 30,7:e184-e188.

Hertzog, M.H. & M. Fahle 1997. The Role of Feedback on Learning and Deciding in a Vernier Discrimination Task. *Vision Research* 39:4232-4243.

Hofman, M.S. & R.J. Hicks 2010. Restaging: Should we Persist without Pattern Recognition? *Journal of Nuclear Medicine* 51,12:1830-1832.

Karni, A., J. Weisberg F. Lalonde & L. Ungerleider 1996. Slow Changes in Primary and Secondary Visual Cortex Associated with Perceptual Skill Learning: An fMRI Study. *Neuroimage* 3,3:S543.

Kundel, H.L. & C.F. Nodine 1983. A Visual Concept Shapes Image Perception. *Radiology* 146,2:363-368.

Kundel, H.L., C.F. Nodine, E.F. Conant & S.P. Weinstein 2007. Holistic Component of Image Perception in Mammogram Interpretation: Gaze-tracking Study 1. *Radiology* 242,2:396-402.

Laclau, E. 2000. Structure, History and the Political. In Butler, J., E. Laclau & S. Zizek (eds.): *Contingency, Hegemony and Universality: Contemporary Dialogues on the Left.* London: Verso.

Leape, L.L. 1994. Error in Medicine. *Journal of American Medical Association* 272,23:1851-1857.

Mail and Guardian 24 May 2009. *SA State Hospitals in a Crisis*. Available at: https://mg.co.za/article/2009-05-24-sa-state-hospitals-in-crisis. (Accessed on 21 September 2017.)

Manning, D., S. Ethell & T. Donovan 2014. Detection or Decision Errors? Missed Lung Cancer from the Posteroanterior Chest Radiograph. *British Journal of Radiology* 77,915:231-5.

Morita, J., K. Miwa, T. Kitasaka, K. Mori, Y. Suenaga, S. Iwano, M. Ikeda & T. Ishigaki 2008. Interactions of Perceptual and Conceptual Processing: Expertise in Medical Image Diagnosis. *International Journal of Human-Computer Studies* 66,5:370-390.

Nodine, C.F., H.L. Kundel, C. Mello-Thoms, S.P. Weinstein, S.G. Orel, D.C. Sullivan & E.F. Conant 1999. How Experience and Training Influence Mammography Expertise. *Academic Radiology* 6,10:575-585.

Norman, G., M. Young & L. Brooks 2007. Non-analytical Models of Clinical Reasoning: The Role of Experience. *Medical Education* 41,12:1140-1145.

Norman, G.R., C.L. Coblentz, L. Brooks & C. Babcook 1992. Expertise in Visual Diagnosis: A Review of the Literature. *Academic Medicine* 67,10:

S78-83.

Oestmann, J., R. Greene, D. Kushner, P. Bourgouin, L. Linetsky & H. Llewellyn 1988. Lung Lesions: Correlation between Viewing Time and Detection. *Radiology* 166,2:451-453.

Peña, A. 2010. The Dreyfus Model of Clinical Problem-solving Skills Acquisition: A Critical Perspective. *Medical Education Online* 15. Doi:10,3402/meo.v15i0.4846. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2887319/. (Accessed on 16 October 2017.)

PPS. 2014. *Doctor Shortages and Training Level Biggest Concerns to South African Medical Field – Survey*. Available at: www.pps.co.za/portal/docs/Doctor%20shortage%20AND%20Training%. (Accessed on 21 September 2017.)

Renfrew, D.L., E.A. Franken, K.S. Berbaum, F.H. Weigelt & M.M. Abu-Yousef 1992. Error in Radiology: Classification and Lessons in 182 Cases Presented at a Problem Case Conference. *Radiology* 183,1:145-150.

Robinson, P. 1997. Radiology's Achilles' Heel: Error and Variation in the Interpretation of the Röntgen Image. *The British Journal of Radiology* 70,839:1085-1098.

Sabih, D.E., A. Sabih, Q. Sabih & A.N. Khan 2011. Image Perception and Interpretation of Abnormalities: Can we Believe our Eyes? Can we do Something About It? *Insights Imaging* 2,1:47-55.

Selinger, E.M. & R.P. Crease 2002. Dreyfus on Expertise: The Limits of Phenomenological Analysis. *Continental Philosophy Review* 35:245–79.

Talbot, M. 2004. Good Wine may Need to Mature: A Critique of Accelerated Higher Specialist Training. Evidence from Cognitive Neuroscience. *Medical Education* 38,4:399-408.

Taylor, P.M. 2007. A Review of Research into the Development of Radiologic Expertise: Implications for Computer-based Training. *Academic Radiology* 14,10:1252-1263.

Tuddenham, W.J. 1962. Visual Search, Image Organization, and Reader Error in Roentgen Diagnosis: Studies of the Psychophysiology of Roentgen Image Perception. Memorial Fund Lecture 1. *Radiology* 78,5:694-704.

Woodman, G.F., E.K. Vogel & S.J. Luck 2001. Visual Search Remains Efficient when Visual Working Memory is Full. *Psychological Science* 12,3:219-22.

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