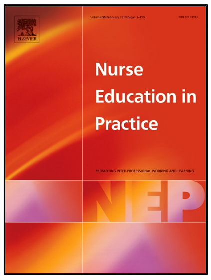
Accepted Manuscript



Developing and integrating nursing competence through authentic technology-enhanced clinical simulation education: Pedagogies for reconceptualising the theory-practice gap

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PII:	S1471-5953(19)30266-5
DOI:	10.1016/j.nepr.2019.04.010
Reference:	YNEPR 2558
To appear in:	*Nurse Education in Practice*
Received Date:	26 March 2019
Accepted Date:	15 April 2019

Please cite this article as: Keith W. Weeks, Prof Diana Coben, David O'Neill, Alan Jones, Alex Weeks, Matt Brown, Prof David Pontin, Developing and integrating nursing competence through authentic technology-enhanced clinical simulation education: Pedagogies for reconceptualising the theory-practice gap, *Nurse Education in Practice* (2019), doi: 10.1016/j.nepr.2019.04.010

Title Page

Developing and integrating nursing competence through authentic technology-enhanced clinical simulation education: Pedagogies for reconceptualising the theory-practice gap

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Acknowledgements:

1. **NETNEP 2018 delegates:** Grateful thanks to the delegates who participated in and evaluated the NETNEP 2018 workshop: *Future-proofing nurses for 21st century healthcare practice – a proposed integrated competence development model.* Participation and evaluation further informed the design, adaptation and international application of the integrated competence model in pedagogical practice.
2. **Professor Sandra Goldsworthy and her team at the University of Calgary:** For their insights into international simulation pedagogy and its application in nursing education practice.
3. **Professor Donna Mead:** As previous Dean of School of Care Sciences (USW), Professor Mead's international and inspirational nursing leadership forged the translational research environment that facilitated the design, development and realisation of the USW Clinical Simulation Centre (CSC) and the high-fidelity clinical simulation education model.
4. **Professor Colin Torrance:** This paper is dedicated to the memory of Professor Torrance, whose inspiration, insight and research leadership acted as a beacon in our strive for pedagogical excellence.

Developing and integrating nursing competence through authentic technology-enhanced clinical simulation education: Pedagogies for reconceptualising the theory-practice gap

Abstract:

The aim of this review and discussion paper is to advance the debate on competence in nursing, simulation education, and literacy in simulation education pedagogy. Building on our previous patient-safety critical translational research work on drug dosage calculation-competence modelling, and *safeMedicate*® virtual learning and diagnostic assessment environment design, we introduce three new concepts. First, we re-conceptualise the cognitive and physical modalities of a theory-practice gap, created by the traditional organisation of health professional education practice. Second, that simulated clinical environments occupy the liminal spaces between the ordered, symbolic and abstract world of the classroom, and the situated, messy world of clinical healthcare practice. Third, technology-enhanced boundary objects (TEBOs) function as simulation pedagogy modalities that (a) support students' transition across the liminal space and boundaries between classroom and practice setting, and (b) support competence development and integration in nursing. We use a constructivist-based clinical simulation education model as a guiding pedagogical framework for applying TEBOs and an integrated nursing competence model. The e-version of the paper has embedded animation and illustrative video content to demonstrate these constructivist principles, using technology and computer animation to make complex education ideas accessible to experienced educators and clinicians, early-stage educators, and nursing and healthcare students.

Key words: translational research; competence; simulation; technology enhanced boundary objects (TEBO); boundary-crossing; constructivism; theory-practice gap.

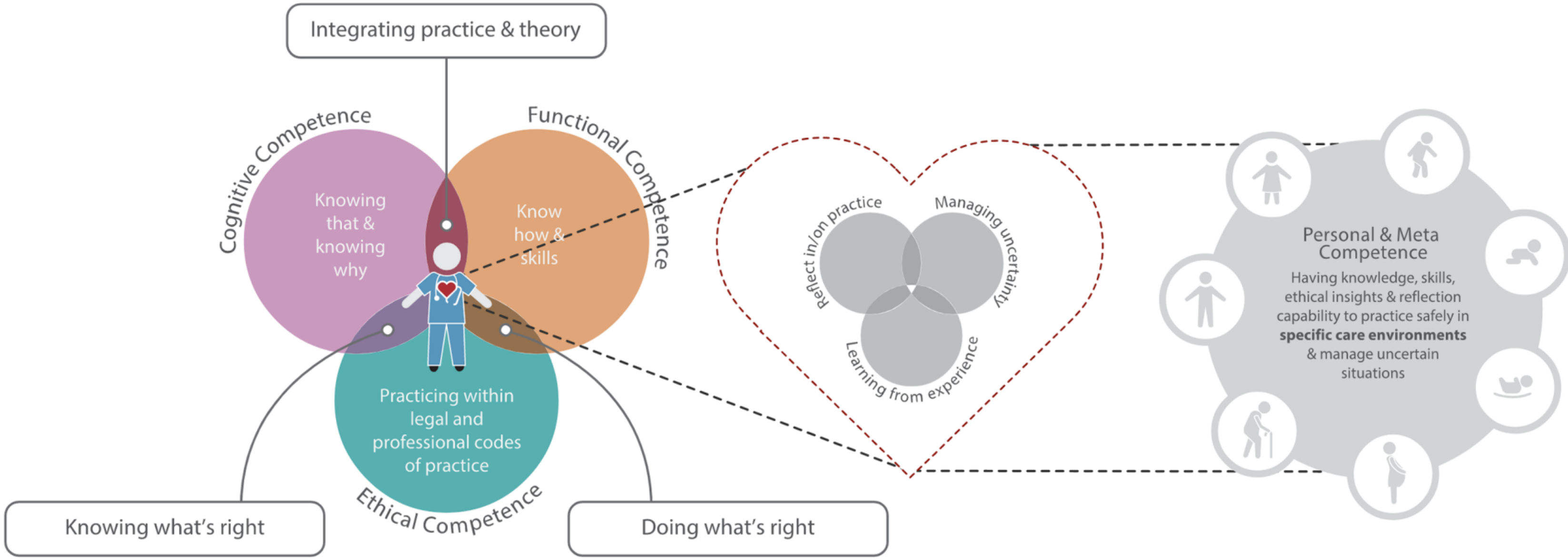
Introduction:

The new education must teach the individual how to classify and reclassify information, how to evaluate its veracity, how to change categories when necessary, how to move from the concrete to the abstract and back, how to look at problems from a new direction – how to teach himself. Tomorrow's illiterate will not be the man who can't read, he will be the man who has not learned how to learn. (Herbert Gerjuoy, cited in Toffler, 1970, p. 414).

Often quoted as, "the illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn (Alvin Toffler)", this latter paraphrased quote reminds us that we must: (a) promote a patient-safety critical education culture that is adaptive to rapidly evolving healthcare environments and the learning orientations of nursing students; and (b) challenge education methods that have failed, or have had limited success, in supporting competence development, integration, boundary-crossing and application.
Its central premise refers to the rapid pace of technological advances and highlights the need for lifelong learning and adaptation to keep up with change. Current healthcare systems and practice are changing at a pace not previously experienced. This is likely to increase as people's health and social care needs shift, and advances in medical technologies and genomics challenge working practices (Wanless, 2002). The UK Nursing and Midwifery Council (NMC, 2018a) reflect this in the new *Future Nurse* proficiency standards expected at the point of registration and beyond.

As health professional educators we need to be at the forefront of this change and contribute to its creation if we are to meet the patient-safety critical education requirements of these demands and challenges. This means reconceptualising the education models and processes previously used to develop and assess nurses' competence and fitness to practice. We must do two things to support the learning, integration and cross-boundary transfer of competence. First, re-conceptualise the cognitive and physical modalities of a theory-practice gap created by the traditional organisation of health professional education practice. Second, help students transition across the liminal spaces between the ordered and abstract world of university classrooms, and the messy situated real-world of clinical nursing practice (Tout, 2014; Weeks, Hutton, Young, et al., 2013). As part of this process, we recently shared a model of nursing competence (see Figure 1) that integrates cognitive, functional, ethical, personal and meta domains (Weeks, Coben, Lum, & Pontin, 2017).

Figure 1: An integrated model of nursing competence (adapted from Cheetham & Chivers, 1996) (click on hyperlink or paste the link into a browser, to see the animated version of the model: https://www.safemedicate.com/publications/elsevier/model_1/)



In this paper we further advance this premise by exploring a clinical simulation education model that aims to re-conceptualise the theory-practice gap, and support boundary-crossing, and competence development and integration. We welcome the revised UK NMC position on the value of simulation education, where,

> Approved education institutions (AEI), together with practice learning partners, must ensure that all students are enabled to learn and are assessed using a range of methods, including technology enhanced and simulation-based learning appropriate for their programme as necessary for safe and effective practice.
>
> (NMC, 2018b, p. 9)

We stress that 'technology enhanced and simulation-based learning' does not mean that the learning is simulated, far from it, learning in appropriate and authentic simulated practice environments is very real. Only the practice environments are re-created and simulated, and this paper addresses (i) our pedagogical model used in simulated practice environment design, and (ii) a model to support early-career educators to craft competence development and literacy in simulation education pedagogy. Our clinical simulation education model is designed to support student competence development, integration and movement across the fuzzy thresholds between higher education institutions (HEI) and clinical practice.

Traditional pedagogical models focus on knowledge, skills and attitude development. Our clinical simulation education model defines simulation pedagogy as supporting competence development, integration and diagnostic assessment in 'liminal spaces'. Liminal space (Latin *limens* = threshold) is the space occupied by a spectrum of virtual-practice learning environments, high-fidelity-simulated practice learning environments and simulated-austere environments sitting at the thresholds between HEI and clinical practice settings. This usage follows recent scholarship on 'the ways in which liminal situations can facilitate understanding of the technologies used to shape identities and institutions' (Horvath, Thomassen, & Wydra, 2015, p. 2).

This paper has two aims:

1. To summarise our previous translational research. This focuses on:
   a. Drug dosage calculation-competence modelling; and
   b. The application of *safeMedicate®* environments and associated technology enhanced boundary objects (TEBOs). These are pedagogical modalities designed to support competence development, integration and boundary-crossing, within the liminal spaces that exist between the ordered and abstract world of university classroom mathematics, and the messy situated world of clinical drug dosage calculation practice.
2. To explore the wider application of a constructivist-based clinical simulation education model to support competence development, integration and cross-boundary transfer within nurse education liminal spaces. This is the guiding pedagogical framework for applying the integrated nursing competence model illustrated in Figure 1.

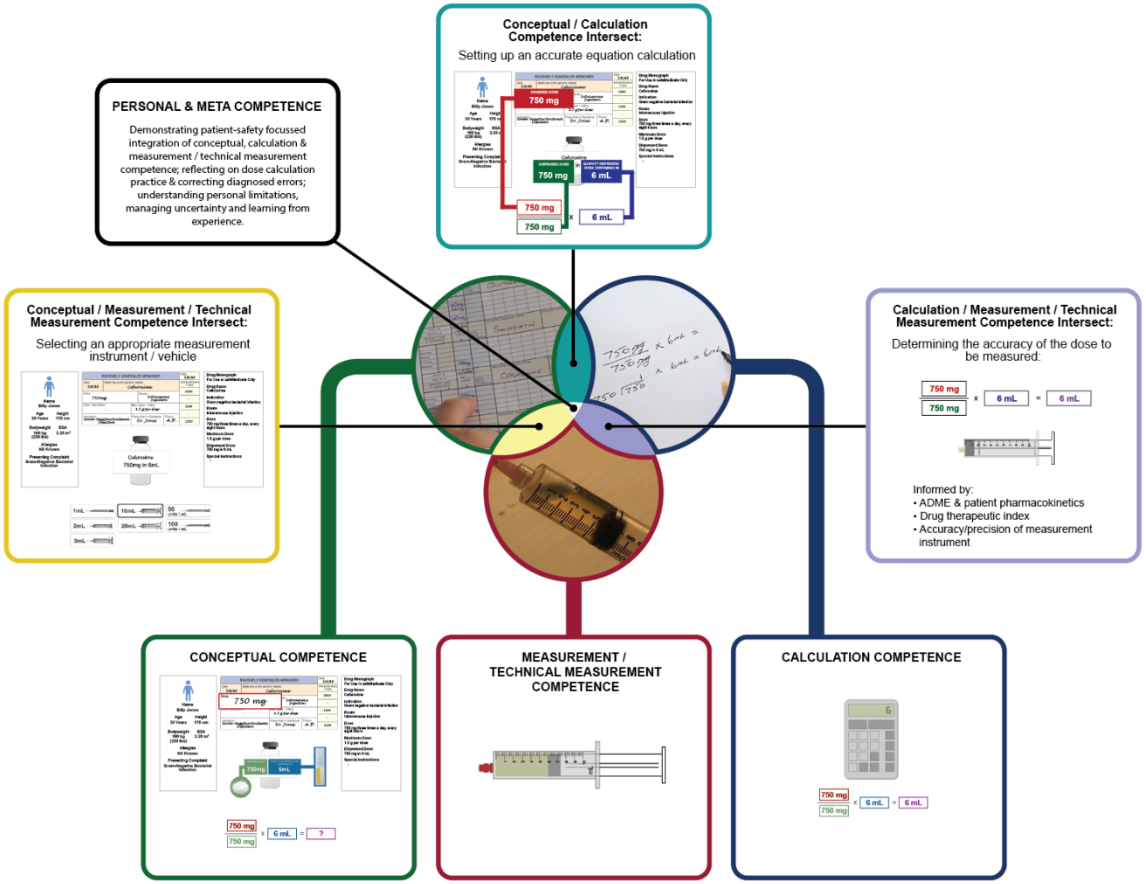
Aim 1: Reviewing the application of safeMedicate® and associated technology enhanced boundary objects (TEBOs), a virtual drug dosage calculation clinical learning and diagnostic assessment environment.

Our 28-year translational research programme on drug dosage calculation and health numeracy is summarised in Coben and Weeks (2014) and Cobbett et al (2017) respectively, and explored more widely in the *Nurse Education in Practice*, Safety in Numbers (2013) Special Issue (https://www.sciencedirect.com/science/article/pii/S1471595312001163): (Macdonald, Weeks, & Moseley, 2013; Sabin et al., 2013; Weeks, Clochesy, Hutton, & Moseley, 2013; Weeks, Higginson, Clochesy, & Coben, 2013; Weeks, Hutton, Coben, Clochesy, & Pontin, 2013; Weeks, Hutton, Young, et al., 2013; Weeks, Sabin, Pontin, & Woolley, 2013; Young, Weeks, & Hutton, 2013).

These papers present the constructivist-based pedagogical design features of *safeMedicate*®. This is a virtual drug dosage calculation clinical learning and diagnostic assessment environment (designed by KWW, AW, MB), that supports competence development, integration, diagnostic assessment and boundary-crossing. *safeMedicate*® is currently used in 12 countries across five continents. Over 4.3 million *safeMedicate*® authentic assessments have been undertaken to date, and this illustrates how nursing translational research is advancing global education practice in patient safety critical domains.

Figure 2 and the associated hyperlink illustrate an animated version of the *safeMedicate*® drug dosage calculation competence model and authentic pedagogical environment. The ensuing discussion further elaborates on the application of the authentic learning and diagnostic assessment environment and associated TEBOs illustrated in Figure 2. It explores how these occupy the liminal spaces between classroom and clinical practice settings, and act as pedagogical modalities supporting competence development, integration and boundary-crossing processes.

Figure 2: A composite *safeMedicate*® drug dosage calculation competence model (click on hyperlink or paste the link into a browser, to see the animated version of the model: https://www.safemedicate.com/publications/elsevier/videos/video_5.html)



Technology Enhanced Boundary Objects (TEBOs):

'Boundary object' is the core concept employed in the design of our cross-boundary environments, which is modified by applying the use of 'technology-enhanced' computer modelling. We present a brief overview of 'boundary object' modalities before addressing the 'technology enhanced' modality. Susan Leigh Star (2010) used 'boundary objects' in her work on problem solving in scientific communities, defining them as, 'objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites' (Star, 1988, p. 251). This allows, 'different groups to work together without consensus' (Star, 2010, p. 602).

An example of boundary objects from the world of drug dosage calculation are the central design features of, and the numerical information embedded in medicines management clinical objects e.g. clinical medication orders, drug monographs, drug vials and their labelling, syringes, IV medication pumps etc (see Figure 2). Although specific design features of these clinical objects may vary across different health communities and countries, the central features retain a common identity.

Bakker, Kent, Hoyles, & Noss, (2011) and Bakker, Kent, Noss, & Hoyles, (2008) used TEBOs to improve employees' understanding of the mathematics behind their work. Interactive software tools were used to model elements of a symbolic artefact embedded in the work process necessary for effective communication. Our use of TEBOs builds on this work. Figure 2 shows how TEBOs are modelled in the *safeMedicate*® environment. Computer technology is used to re-create the *technology enhanced* authentic features of medicines management objects (medication orders, vials, syringes, etc.) at the *boundaries* (third-space intersects) between the abstract world of classroom mathematics and the situated world of clinical drug dosage calculation and measurement. This helps nursing students move between the symbolic (number and symbol-based) and situated (in-context) real-world elements of the drug dosage calculation problem.

TEBOs help students in three ways here. First, to understand the context and meaning of the mathematical symbols and measurement units used in drug dosage calculation. Second, to understand how numerical symbols and measurement units are situated in clinical objects in practice settings, and how they represent quantification of drug dose weights (mass) or biological activity, volumes and rates of administration, etc. Third, they support understanding, integration, diagnostic assessment and cross-boundary transfer of the processes for developing:

a) *Conceptual competence:* horizontal mathematisation processes (Freudenthal, 1983; Treffers, 1987) involving understanding and translating situated problems into a mathematical form (i.e. setting up an equation);
b) *Calculation competence:* vertical mathematisation processes (Freudenthal, 1983; Treffers, 1987) involving a series of mathematical translations (i.e. undertaking accurate dose calculations of numerical values and measurement units);

c) *Measurement/technical measurement competence:* measurement of the resultant calculated dose numerical value using various forms of instrumentation/vehicles (e.g. syringes, IV pumps, capsules/tablets etc.; facilitated in the virtual environment by use of computer-generated, technology enhanced and interactive TEBOs); and,

d) *Personal and Meta competence:* demonstration of patient-safety focused integration of conceptual, calculation and measurement / technical measurement competence; reflection on dose calculation practice and correction of diagnosed errors; understanding personal limitations, managing uncertainty and the ability to learn from experience.

Using authentic learning and diagnostic assessment environments and TEBOs like this is very different from traditional pedagogical methods. These typically rely on classroom-based 'chalk and talk' teaching methods and word problems. The word problem example below is analogous to our authentic TEBO-mediated problem in Figure 2:

> *Cefuroxime 750mg has been prescribed for a patient with a gram-negative bacterial infection. You have Cefuroxime 750mg/6mL on hand following reconstitution of the drug. Calculate the drug dose/volume to be given to the patient.*

Word problems are highly stylized and try to describe clinical drug dose calculation problems. However, they do not represent the authentic, situated and nuanced problems students see in practice, and have limited capacity to support competence development, integration and cross-boundary transfer from classroom to practice settings, as we have illustrated in Figure 2 (see also Coben & Weeks, 2014; Weeks, Clochesy, Hutton, & Moseley, 2013; Weeks, Higginson, Clochesy, & Coben, 2013, for wider exploration of this concept).

In contrast to the typical representation and modelling of drug dose problems in a word-based form, Figure 2 illustrates an authentic integrated competence model re-created in a virtual clinical environment. It uses TEBOs (computer generated patient biographical, physiological and pathophysiological data formats, drug monographs, orders, vials and interactive syringes) to:

a) Model and support cross-boundary integration of iconic (concrete) and symbolic (numeric) features of drug-dosage calculation problems, within ‘third intersecting spaces’ between the authentic, situated and messy world of drug dosage calculation and the ordered and abstract world of classroom mathematics;
b) Support student transition across the cognitive and physical boundaries and thresholds that exist between HEI classrooms and clinical practice. This is facilitated through student sensitization and enculturation into the commonly anxiety-provoking world of vocational mathematics and drug dosage calculation and measurement.

The *safeMedicate*® virtual environment exists in a liminal space. It situates and supports student competence development and assessment at the interface and threshold between classroom and clinical practice. It does not attempt to bridge the theory-practice gap, rather it occupies it. Active student immersion, engagement and interaction with the virtual environment allows them to safely explore and harmlessly practice boundary-crossing between clinical medicines management and abstract mathematics modalities. This prepares students for transition and translocation across these boundaries into the real world of drug dosage calculation and wider medicines management (Weeks, Higginson, Clochesy & Coben, 2013). Following transition, translocation and demonstration of competence in practice, students no longer occupy a liminal space. They synthesise and integrate drug dosage calculation competence with the cognitive, functional, ethical, personal and meta competence requirements of wider medicines management practice.

At this juncture, we now explore the wider application of this model to support competence development, integration and cross-boundary transfer within the liminal spaces that exist between nurse education classrooms and clinical practice settings.

Aim 2: To explore the wider application of a constructivist-based clinical simulation education model to support competence development, integration and cross-boundary transfer within nurse education liminal spaces.

The UK NMC *Future Nurse* proficiency standards are ambitious in the level of knowledge and skill expected at the point of registration (NMC, 2018a). They will challenge nursing students' competence development, integration and boundary-crossing in many domains, e.g. in patient-safety critical areas such as advanced assessment, nursing diagnostics, pharmacology, preparation for prescribing and advanced health numeracy. The new standards will also challenge educators and clinical mentors when supporting students during their quest to achieve competence development, integration and boundary-crossing within professional nursing practice.

Within this latter context, Figure 1 models three-core *cognitive* (knowledge), *functional* (know-how and skill) and *ethical* (practicing within legal & professional codes of conduct) competence domains, together with four intersecting domains. We outline the characteristics of the four "third space" intersects below:

1. Cognitive-functional intersect (third space for facilitating ***synthesis and integration of professional practice with its underpinning professional knowledge base***).
2. Cognitive-ethical intersect (third space for facilitating ***knowing what's right*** by developing a professional moral compass and understanding

legal and professional codes of conduct).

3. Functional-ethical intersect (third space for facilitating ***doing what's right*** by demonstrating practice and emotional intelligence that is predicated on legal, ethical and professional codes of conduct and practice).
4. Central cognitive-functional-ethical intersect (third spaces for facilitating ***demonstration of personal and meta competence***, via reflecting in and on practice, managing uncertainty and learning from experience, which supports patient-safety critical reflexive practice and transition along the novice-expert continuum).

We now explore the alignment of this integrated competence model with a constructivist-based clinical simulation education model, aimed at supporting wider competence development, integration and cross-boundary transfer in nursing. The model has been adopted at the University of South Wales' (USW) Clinical Simulation Centre (CSC) to support advanced clinical practitioner competence development. It is currently being considered in an adapted form to support competence development aligned with the new NMC *Future Nurse* proficiency standards.

We continue the application of the constructivist work used to design and develop *safeMedicate*® to show how the USW CSC high-fidelity clinical simulation education model was developed. The paper concludes with an analysis of how the model informed the development of an environment designed to, (a) support nursing student competence development, integration and boundary-crossing, and (b) support early-career educators to craft competence development and literacy in simulation education pedagogy.

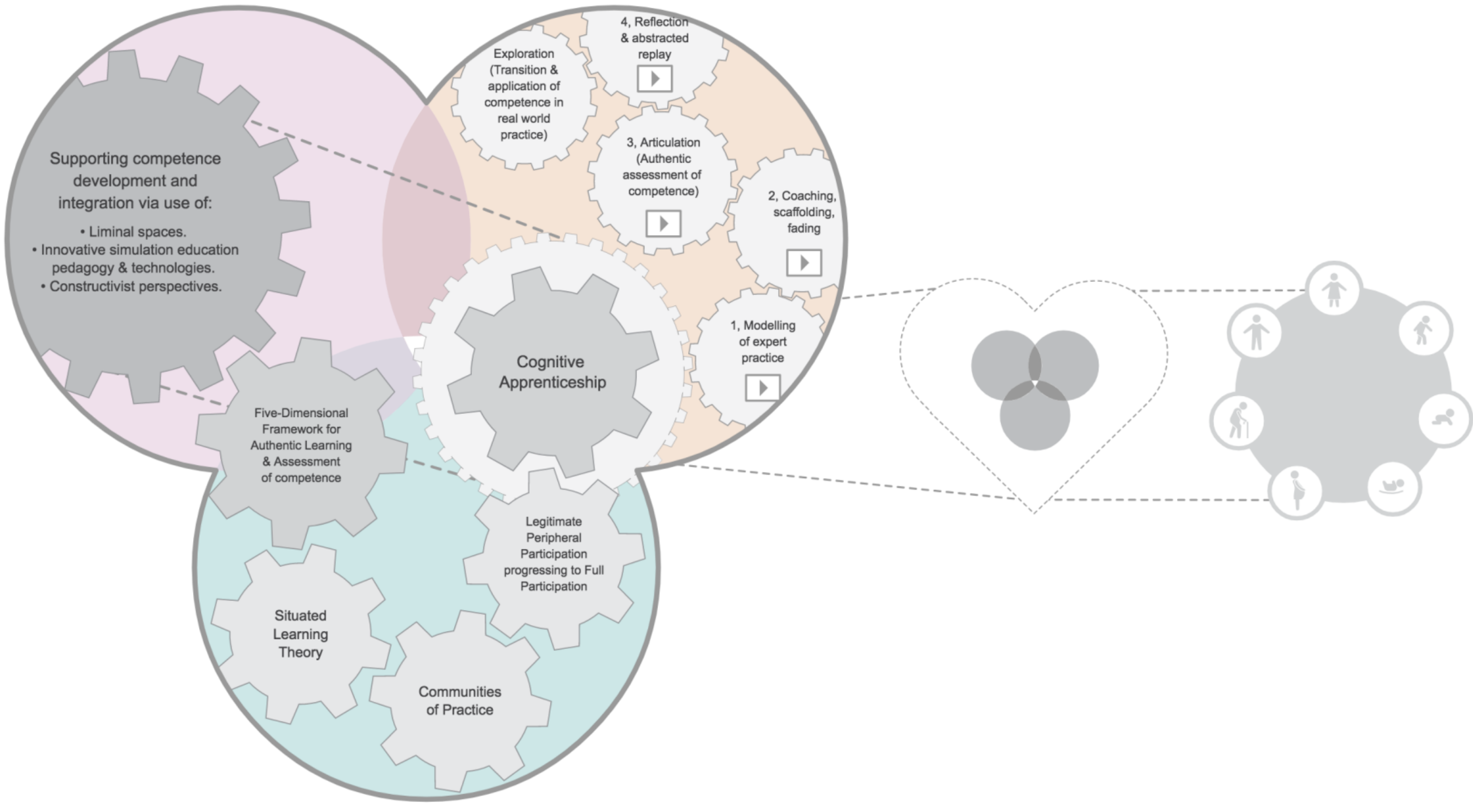
Murphy (1997) provided a useful checklist summarising constructivist characteristics. The checklist and associated guiding principles show how constructivist philosophy can be translated into practice. It can be used by early-stage and experienced educators to design constructivist learning environments and to operationalise constructivist concepts in virtual and other simulated practice learning environments. In Figure 3 we illustrate how multiple constructivist perspectives require integration to optimise the design and application of virtual *safeMedicate*® and high-fidelity simulated practice learning environments.

Figure 3 shows an animated interactive clinical simulation education model. The model uses a series of interconnected cogs to highlight how integrating constructivist perspectives operationalises our model of nursing competence (Figure 1). It shows the synergistic relationship between six components of our pedagogical framework, i.e.

- Competence development and integration within liminal space environments, using innovative simulation education pedagogy, technologies and TEBOs, and multiple constructivist perspectives;
- A five-dimensional framework for authentic learning and assessment of competence;
- Situated learning theory;
- Communities of practice;

- Legitimate peripheral participation leading to full participation;
- Cognitive apprenticeship.

Figure 3: Animated interactive clinical simulation education model that articulates the underpinning synergistic relationship between 6 components of the pedagogical framework (click on hyperlink or paste the link into a browser, to see the animation and four cognitive apprenticeship-based videos:
(https://www.safemedicate.com/publications/elsevier/model_2/)



Constructivist perspectives:

Constructivism as a philosophy and learning and education theory is based on ideas that people actively build knowledge and competence themselves, rather than receiving pre-formed knowledge by transmission from teachers or other sources. People draw on experience and engage with social environments where competence is to be applied (Reese & Overton, 1970). Understanding is achieved by actively building mental structures: schemata (Bruner, 1975; Murphy, 1997; Piaget, 1954, 1983; Rumelhart & Norman, 1978, 1981; von Glasersfeld, 1987, 1989; Wood, Bruner, & Ross, 1978); and representing generic concepts stored in memory (Gagné, Yekovich, & Yekovich, 1993; Mayer, 1992; Weeks, Hutton, Young, et al., 2013). Schemata are units of organized information and active mental models. They can modify and be modified by experience.

Piaget proposed two fundamental cognitive processes: assimilation and accommodation. These work reciprocally during schema construction. In adults, assimilation is the incorporation of new information into an existing cognitive structure. Accommodation involves the acquisition of new knowledge that challenges an existing schema to such an extent that it needs to be reshaped or replaced to accommodate the new idea. Both processes occur in nursing students to differing extents, depending on their previous schema constructions, and their experience and competence development in a wide range of subject areas e.g. biology, mathematics, pharmacology, behavioural and social sciences, professional studies, law and ethics, etc. (Weeks, Higginson, Clochesy & Coben, 2013).

In constructivist-orientated learning environments, there is a shift in the traditional teacher-student relationship dynamic. Teachers move from being 'mechanics of knowledge transfer' (traditional learning environments) to become 'midwives in the birth of understanding' (constructivist learning environments) (von Glaserfeld, 1995, cited in Murphy, 1997), with an emphasis upon the use of teacher-guided and learner-centric approaches (Backhouse, Haggarty, Pirie, & Stratton, 1992). Such approaches are designed to support nursing students in the development of the deep learning, competence and metacognitive skills required for clinically autonomous practice.

We next explore how we use such constructivist-based approaches to inform the design of the clinical simulation education model, within an authentic and situated community of practice, where engagement in phased participation, and apprenticeship-based learning activities, support competence development, integration and boundary-crossing.

A Five-Dimensional Framework for Authentic Learning & Assessment of Competence:

The USW CSC clinical simulation education model uses an adaptation of Guliker et al's (2004) five-dimensional framework for authentic learning and assessment (see Table 1).

Table 1 *Guliker et al's five-dimensional framework for authentic learning and assessment*

Dimension	Focus and Activity
Competence-based activities	Students exposed to authentic problem-solving activities. Involves integration of cognitive, functional, ethical, personal and meta competences. Competence-based activities should be meaningful and relevant to students, and reflect the full range of complexity, practice domains and problem-solving activity encountered in real practice settings.
Physical context	Competence development is learned and assessed in high-fidelity physical contexts. Should be as close to real situated setting structure and content as possible. Typical practice-based technical instrumentation should be used in similar time frames during clinical assessment, planning, intervention and evaluation processes.
Social context	Clinical simulation activities closely aligned to individual or professional group(s) involved in problem-solving and competence-based activity completion (e.g. nursing, medical, paramedic, physiotherapy, occupational therapy, social work etc.).
Criteria	Diagnostic-assessments use criterion-referenced outcomes based on criteria and expert rubrics (diagnostic frameworks) used in professional practice. They are realistic and transparent about processes and outcomes expected in practice.
Form/result	Demonstrated competence is measured against professionally relevant rubrics and outcomes that are observable, measurable and subject to multiple indicators of learning.

Situated Learning Theory

This theory proposes that knowledge and skills are inseparable. They are learned in real life situations, contexts and environments (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Resnick, 1987; Wakefield, 1996). We advocate situated learning approaches using authentic simulated clinical scenarios and associated competence-based activities. These form part of typical real-world clinical problem-solving requirements. Nursing activities sit in the physical and bio-psycho-social world of healthcare practice, alongside patients, multi-disciplinary team (MDT) practice, clinical objects, events and technological devices. Recent examples of embedding learning and assessment in authentic environments may be seen in Gieselman and Farruggia (2000), Gulikers et al. (2004; Gulikers, Kester, Kirschner, & Bastiaens, 2008), and Gonen et al. (2016).

Communities of Practice and Legitimate Peripheral Participation

We advocate a process that facilitates and supports the transition of early-stage educators and nursing students along a continuum of increasing participation and competence development in a simulated clinical environment and community of practice.

For educators: this is the phased development and advancement of competence, innovation and literacy in simulation education pedagogy and practice.

For nursing students: this is phased participation in a clinical simulation community of practice. It supports two elements – the integration of cognitive, functional, ethical, personal and meta nursing competence; and recursive preparation, cycling and transition of students from the university setting, through the CSC liminal space, and into real-world professional healthcare practice. The intention is not to bridge a theory-practice gap but to occupy a liminal space of cross-boundary transition. This is articulated in a cognitive apprenticeship framework (see below). Wenger and Wenger-Trayner (2015) identify three community of practice characteristics which we include in the model (see Table 2).

Table 2: *Incorporation of community of practice characteristics (Wenger & Wenger-Trayner, 2015) into the model*

Community of Practice characteristics	**Use in the model**
Domain of practice	Development of competence and diagnostic assessment in professional nursing practice, and simulation education pedagogy and practice.
The community	Active engagement of health professional educators, registered nurses, MDT and students in shared, supportive and interactive learning, and development of competence (Lave & Wenger, 1991). The model involves two communities: 1. Health professional educators who develop and advance their competence, innovation and literacy in simulation education pedagogy and practice. 2. Health professional educators, registered nurses and nursing students who actively engage with, and support the development, integration, diagnostic assessment and cross-boundary transition of nursing students' competence.
The practice	Engagement in the shared practice of competence development in the two communities. We advocate two processes: 1. Legitimate peripheral participation leading to full participation, and cognitive apprenticeship. Together these form integrated features of practice in a community underpinned by a shared and structured learning environment philosophy. 2. Legitimate peripheral participation involves the phased participation of learners in the vocational and professional practices of the community of practice. This typically starts with observation of experts' practice, and advancement along a continuum of increasing participation congruent with learners' experience and developmental stage (Lave & Wenger, 1991).

Cognitive apprenticeship:

This is a method for externalizing expert problem-solving processes that are often obscured from students. It facilitates learners' understanding, development and demonstration of the process, and their reflection on their own and expert practice (Collins & Brown, 1988; Collins, Brown, & Newman, 1989). See Weeks et al (2001), Weeks, Hutton, Coben, Clochesy and Pontin (2013), and Coben and Weeks (2014) for the theoretical basis of applying this framework to designing authentic clinical learning and diagnostic assessment environments. Figure 3 illustrates the five-phases:

1. Modelling of expert practice
2. Coaching, scaffolding and fading
3. Articulation and authentic assessment
4. Reflection and abstracted replay
5. Exploration

The central features of the five-phases are outlined below and video examples of phases 1-4 can be accessed via the embedded links below and within the model. The videos illustrate the central premise of a cognitive apprenticeship framework, applied within a community of practice, and organised to support nursing competence/simulation education pedagogy competence development, integration and cross-boundary transfer, among both students and early career educators respectively (the latter simulated here for illustrative purposes).

Modelling of expert practice:

This is the overt externalization and demonstration by expert educators and practitioners of competent practice and expert problem-solving processes. It takes place in an authentic simulated clinical environment in a community of practice. High-fidelity simulated clinical environments use TEBOs (e.g., human patient simulators, associated technology and instrumentation, patient records, etc.) situated in "third space" liminal thresholds between HEI and clinical practice, to support student competence development, integration and authentic assessment. Modelling of expert practice using TEBOs gives an observable and objective frame of reference against which students can model their assimilation and accommodation schema construction, and competence development and integration. At this point, students are typically observers. See Box 1 for a review of the Expert Modelling video embedded in Figure 3.

Box 1: Expert Modelling Video:
*(*https://www.safemedicate.com/publications/elsevier/videos/modelling.html*)*

The video captures expert modelling of:

- ***Functional competence*** (skills and know-how of the target process) integrated with an expert practitioner verbal commentary reflecting the…
- ***Cognitive competence*** (underpinning professional knowledge-base; the knowing-that and knowing-why rationale for the assessment/ intervention/evaluation target process)*;* and the…
- ***Ethical competence*** (the knowing what's right and doing what's right facets of legal and professional codes of conduct, associated with the target process).

This gives a diagnostic framework against which students' externalized schema for functional, cognitive, ethical, personal and meta competence can be assessed and evaluated. It is also a shared resource for the community of practice and is accessible to members of the educator, clinical practitioner and student community.

In this example we illustrate competence in chest percussion clinical assessment (an example typical of advanced assessment and examination skills that may form part of the new NMC proficiency standards). During modelling, the expert illustrates and explains the percussion technique, rationale and alternating right-to-left chest sequencing clinical assessment process.

Coaching, scaffolding and fading:

Following expert modelling, students are exposed to a variable period of coaching by expert educators/practitioners. During this process, students begin active supported engagement and legitimate peripheral participation in the community of practice. Under guidance, students practise and attempt demonstrations of the target competence process. A critical feature of coaching is *scaffolding,* i.e. expert help and reminders for students to increasingly approximate their competence development to the expert model, and to advance the development and integration of competence to a point of autonomy (Collins et al., 1989).

In primary and secondary education, Vygotsky defined the 'zone of proximal development (ZPD)' as, 'the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers' (Vygotsky, 1978, p. 86). In professional education, the ZPD supports the premise that learning can be 'stretched' by scaffolding students' extension of their current skills and knowledge to a higher competence level (Harvard, 1997). Once students have grasped the principles of the target competence process, the expert *fades* (reduces) support and feedback. Students continue to practise until they believe they are ready for formative/diagnostic or summative assessment. See Box 2 for a review of the Coaching, Scaffolding and Fading video embedded in Figure 3.

Box 2: Coaching, Scaffolding and Fading video:
*(*https://www.safemedicate.com/publications/elsevier/videos/coaching.html*)*

A critical feature of this phase is expert support for students in *assimilating* (incorporation of new information into an existing cognitive structure), *accommodating* (reshaping or replacing a schema to accommodate a new idea) and *constructing* accurate schemata for the target process. This involves:

- Giving students an advanced organizer for their initial attempts to execute a complex target process and to develop and integrate competence. In the video the student attempts to recall, verbalize and execute the target skill of chest percussion technique.

- Giving an interpretive structure for making sense of the scaffolding. This involves 'hand holding', hints, feedback and corrections from the expert during interactive coaching sessions. Scaffolding may take a number of forms along a spectrum of direct to faded support in the community of practice, and at various phases of legitimate peripheral participation. Scaffolding is shown at the start of the video, literally as 'hand holding'. The student is coached in hand positioning and the correct technique for eliciting appropriate sounds over areas of resonance or dullness of the chest.

- Giving an internalized guide for the period of relatively independent practice by successive approximation. The video capture of coaching and scaffolding sessions is an individual resource for students. It allows tracking of progress toward competence development and integration, and updating assimilation and accommodation, and schema construction. Once schema construction has begun, the cognitive structure can be updated by further observation and feedback. This encourages progress toward autonomy through reflection, learning from experience and managing uncertainty.

Articulation or authentic assessment:

A full review of articulation and authentic assessment applied to nursing is in Weeks, Hutton, Young, Coben, Clochesy and Pontin (2013); Weeks, Hutton, Coben, Clochesy and Pontin (2013) and Coben and Weeks (2014). Mueller (2005) defined authentic assessment as,

> a form of assessment in which students are asked to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills.
>
> (Mueller, 2005, p. 2)

In cognitive apprenticeship, articulation requires students to externalize their current schema for functional, cognitive, ethical and personal and meta competence. It externalises and articulates students' current competence schemata and its level of congruence when measured against clearly-articulated expert performance standards and rubrics. Authentic assessment like this is consistent with objective structured clinical examination (OSCE) principles. See Box 3 for a review of the Articulation and Authentic Assessment video embedded in Figure 3.

Box 3: Articulation and Authentic Assessment video:
(https://www.safemedicate.com/publications/elsevier/videos/articlulation.html)

Student externalized schemata are:

- Captured for authentic ***functional competence*** (skills and know-how of the target process).
- Integrated with student verbal descriptions of the rationale for the process, reflecting their ***cognitive competence*** (underpinning professional knowledge-base and knowing-that and knowing-why rationale for the target process).
- Integrated with their ***ethical competence*** (knowing what's right and doing what's right facets of legal and professional codes of conduct and practice, associated with the target process).

Students verbalise their underpinning cognitive competence of the target process, synchronised with demonstration of functional, ethical, personal and meta competences. This is analogous with the 'think aloud' approach (Banning, 2008) and supports integration of competence.

Reflection and abstracted replay:

Reflection in and on practice is a critical component of professional education and practice (Schön, 1983), and of personal and meta competence development. Reflection on the learning experience is a common feature of post-simulation/clinical event education practice in clinical practice and simulated clinical practice environments. However, students are commonly required to recall from memory 'what the clinical experience, incident, activity or assessment involved' or 'what you did' during the learning event.

From our experience, student recollection of the learning and assessment process may be flawed, particularly where multiple stimuli are competing for student attention during stressful assessment situations. An abstracted replay process may resolve this (Collins et al., 1989), as students focus their observations and comparisons directly on the determining features of their own and expert externalized competence schemata. See Box 4 for a review of the Reflection and Abstracted Replay video embedded in Figure 3.

Box 4: Reflection and Abstracted Replay video:
(https://www.safemedicate.com/publications/elsevier/videos/replay.html)

We video and synchronously *replay* an *abstraction* of the expert and student externalized schemata for:

1. Functional competence (skills and know-how of the target process).

2. Cognitive competence (underpinning professional knowledge-base, and knowing-that and knowing-why rationale for the target process).

3. *Discriminative error diagnosis* of the student's externalized schemata for competence in the target process.

We show an enhanced guided reflective and abstracted replay process using motion tracking technology principles to compare between the:

a) Expert externalized schemata for functional and cognitive competence in chest percussion: illustrating *appropriate and correct* right-to-left percussion and direct comparison of the right and left lung lobes; and

b) Student externalized schemata for functional and cognitive competence in chest percussion: illustrating *inappropriate and incorrect* unilateral, right-sided followed by left-sided percussion error of the right and left lung lobes.

This technology-enhanced reflection and abstracted replay process gives an expert frame of reference against which students can directly compare and adjust their developing schema for ever closer approximation to expert schemata and integrated competence models of practice.

Focusing student attention on features of schema and competence development and integration that are congruent with the expert model, and demonstration and diagnosis of errors does two things. First, it gives a diagnostic framework for supported remediation activity in the community of practice. Second, it supports progressive transitioning along the spectrum of legitimate peripheral participation and the novice-to-expert continuum.

Exploration:

This is the final phase of cognitive apprenticeship. The expert gradually withdraws support and the student gradually transitions into *exploring*, applying and integrating competence in real-world practice. This follows completion of expert modelling, coaching, scaffolding and fading, articulation and authentic assessment, reflection and abstracted replay, and any necessary remediation. It is recursive and mediated by continuous cycling of education support and student competence development, integration and cross-boundary transfer in the HEI, simulated clinical environments and clinical practice settings.

Similar to *safeMedicate*®, high-fidelity simulated clinical environments exist in a liminal space. They use TEBOs that situate and support student competence development and assessment in the third-space interface and threshold between HEI and clinical practice. They occupy the space rather than trying to bridge the gap between theory and practice.

Active student immersion, engagement and interaction with these processes in a high-fidelity simulated clinical environment allows them to safely explore and harmlessly practice crossing the thresholds and boundaries between classroom and clinical modalities. The mastery and demonstration of competence in the liminal space sensitises, encultures and prepares students for transition and translocation across the threshold and boundary into the real world of situated clinical practice. Following transition, translocation and demonstration of competence in practice, students no longer occupy a liminal space. They synthesise and integrate cognitive, functional, ethical, personal and meta competence requirements of professional nursing practice.

Conclusion

Given the rapid change facing nursing, now is the time to reconceptualise the education models and processes used to develop and assess competence. Educational inertia must be overcome if we are to prepare future nurses for the challenges of 21st century practice, and the new regulatory standards. As part of this process we have re-conceptualised the cognitive and physical modalities of a theory-practice gap created by the traditional organisation of health professional education practice. Here our pedagogical intention is not to bridge a theory-practice gap but to occupy a liminal space of transition. Having shared a nursing competence model that integrates cognitive, functional, ethical, personal and meta competence domains, we illustrated how the model may be supported using innovative simulation pedagogy and technology. We presented *safeMedicate*® and high-fidelity simulated clinical learning and diagnostic assessment environments as exemplars.

Virtual and high-fidelity simulated clinical environments are a powerful medium to support student transition across liminal space thresholds between HEI and clinical practice settings. We propose that this transition may be enhanced through our education models and a community of practice underpinned by constructivist and cognitive apprenticeship principles. Our environments occupy the liminal spaces where critical design features focus on authentic representations of real-world professional clinical practice. They use technology-enhanced boundary objects (TEBOs) as pedagogical modalities for supporting threshold and boundary crossing, and competence development and integration. We think there is scope for further development and application of TEBOs in developing, integrating and supporting boundary-crossing transition of nurse competence.

Using the language attributed to Alvin Toffler, our journey in developing *literacy in clinical simulation pedagogy* as educators, authentic simulated clinical environment designers, researchers, and clinicians, has followed a process of advancing patient safety through high quality health professional education theory development and praxis. This journey has involved:

1. ***Learning*** through (a) engagement with the wide range of pedagogies used in HEI, practice and simulated practice environments; (b) critically exploring the relationship between using these pedagogies with the students and early-stage educators we support and mentor; and (c) critically evaluating the experiences of the students, practitioners and educators we support in the development, integration and transferability of competence in professional nursing and education practice; and
2. Adapting to a changing world and the changing needs of students, through reflexivity and adjustment (***unlearning***), and evolving and updating (***relearning***) our pedagogical schemata.

We welcome reviews/critiques of our patient-safety critical education translational research, simulation pedagogy, education models, and virtual and simulated clinical learning and diagnostic assessment environments so the field may progress. Future papers will offer further analysis and evaluation of our *safeMedicate*® and clinical simulation education models within a spectrum of virtual and high-fidelity simulated clinical environments.

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Conflict of Interest:

Professor Keith W. Weeks, Alex Weeks and Matt Brown are officers of Authentic World Ltd, a nursing spin-out company of the University of South Wales and Cardiff University. Authentic World Ltd was the first joint university nursing spin-out company in the UK, and is responsible for the international translational research, knowledge transfer, design, development, health professional education technology evaluation, and international distribution of the *safeMedicate*® suite of virtual drug dosage calculation clinical environments. Professor Diana Coben is an officer of *SafeCalculate Ltd*, which distributes *safeMedicate*® in Australasia, under licence from Authentic World Ltd.