Numeracy in Action: Combining task models of medical devices with numeracy skills and technical competence

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Boundaries and Bridges: Adults learning mathematics in a fractured world
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Crossing disciplinary boundaries

• In this paper we cross disciplinary boundaries to focus on nurses’ numeracy in action as they engage with medical equipment via digital interfaces.

• We propose that by more closely aligning interdisciplinary work in numeracy for Nursing and the delivery of medication using medical devices we may help address the incident-rate in incorrect medication calculations and delivery.

• We are exploring the use of task models as a way of supporting safe, effective and efficient delivery of medication to the patient, taking as our example the use of infusion and syringe pumps in Nursing.
Judy Bowen
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• Computer Science researcher in formal methods and modelling for safety critical software
• Focus on medical devices such as syringe drivers and infusion pumps for the past 6 years
• Interested in users, usability, correctness and safety properties
Diana Coben

- Specialist in adult numeracy practices and education, especially in safety-critical work contexts
- Particular research interest in numeracy for Nursing for 25 years
- Member of an international interdisciplinary team investigating medication dosage calculation problem-solving (MDC-PS)
Our shared concerns in the safety-critical context of Nursing

Judy
• Engineering interactive safety-critical systems e.g., medical infusion pumps and syringe drivers
• Seeking to ensure devices behave correctly at all times
• Seeking to improve the design so that devices are easier to use

Diana
• Identifying and supporting the development of numeracy skills required to practise safely, effectively, efficiently and ethically including calculating and delivering medication dosages correctly using diverse delivery mechanisms
What’s the problem?

In the course of their work, Nurses and other healthcare professionals frequently engage with medical equipment via digital interfaces. Those interfaces typically involve activities such as entering numbers, checking that equipment is correctly calibrated, measuring and recording data, etc., sometimes calculation.

Patient safety is paramount so the stakes are high.
An example:
infusion / syringe drivers / syringe pumps
- designed to deliver drugs automatically, relieving the need for multiple injections

... and what can go wrong
Hunt orders probe into faulty opioid syringe pumps amid allegations thousands may have died*

Graseby MS 16 A and MS 26 syringe pumps were used in UK palliative care until they were phased out in 2015

While one model is set to deliver opioids over 24 hours, the other, which looks identical, performs the same task in 60 minutes, meaning patients risk being given a day’s worth of drugs in just one hour. Doctors have said they resorted to sticking on makeshift aluminium strips so they could tell the difference.

Dr Richard Ian Reid ... told police he could not remember which Graseby device was which, saying they were “totally confusing” and “really dangerous”.

Both models were in use at Gosport War Memorial Hospital during the tenure of Dr Jane Barton, who was last week held responsible for policies which led to the deaths of 656 patients between the late 1980s and 2001 due to excessive use of diamorphine by an inquiry led by the former Bishop of Liverpool.

An ongoing global problem

Between 2005 and 2009:

• United States Food and Drug Administration (FDA) received approximately 56,000 reports of adverse events associated with the use of infusion pumps, including numerous injuries and deaths

• manufacturers recalled 87 infusion pumps to address identified safety concerns

Since 2009 the situation has improved very little, despite increased focus on these issues
Common problems with devices

• Number entry
  – Number entry methods
  – Number position and decimal point handling
  – Number roll-over problems

• Same but different
  – Devices that look identical but have different firmware leading to subtle differences in use

• Similar but different
  – Devices that look similar but behave differently
... more syringe pumps
Underlying causes

• User interfaces, interaction and users are not treated with the same rigour as the underlying functionality of the device
• No common method for verifying correctness prior to FDA approval
• No common methods for reasoning about user interaction at a formal level (that allows for model-checking and theorem proving)
What’s the solution?
Towards an effective solution through interdisciplinary research 1

Engineering interactive systems

• Model-based development
• Models at varying levels of abstraction with a common formal underpinning
• Models of functionality, interfaces and interaction
  – Verification and validation
  – Model-checking
  – Testing
Towards an effective solution through interdisciplinary research: 2

Authentic numeracy education based on a sound model of competence

e.g., in medication dosage calculation problem solving (MDC-PS) based on research set out in the ‘Safety in Numbers’ Virtual Special Issue of Nurse Education in Practice

https://www.nurseeducationinpractice.com/content/safety
MDC-PS competence model

(Weeks et al, 2013)
Competence model

The competence model for MDC-PS represents

- the intersection between the ability to interpret the dosage calculation problem and accurately set up rate equations (conceptual competence)
- the correct calculation of accurate numerical values for the dose and rate of administration (calculation competence)
- the selection of appropriate measurement vehicles and accurate measurement of the dose and rate of administration (technical measurement competence)

An uncorrected error in any one or more of these will result in a medication dosage error in the practice setting

Technical measurement competence is particularly relevant to our focus here as it involves the use of medication delivery devices
Towards an effective solution through interdisciplinary research: 3

Task Models

• Provide a link between the interactive system design and the numeracy demands, practices and associated education

• Tasks are fundamental to both
  – ensuring devices are designed to correctly support tasks in a usable fashion
  – ensuring healthcare personnel can complete specific tasks relating to medication calculations
Task Models of Medical Devices

Set up and start infusion

Turn on --- Insert syringe --- Set volume * --- Set time * --- Confirm rate --- Start infusion
Our goals

### Formal Models of Medical Devices
- Interface
- Interactions
- Functionality

### Technical Competence Models of Healthcare Tasks
- Numeracy demands
- Numeracy practices
- Authentic numeracy education

### Task Models
- Based on device models
- Based on user actions and knowledge

Using task model comparisons:
- Inform device design
- Inform user education
- Identify and mitigate risk of error
We believe it’s worthwhile continuing to explore this approach

- Formal models and device models may suggest areas that should be included in numeracy education, especially for the development of technical competence.
- Task models of authentic numeracy tasks may suggest improvements or enhancements of medical devices.
Comments and questions welcome!

Thank you

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References


• Weeks, K.W. & various authors (2013/2016) ‘Safety in Numbers’ Special Issue of Nurse Education in Practice
  https://www.nurseeducationinpractice.com/content/safety