Original Article

Effect of Exposure to Asynchronous Virtual Clinical Environments on Actual/ Perceived Competence in Drug Dosage Calculation: A Pilot Study

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Abstract

Introduction: Nursing students are expected to be 'practice ready' on qualifying. This includes safe medication administration. This pilot study investigates the relationship between exposure duration to asynchronous virtual drug dosage calculation scenarios and nursing student actual and perceived competence.Methodology design planned for larger scale main study was tested and piloted.

Methods: A randomised quasi-experimental research design (pre- and post-test) was used. Purposive sampling was used to recruit six groups of second/third-year pre-registration undergraduate nursing students from six sites (UK and Canada). Students were randomly assigned to four groups of different exposure to the safeMedicate® COVID-19 education module.

Results: Student actual competence increased across all four groups, and their perceived competence mirrored this. There was no clear dose-response relationship demonstrated.

Conclusion: Valuable insights into the effects of asynchronous virtual learning on drug dosage calculation competence among nursing students were generated. Improvement in actual and perceived competence was found, but no clear dose-response relationship. Further research on a larger scale is needed to explore the impact of instructional design, feedback, and interaction on learning outcomes.

Keywords: medication errors; medication calculation; simulation; competence; nursing student; patient safety.

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Introduction

Administering medications is one of the most high-risk tasks in health care. Few studies have examined the barriers nurses experience, and the strategies used to prevent medication related harm. The World Health Organisation (WHO) highlight medication errors as a serious global issue. It is the third leading cause of death in the USA[1]; 1:20 patients globally experience preventable medication-related harm[2]. In 2017 WHO launched‘ Medication Without Harm’ to address medications as a top priority [2] and stressed the topic’s importance in healthcare curriculum[3][4].

Medication competence is complex and requires strong theoretical pathophysiology, pharmacology knowledge, critical analysis, numeracy and calculation skills[5][6]. Nursing students report increased anxiety about medication calculation and administration, which can result in medication errors, near misses or actual patient harm[7][8]. These frequently occur at administration due to inaccurate dosage calculation[9][10]. Nursing student under-reporting of medication errors may be due to shame, guilt, fear of repercussion, decreased confidence, and anxiety[11][12]. It is prudent to understand the complexity of how nurses are educated in preparing to administer medication.

Since the COVID-19 pandemic, medication safety concerns have continued due to the pandemic’s lasting impact on the ongoing global nursing shortage. COVID-19 triggered a call for nursing students to be practice ready and competent in calculating and administering medication on qualifying[4][13][14][15][16][17][18]. The pandemic highlighted that all nurses must be ready to safely practice where rapid mobilization/ healthcare resource adaptation was needed to minimize COVID-19’s impact on populations and health systems[19][20][21][22][23].

Medication administration is a practice-based skill. Nurses need the opportunity and right environment to acquire this skill before administering medications to real patients. Consistency and practice opportunity availability throughout each nursing curricula year is important for improving medication safety competence and confidence[5][24][25]. These may not be routinely available in practice settings[28][8]. Medication errors account for 38% of adverse practice events reported by undergraduate nursing students[3][10]; difficulty in dosage calculations and poor mathematics skills are key contributory factors[12][26][27]. Traditional clinical learning environments are not the best, safest or only locations for students to develop competency and confidence in medication calculation and administration skills[7][29][30].

safeMedicate® developed an international COVID-19 version of its Authentic Virtual Drug Dosage Calculation Clinical Learning Environment (VLE) in 2020 to support RN competence adaptation. It included typical COVID-19 therapies for hospital patients with pneumonia and pyrexia and for patients requiring critical care therapies.[39][40]

Given the knowledge and experience of the nursing student sample in this study, actual competence assessments excluded critical care therapies, focussing on minimal requirements for safe pandemic practice[41]. The 12 test items included varied drug formulations/administration routes and complexity levels (Table 1). Perceived competence is a pertinent corollary for investigation given the commonly reported decreased confidence and anxiety associated with drug dosage calculation, i.e. how confident students perceive they correctly solve each test-item.

Simulation-based education has a positive effect on developing knowledge and confidence for medication administration[31][32][33][6]. There is opportunity to understand how simulation-based education and technology may improve medication administration due to increased use of technology-driven strategies to support quality and safety teaching in nursing education[34][35][36][37].

Table 1: 12-item-safeMedicate® COVID-19-specific drug therapy test of actual competence

Number of Pre- & Post-Test items (questions)	Drug Formulation	Drug Administration Route (PO=Oral; IV= Intra-venous)	Item Rubric (Complexity) Level	Item- Score weighted by total problem-solving phases (% per phase)	Total Score
2	Tablets & Capsules	PO	Unit Dose	3 x (33.3%)	6
2	Oral Suspension	PO	Multiple Unit-Dose	3 x (33.3%)	6
1	Intravenous Injection	IV	Slow IV-Injection (Timed)	4 x (25%)	4
2	Intravenous Infusion	IV	Intermittent Infusion (Standard Dose)	3 x (33.3%)	6
5	Intravenous Infusion	IV	Intermittent Infusion (Bodyweight-Based Dose)	6 x (16.6%)	30
					52

Method

Aim

To investigate the effect of exposure to asynchronous online virtual clinical environments of differing duration on actual and perceived competence in COVID-19 related drug dosage calculation.

Research Questions

1. What is the effect of exposure duration to an online virtual clinical environment on nursing students' actual competence in COVID-19 support drug therapy?
2. What is the effect of exposure duration to an online virtual clinical environment on nursing students' perceived competence in COVID-19 support drug therapy?

Design

A pilot pre/post-test randomised quasi-experimental research design was used.

Sample/setting

Second- and third-year pre-registration Bachelor of Science nursing students were recruited via purposive sampling from four UK sites: University of Chichester, Anglia Ruskin University and Bournemouth University (England), and Robert Gordon University (Aberdeen, Scotland), and two Canadian sites: Nipissing University and Queen's University. We recruited 128 students (n=38 completed the study following high attrition rates); the International Standard Randomised Controlled Trial Number registry identifies a sample size of 30-40 for feasibility studies(38).

Data Collection

Ethical approval was obtained from each site in late 2022. The target population received an invitation-to-participate email from the study administrator. Controls were put in place for numeracy skill variation and orientation to the virtual learning environment (VLE) (safeMedicate® VLE/ competence-perceived competence metric). Data was collected January-October 2023 at each site using:

1. 12-item-safeMedicate® COVID-19 specific drug therapy test (0%-100%) to measure actual competence.
2. safeMedicate® VLE/competence-perceived competence metric(0%-100%) to measure perceived competence.

Concept and Operational Definitions

Actual Competence is an objective measure of individual knowledge, skills and abilities in a specific context. The safeMedicate competence model was used as the operational definition.

Supplementary Material: Video 1[42]: Models drug dosage calculation problem-solving and error diagnosis for:

- Conceptual competence: Dose/Rate of infusion equation set-up ability.
- Calculation competence: Dose/Rate of infusion computation ability.
- Measurement/Technical Measurement competence: Dose/Rate of infusion measurement ability.

Perceived competence is a psychological construct based on individual self-evaluation of capability in a specific context. We defined it as how confident students were that a test-item was correctly solved. A slide-bar scale metric (range 0%–100%) was used to record perceived competence. We looked for any discrepancy between actual and perceived competence, i.e. were students under/ over-confident, or accurate in their perception of their actual competence.

The intervention used the safeMedicate® Authentic Virtual Drug Dosage Calculation Clinical Learning Environment (VLE) to engage students. The VLE is based on an adapted cognitive apprenticeship model[42]. This is a method for externalizing expert problem-solving processes that are often obscured from students. It uses constructivist-based modelling, coaching, scaffolding and abstracted replay feedback that facilitate learners' understanding, development and application of competence, and reflection on their own and expert problem-solving practice[42].

Students undertook authentic diagnostic assessments compared with expert problem-solving models (**Supplementary Material: Videos 2, 3 & 4**)[42]. They had detailed diagnostic reports and feedback on their actual and perceived competence assessment activities and outcomes compared to correct answers throughout the study. Abstracted replay feedback loops and error diagnosis help students identify their strengths and areas needing remediation. They had variable 0–3-week exposure to the safeMedicate COVID-19 Education Support Module (Intervention).

Supplementary Material: Video 2: Illustrates a comparison of student conceptual, calculation and technical-measurement competence assessment processes and outcomes, compared with an expert problem-solving model.

Supplementary Material: Video 3: Illustrates an example of abstracted-replay feedback, diagnosis of an actual competence problem-solving error, and self-rated over-estimation of competence. Over-estimation of competence was a limited finding in the study (Figure 2). It has been illustrated here to highlight early diagnosis of patient-safety critical errors, and how this can act as a powerful learning event in the education process.

Supplementary Material: Video 4: Shows diagnosis of actual-competence development, and self-rated under-estimation of competence. Under-estimation of competence was a common finding (Figure 2).

Healthcare Numeracy Assessment

The safeMedicate® 25-item Healthcare Numeracy Assessment (HNA) assessed student baseline competence in 14/20 essential healthcare numeracy skills[41]. Test items focused on fundamental mathematics stripped of specific nursing contexts. Test item-score reliability was used as a criterion for item selection. HNA test results were used to assign students to four groups via stratified competence profiling. This controlled for student numeracy skill variability.

Procedure

Phase	**Activity**	**Group**	**Weeks**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Orientation	All								
	HNA Assessment	All								

Continue.........

2	Group assignment	All								
3	safeMedicate orientation module	All								
4	12 item COVID-19 Pre-Test	All								
5	Exposure to safeMedicate COVID-19 Education Support module intervention	Control								
		1								
		2								
		3								
6	12 item COVID-19 Post-Test	Control								
		1								
		2								
		3								

Figure 1: Study design

Figure 1 documents the study design. It sets out project activities and timelines.

Ethics considerations

Ethics approval was obtained at all sites.

Data analysis

Data analysis methodology consisted of:

(a) Descriptive and inferential statistical analyses conducted using SPSS V29. Data were quantified using means and standard deviations (SDs). Non-parametric statistical tests were carried out as participant attrition resulted in a dataset (n=38) that did not meet assumptions for parametric analysis. Statistical significance was set at an alpha level of $p < 0.05$.

(b) Piloting analysis of correlation between actual and perceived competence [Spearman's Correlation]; and analysis of treatment effect for pre-test/post-test actual and perceived competence [ANCOVA] as part of methodology design testing. This will be used for larger sample size data analysis in the main study.

Results

Study Assessments

Students' actual competence and perceived competence results were compared before/after variable exposure to the intervention. The four groups were homogeneous at baseline, i.e. no differences in the mean pre-test assessments. Actual and perceived competence mean scores increased in the post-test assessments, including the control group which did not have any intervention exposure (Table 2; Figure 2). However, abstracted replay pre-test competence/error diagnostic feedback (see Video 3) may have acted as a learning event; this will be considered during the design of the main study.

Table 2: Analysis of difference between mean HNA and pre-test to post-test actual and perceived competence percentage scores (*Based on Kruskal-Wallis test)[43]

Intervention Group	Statistic	HNA	Pre-Test		Post-Test	
			Actual Competence	Perceived Competence	Actual Competence	Perceived Competence
Group 1	N	15	15	15	15	15
	Mean	83.47	77.18	64.53	95	82.78
	SD	14.09	22.6	27.05	6.77	25.45
	Min	52	38.46	15.83	80.77	0
	Max	100	100	99.17	100	100
	Median	88	86.54	77.33	98.08	91.25

Continue.......

Group 2	N	11	11	11	11	11
	Mean	88.73	79.72	73.48	87.94	83.9
	SD	11.98	24.16	22.89	21.71	20.98
	Min	60	32.69	39.42	34.62	38.25
	Max	100	100	100	100	100
	Median	92	86.54	77	100	92.92
Group 3	N	8	8	8	8	8
	Mean	81.5	78.85	77.93	95.67	97.68
	SD	17.75	24.59	20.92	5.51	3.78
	Min	48	40.38	39.83	86.54	89
	Max	100	100	100	100	100
	Median	86	87.5	79.79	98.08	99.17
Control Group	N	4	4	4	4	4
	Mean	84	67.31	66.98	84.62	82.63
	SD	13.86	19.8	24.75	20.05	9.31
	Min	64	44.23	40.83	55.77	69.25
	Max	96	86.54	99.58	100	89.5
	Median	88	69.23	63.75	91.35	85.88
Group Comparison*	p-value	0.712	0.682	0.627	0.738	0.085

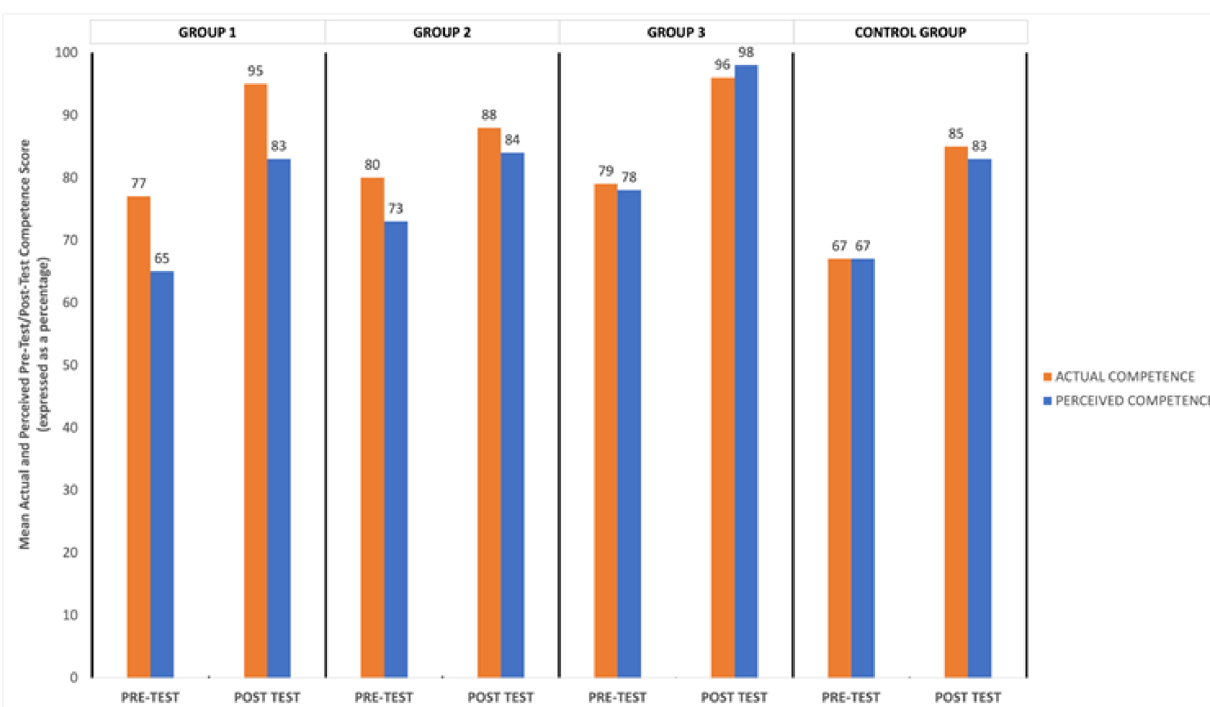

Figure 2: Mean pre-test/post-test actual/perceived competence scores

Students performed better on the 12 item COVID-19 post-test of actual competence after the intervention. Figure 3 shows the change between individual student pre-test score and post-test score. Table 3 shows the change in average pre-test score (mean 77%; median 87%), to post-test score (mean

92%; median 98%). A Wilcoxon Test indicated this was statistically significant (p <0.0004). Although a small pilot study sample, students achieved these outcomes over 0-3 weeks rather than the typical 3-4 years associated with pre-registration/licensure nurse education programmes.

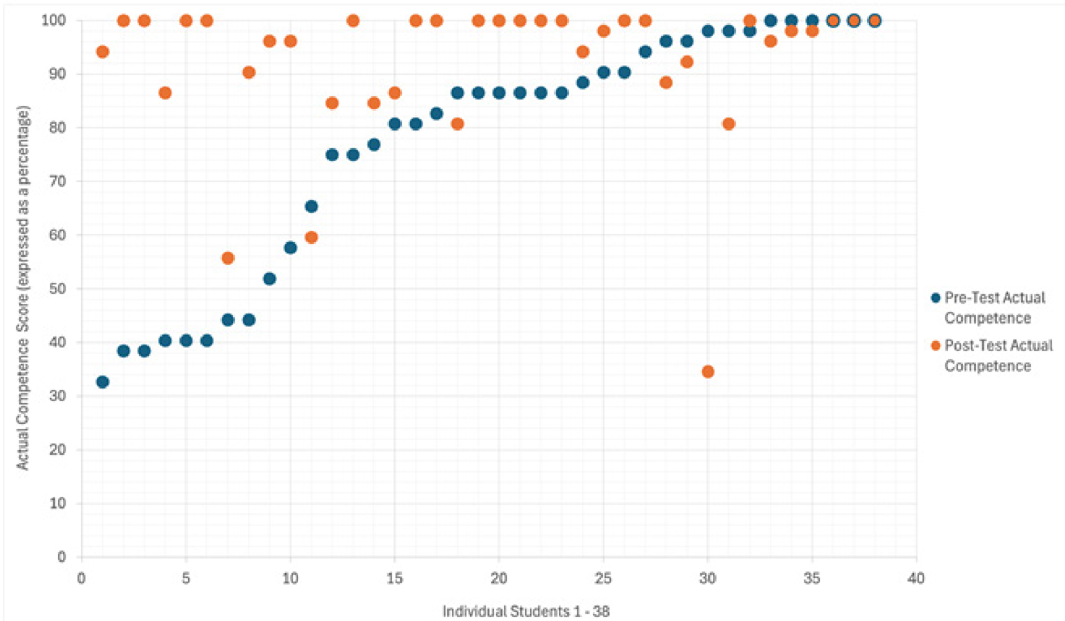

Figure 3: Change in Pre-Test/Post-Test Actual Competence scores

Table 3: Wilcoxon Signed Rank Test Analysis

Descriptive Statistics

						Percentiles		
	N	Mean	SD	Minimum	Maximum	25th	50th (Median)	75th
Pre-Test Actual Competence	38	77	22.59	32.69	100	59.61	86.54	96.15
Post-Test Actual Competence	38	92	14.16	34.62	100	88.94	98.08	100

Ranks

	Mean Rank	Sum of Ranks
Pre-Test Actual Competence	20.5	532.5
Post-Test Actual Competence	10.8	97.5

Rank Differences

Negative Ranks	26
Positive Ranks	9
Ties	3
Total	38

Test Statistics

p-values	
1-tail	0.0002
2-tail	0.0004

Discussion

Findings suggest general improvement across all groups in actual and perceived competence including the control. Significant outcome differences between groups with varied exposure duration were not evident. Increasing exposure time did not translate into substantial competence improvement.

Improvement in actual and perceived competence suggests initial VLE and baseline assessment exposure might have enhanced competency. Assessment outcome feedback can foster incremental learning, boosting competence and confidence[44][42]. Increased post-test perceived competence aligns with research on VLE and self-assessment influence on learners' perceived proficiency[45] [46]. Lack of significant differences between groups with varying exposure durations contradicts earlier studies advocating for prolonged engagement with VLEs to achieve competence[47].

Our findings indicate a shift in students' self-awareness and competence perception. This counters existing evidence that suggests students overestimate their competence[48]. Our work suggests students are cautious in overestimating their competence, which is an understandable safety conscious response.

Our study included VLE feedback on student performance for review, and indicates that simulation-based intervention effectiveness is based on instructional design and not dependent on exposure time. Findings may be related to small sample size and need repeating with a larger sample. The differences in perceived competence before/after intervention highlight the psychological and confidence-building value of VLEs, consistent with previous research on self-efficacy enhancement effects of digital learning[36] [49].

The results suggest revisiting VLE design. Prolonged exposure alone did not result in significantly better outcomes. Our findings indicate the potential of short-term exposure to VLEs to positively influence actual and perceived competence. Brief, focused interventions may rapidly bolster nursing students' confidence and awareness. This may be valuable in pandemic preparedness or acute care settings where speedy upskilling to mobilize healthcare staff adaptation is critical. However, we would strongly advocate for repeated periodic assessment to evaluate competence retention and address any skill decay.

Implications

This pilot study provides valuable insights into the use of asynchronous virtual learning environments (VLEs) for developing drug dosage calculation competence i.e. brief exposure, actual competence development, and feedback design.

Repeated simulation exposure is associated with improvements in nursing students' self-efficacy, perceived competence, and learning satisfaction[50]. However, our findings suggest that even brief exposure to accessible, simulation-based learning with structured feedback and opportunities for repetition, can enhance actual as well as perceived competence. This has practical implications for nursing education and healthcare provider strategies where rapid upskilling is required, such as public health emergency response or workforce shortages.

Our study adds weight to Koukourikos et al's findings[51] of increased perceived clinical competence through VLE use during COVID-19, by showing positive changes in actual competence. Although we faced challenges as a multisite, international collaboration over differing time zones, this allows us to share diverse perspectives on undergraduate nursing learning strategies in a global context. Our findings echo Bae et al's systematic review[52]. This supports using VLEs to enhance clinical reasoning, problem-solving, and communication competencies when traditional clinical placements are limited and may not provide consistent or safe opportunities for skill acquisition. Our work helps educators incorporate targeted, technology-driven interventions to complement traditional clinical placements.

The results show the importance of feedback design, where instructional strategies may be more influential than exposure duration alone. Future research should expand on these findings by using larger samples, and longitudinal designs to assess skill retention and explores stematic integration of VLEs into curricula to build confidence and competence in drug dosage calculation.

Limitations

This study has several limitations. First, the small sample size (n=38) as a result from the high attrition rate, limit the statistical power of the findings and restrict generalizability beyond the study population. As a pilot study, results should be interpreted with caution until replicated with larger, more diverse cohorts. Second, participants were recruited from selected universities in the UK and Canada; therefore, findings may not reflect the experiences of students in other regions or curricula. Third, the reliance on self-reported measures of perceived competence introduces the possibility of response bias, as students may have under- or over-estimated their abilities despite efforts to mitigate this through diagnostic feedback. Fourth, the short duration of exposure (0–3 weeks) provides only a snapshot of competence development; longer-term retention of knowledge and skill decay were not assessed. Finally, while the intervention targeted drug dosage calculations related to COVID-19 therapies, exclusion of critical care scenarios limits insight into competence in more complex, high-acuity contexts.

Conclusion

This pilot offers valuable insights into the effects of asynchronous VLEs on drug dosage calculation competence among nursing students. Improvements were observed in actual and perceived competence, but lack of a clear dose-response relationship points to future research to explore the impact of instructional design, feedback, and interaction on learning outcomes. Simulation-based education remains a promising avenue, but its implementation should be refined to maximize actual and perceived competency in high-risk tasks like medication administration.

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Ethical Clearance : This research received Ethical approval from the Research Ethics Board at Nipissing University, North Bay, Ontario, Canada.

Conflicts of interest statement

Dr Keith W. Weeks, Alex Weeks and Matt Brown are directors of Authentic World Ltd, a nursing spin-out company of the University of South Wales and Cardiff University, UK.

Authentic World Ltd was the first joint university nursing spin-out company in the UK (founded 2004), and its Thought Leadership team is responsible for the international translational research, knowledge transfer, design, development, health professional education technology evaluation and international distribution of the safeMedicate® suite of authentic virtual medicines calculations and nursing mathematics clinical education environments. Dr David Pontin is a director of Numeric Generics Ltd, an associate company of Authentic World Ltd.

A university-engaged statistician independent of the research team carried out the data analysis reported here.

The authors declare no conflict of interest in the completion of this research.

Supplementary Material

1. Supplementary Material: Video 1: safeMedicate competence model https://safemedicate.com/publications/comp pilot study/sm model..html
2. Supplementary Material: Video 2: Example of safeMedicate authentic actual/perceived competence pre-test assessment process. https://safemedicate.com/publications/comp pilot study/sm pre assessment.html
3. Supplementary Material: Video 3: Example of safeMedicate pre-test abstracted-replay feedback on student and expert problem-solving processes. https://safemedicate.com/publications/comp_pilot_study/sm_pre_feedback.html
4. Supplementary Material: Video 4: Example of safeMedicate post-test abstracted-replay feedback on student and expert problem-solving processes. https://safemedicate.com/publications/comp pilot_study/sm post feedback.html

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