

PROGRAMME DESCRIPTION

Virtual patients in clinical decision making – A design-based research approach

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Abstract

This paper reports on a longitudinal, design-based research (DBR) study to promote clinical decision making using a virtual patient (VP) simulation for emergency renal care. The VP was piloted with pharmacy students, then offered as an interprofessional learning exercise for pharmacy and medical students, before being introduced as part of the curriculum. In this paper, the DBR framework used to design, implement and evaluate the VP is described. The iterative changes made and implications for integration of the virtual patient simulation in the pharmacy curriculum are discussed.

Introduction

Design-based research (DBR) aims to improve education practices through an iterative process that not only evaluates the innovation but systematically attempts to refine it. The process results in design principles that can guide similar research and development (Amiel & Reeves, 2008; Wolcott *et al.*, 2019). Existing literature is used to inform a response to a complex educational scenario. The resulting intervention is designed to be iteratively developed through a pilot offer and ongoing evaluation. The end result of a DBR process is a viable educational intervention, which either furthers the understanding of the current literature or adds new knowledge and understanding to help educators make sense of similar complex educational problems and interventions. The DBR framework was applied to identify and address the need for clinical decision making in the pharmacy curriculum at the University of Auckland (Figure 1).

In this paper, the research process and how a virtual patient simulation was designed, piloted and evaluated as a useful learning intervention to develop clinical reasoning within pharmacy and interprofessionally is

discussed. The research and development presented here occurred between 2014 to 2019 with the actual trials of the simulation conducted over a two-year period (2017-2018). Data were collected through direct observation, student feedback (online and paper-based questionnaire, interview), educational design (user testing) and teacher reflections and expert reviews of the intervention. Approval for evaluative data collection and reporting was granted through the University of Auckland Human Participants Ethics Committee (Ref 022393).

Why design-based research?

Two main reasons for using a DBR framework to guide this study were to collaboratively research, adopt and disseminate evidence-based educational practices in pharmacy; and to promote a shift away from the technology focus of interventions to deepen understanding of how learning occurs. The research drew on the expertise of specialist renal consultants, pharmacists, technologists, educational designers, teachers and learners.

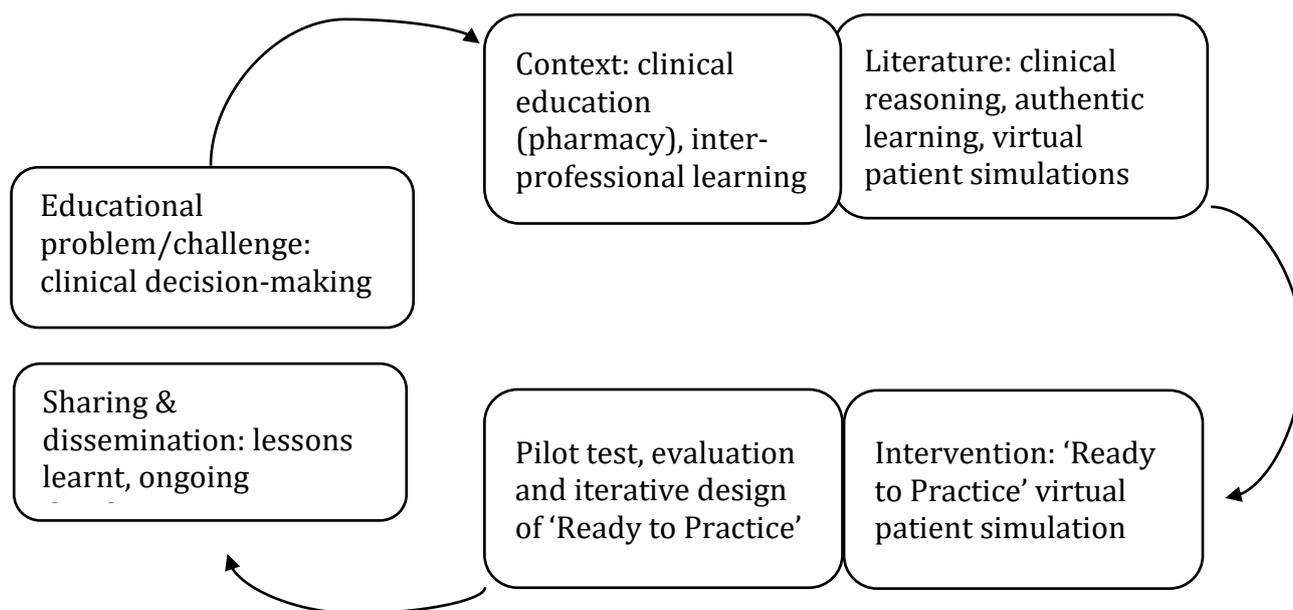


Figure 1: DBR framework for developing clinical decision making

Educational problems are complex, so a purely experimental approach is unhelpful in developing and adapting a contextualised intervention that also furthers our understanding of the broader educational issue. Educational researchers are encouraged to move towards systematic and collaborative methods of investigation to ensure their research can make a difference (Wang & Hannafin, 2005; Wolcott *et al.*, 2019). DBR embodies this and makes researchers develop a purposeful concern for the values and principles guiding their research. As a research approach, it enables a good balance between theoretical focus and contextual problem solving that is authentic, practical and iterative.

The DBR approach has already been used for research in clinical education. For example, Wolcott and authors (2019) have demonstrated the relevance of the DBR framework by successfully applying it to investigate collaboration in pharmacy education. Similarly, the iterative phases of the DBR process were found to be very helpful in exploring, designing, developing and evaluating the existing intervention: using a virtual patient simulation to teach clinical decision making.

A further benefit of adopting the DBR approach was that technology was treated as part of the process rather than an artefact (Amiel & Reeves, 2008). There is a common assumption that most, if not all, innovative educational interventions are mediated through technology. However, the impact of technology on any educational intervention can vary and be challenging to evaluate. Through DBR, it was possible to investigate and leverage the potential of technology during the process of this research for the design of a virtual

patient (VP) simulation, while maintaining focus on the core educational problem of clinical decision making.

Use of a virtual patient simulation

Virtual patients (VPs) are “computer programmes that simulate real-life clinical scenarios in which the learner acts as a healthcare professional obtaining a history and physical exam and making diagnostic and therapeutic decisions” (Cook & Triola, 2009; Tworek *et al.*, 2010; Hege *et al.*, 2016). VPs are a natural supplement to traditional clinical teaching, and their greatest pedagogical value lies in their ability to strengthen clinical reasoning skills (Cook & Triola, 2009). Provision for immediate feedback, opportunities for deliberate practice, diverse case scenarios, and varying levels of case complexity and/or difficulty, further make VPs an attractive teaching tool.

The VP simulation, called “*Ready to Practice?*” (R2P), was designed as a screen-based patient case that introduced students to a critical and challenging emergency situation in renal care. The use of a VP ensured that students had the opportunity to apply their clinical knowledge, and practice decision-making skills in an authentic context. Being online, R2P also provided flexibility in delivery. Learners could engage with R2P independently or with peers in the classroom or outside the classroom at a time convenient to them and could repeat it as many times as they wished.

Key learning objectives of the simulation were to 1) Identify, retrieve and utilise different sources of medical information for the purposes of taking a patient history; 2) Apply knowledge and clinical problem-solving skills to

identify the cause of the patient's medical condition and to make appropriate treatment recommendations; 3)

Reflect on clinical decision making in the treatment and management of a patient with an acute medical condition.

Background

In 2016, the School of Pharmacy underwent a major curriculum restructure, which saw a number of changes being implemented across the four-year degree. These included a higher integration of subject content and assessment; a greater emphasis on the development of professional competencies such as problem-solving, critical thinking, information literacy and more experiential learning opportunities. To enable these requirements, the curriculum was revised into a series of system-based modules, which commenced in the second term of the second year and continued throughout the remainder of the degree. Prior to this, students had been taught content in distinct subject areas through lectures, self-directed readings, workshops and/or laboratories. Although attempts were made to align clinical pharmacy content with other subject areas, this did not always occur seamlessly. Clinical teaching staff were also concerned that students were not exposed to sufficient clinical cases earlier in their programme to help them develop sound clinical decision-making skills and/or were not practising these skills adequately through workshops and externships. Student evaluations largely supported those opinions and the majority of students requested more clinical workshops and learning opportunities. Although the curriculum restructures saw a positive shift in aligning and integrating content - with clinical content introduced earlier in the programme - this did not necessarily allow for more in-class opportunities for students to practice decision-making skills. Our three-part web-based simulation (R2P) using an interactive VP was developed to address this gap.

Literature review

Clinical decision-making

Educational institutions are expected to produce clinically competent graduates (Baumann-Birkbeck *et al.*, 2017). Clinical decision-making is a skill that underpins professional clinical practice (Higgs, 2008). Defined as: "*a contextual, continuous, and evolving process, where data are gathered, interpreted, and evaluated in order to select an evidence-based choice of action*" (Tiffen *et al.*, 2014), clinical decision-making is a context-dependent dynamic phenomenon used by healthcare professionals to achieve appropriate decisions regarding patients and their care (Levett-Jones *et al.*, 2010). Effective decision-making involves step-by-step thought processes that reduce error and lead to positive patient outcomes

through the recommendation of appropriate intervention in a timely manner (Levett-Jones *et al.*, 2010). Where decisions are characterised by uncertainty, healthcare professionals must utilise a diverse knowledge base to solve problems, considering multiple foci such as diagnosis, intervention and evaluation of outcome (Higgs, 2008).

Clinical decision-making is often used interchangeably with clinical reasoning, problem-solving, diagnostic reasoning, clinical judgement and critical thinking (Levett-Jones *et al.*, 2010). Clinical reasoning is framed by the thought processes involved when using professional judgement to identify, understand and solve clinical problems as they unfold (Banning, 2008). This involves assessing information, generating options, considering their value against the evidence and choosing the most appropriate alternative (Tanner CA, 2006). In pharmacy, clinical decision-making skills have been identified as an essential core competency for graduates (Tietze, 2019). However, pharmacy educators are often faced with the challenge of how best to facilitate the development of such skills. Clinical decision-making is often not explicitly undertaken in the undergraduate curriculum and opportunities to practice and develop such skills are often inadequately resourced. A lack of available placement sites, poor student engagement and safety concerns in using real patients, means that traditional teaching methods and clinical placements often do not adequately address this need (Baumann-Birkbeck *et al.*, 2017). Hence there is a need to explore alternative, authentic learning opportunities that socialise students to the concept of clinical reasoning and help develop their clinical decision-making skills. Simulation technologies can play a vital role in this process.

Authentic learning

Authentic learning is concerned with the design of learning activities and or tasks that emulate real-life settings. If it is impossible to situate learning or activities in the exact context, then simulated scenarios can enable students to "*become immersed in problem-solving within realistic situations resembling the contexts where the knowledge they are acquiring will eventually be applied*" (Herrington *et al.*, 2006). Authentic tasks have real-world relevance and are designed to guide learners to explore multiple perspectives, use a variety of resources and choose relevant pathways to successfully complete the task. Opportunities to reflect and collaborate across different 'domain-specific outcomes' are an advanced affordance of authentic learning. In Table I, the authors described how the activities at the core of the R2P simulation align with the elements of authentic learning identified by Herrington and authors (2006).

Table I: Design of R2P using authentic learning elements

Key learning objectives of R2P	Elements of authentic learning	Design features of R2P
1. Identify, retrieve and utilise different sources of medical information for the purposes of taking a patient history.	Authentic context, task and assessment.	Context: Ambience (sounds and imagery) of a real hospital setting, presenting a VP with acute renal failure. Access to different forms of information, e.g. GP letter, ECG monitoring, and laboratory results using actual hospital computer software (Concerto). Task: Clinical decisions made under time pressure to diagnose and treat the VP. Assessment: Simulation successfully completed independently or with peers (interprofessionally).
2. Apply knowledge and clinical problem-solving skills to identify the cause of the patient's medical condition and to make appropriate treatment recommendations.	Multiple roles and perspectives.	Interprofessional aspects of the simulation: engaging with other health care professionals, e.g. nurse and doctor(s). Access to medical records, e.g. lab results.
3. Reflect on clinical decision making in the treatment and management of a patient with an acute medical condition.	Collaborative construction of knowledge.	Tasks performed and decisions made with simulated and/or real peers.
	Access to expert performance, coaching and scaffolding.	Senior Medical Officer in Part II and the Morning Handover in Part III. Responsive simulation: pre-programmed options based on student input; feedback provided during tasks with the choice to rethink and change decisions. Communicate with the SMO and access the Morning Handover Meeting.
	Reflection and articulation.	

VP simulations for authentic learning

Simulator training has become widespread in medical education (Cook *et al.*, 2011; Guze, 2015; Webster *et al.*, 2018). Described as early as 1582, when mechanical mannequins were used to teach corrections of dislocations and prosthesis-making skills, simulation technologies have been embraced by educators across professional disciplines and levels of teaching (Hofmann, 2009). Simulation training has unequivocally been shown to improve an array of clinical outcomes (Cook *et al.*, 2011) and can fast-track the achievement of expertise through teamwork and leadership (Tworek *et al.*, 2010). It is therefore becoming an ever-increasing component of accreditation and outcome assessment (Hofmann, 2009; Tworek *et al.*, 2010). Simulations provide learners with a chance to make diagnostic and therapeutic decisions in a safe space where deliberate practice is promoted, and where errors have no negative consequences on real patients (Cook & Triola, 2009; Hege *et al.*, 2016). Such authentic learning opportunities are invaluable for developing clinical reasoning and decision making. However, the effectiveness of the simulation may be influenced by its design, which in turn is dependent on the type of technology being utilised and the design thinking. For example, high-fidelity mannequins are particularly effective for authentic learning (Issenberg *et al.*, 2005), but their scalability is heavily constrained by logistical and cost barriers. Similarly, more high-end solutions such as virtual reality (VR) are still limited by hardware costs and space availability (Chittaro & Ranon, 2007). This is where simple computer-based virtual patients

can provide a useful basis for authentic learning simulations.

VPs can be scaled inexpensively to larger cohorts of students, and can be available from a range of devices, anywhere and anytime (Fletcher & Wind, 2013; Hege *et al.*, 2016). VPs are an effective way to teach certain clinical skills, clinical decision making, teamwork, and communication (Cook & Triola, 2009; Hege *et al.*, 2016), proving it a major drawback in comparison to high fidelity options. VP scenarios - with interaction as a key feature - are a suitable way to generate an authentic learner experience outside of a real environment (Chittaro & Ranon, 2007). Interactive patient scenarios are a common form of VP used to advance clinical reasoning skills in learners through interaction with a series of questions, menus or decision points (Hege *et al.*, 2017). By engaging the learners' senses through sound, sight, and interaction, VPs can enhance information gathering (Chittaro & Ranon, 2007), a critical component of the clinical reasoning process. Furthermore, lifelike characters are known to augment the learning experience through the "persona effect" (Chittaro & Ranon, 2007). VPs can deliver an authentic context that reflects the way knowledge will be used within a real clinical environment (Chittaro & Ranon, 2007) and promote learning by allowing students to make mistakes without patients being adversely affected (Tworek *et al.*, 2010). At a curricular level, VPs allow for greater consistency in teaching, and offer educators an opportunity to be flexible in their teaching approach to meet learning objectives (Tworek *et al.*, 2010).

Design and development of the simulation

Convinced by the potential of interactive clinical cases to address clinical decision making in the curriculum, funding received through a Teaching Improvement Grant helped to secure technical expertise and commit resources to develop an interactive module in a virtual environment. Several three-dimensional animations that had already been created by members of the project team were used as the basis to focus the simulation on the renal system.

Guided by the principles of authentic learning, the main premise for the design of an interactive simulation was to provide realistic tasks in an academic setting. Consistent with the work of Cela-Ranilla and authors (2014), the simulation intended to 1) Offer an alternative yet authentic approach to learning patient care and management plans; 2) Extend the learning in lectures and clinical practice; and 3) provide an opportunity for interaction between potential team members, portrayed as characters in the simulation.

Before deciding on the final design of R2P, various other simulation options such as Second Life - the online virtual world developed by Linden Lab (San Francisco, USA) - were explored. However, with rising subscription costs, the bandwidth and processing power required for running Second Life, and the time and technical expertise required for ongoing maintenance, meant other screen-based interfaces

were investigated and utilised instead. Backed by the reasons outlined in the literature review, R2P design was kept technically simple yet realistic, suited to a simulated clinical activity that would be self-directed, learner-driven and useful for independent study. This ensured relevance, ease of access/use and cost-effectiveness. It also did not require learners to undergo a familiarisation phase before the learning activity could begin. This was considered important in giving learners a choice to undertake the simulated activity anywhere, anytime. Limited funding was available to make iterative changes to the design post usability testing by the technical team and trialling with volunteer students before use in the classroom.

Clinical decision-making is a learned skill that requires conscientious effort (Higgs, 2008; Levett-Jones *et al.*, 2010) and involves procedural and situational simulation aspects. The former requires students to follow a correct sequence of steps to achieve the appropriate end goal, while the latter prompts them to think critically and make relevant decisions with constant feedback to rethink and adapt (Lyons, 2012). Students were guided to make patient care decisions through a clinical decision-making process that included a specific task, provided contextual information and an avenue to confer with peers and receive expert feedback. All these features aligned well with the elements of authentic learning, as shown in Table I.

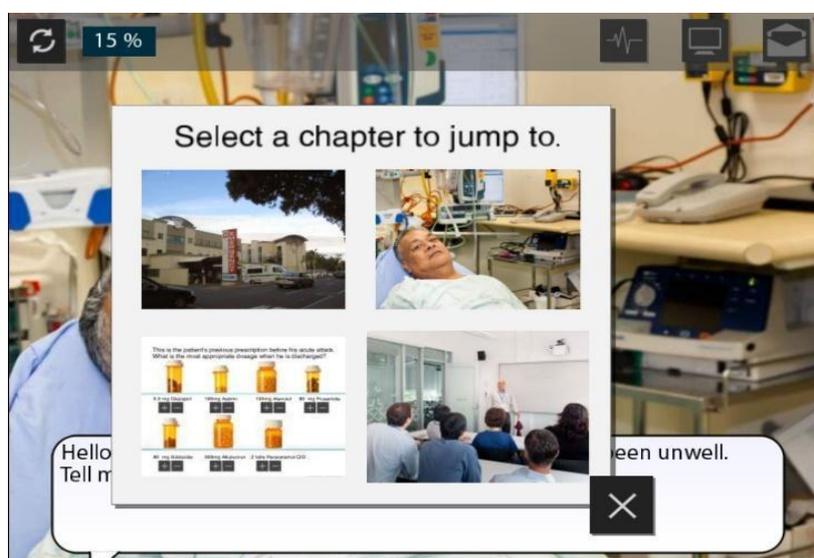


Figure 2: Ready to Practice simulation interface

“Ready to Practice?” design

R2P falls within the second most common use of simulations, which is for patient care (Damassa, 2010). Students are provided with a series of options and

decision-making guidance to develop a care plan for a virtual patient with an acute, life-threatening renal failure. By simulating patients and interprofessional members of the healthcare team in a clinical decision-making scenario, R2P allows students to become

socialised to collaborative, interprofessional decision making without causing harm or embarrassment. Extensive details on R2P design are available elsewhere (Martini *et al.*, 2015; Martini *et al.*, 2019). In brief, it is a multimedia simulation with interactive prompts and decision menus overlaid on static photographs of a patient actor and clinical staff. Multiple sources of information like laboratory results, a GP letter and cardiac monitor are available to aid decision-making.

Part I of the simulation focuses on clinical decisions made under time pressure. It presents a case that is a life-threatening emergency and requires students to act quickly. The system is highly adaptive, so responses change depending on the care choices made by the student. The patient's status is illustrated by a cardiac monitor, which warns the student when or if the patient is deteriorating. The virtual nurse provides background and patient assessment and asks for the student's recommendation. Students also complete a drug chart for the patient. Should the student take too long to reach an appropriate treatment recommendation, they are informed that the patient has died, at which point they have the option to restart the simulation. A number of distractors add realism, requiring the student to assess the situation and determine the most important and relevant information.

Parts II and III of the R2P simulation allow students to reflect on decisions made in Part I through interaction with other characters who ask a series of questions - multiple choice and open-text. Part III also provides a Medical Handover Meeting with the experts, to further reflect and learn what an ideal care plan would look like for the VP concerned.

Students have control of the pace and interactions in the simulation, with a progress bar visualising the steps completed. Although not representative of the time it takes to attend to a real-life emergency crisis, progress indicators are useful for users to track how much of a task has been completed and may help to reduce anxiety by visually representing a goal with a beginning and an end (Myers, 1985). User satisfaction has been found to occur more readily if the feedback conveys that the task is brief, or moving quickly, particularly in the beginning stages (Conrad *et al.*, 2010).

Description of innovation

R2P implementation occurred over multiple overlapping phases. This was due to iterative changes being made to the design of the R2P simulation through ongoing reflection and testing, inherent in the DBR approach. Reflections from teachers and learning

experts – gathered through a reflective journal and identifying common themes – were used to make iterative changes. This meant a strong alignment was maintained between the intended learning objectives of the simulation and the design of R2P. The formal evaluations were focused on how useful the simulation was for clinical decision-making in uni- and interprofessional groups, and whether there were any differences in learning in students who completed the simulation in the classroom (possibly with peers) versus those who did it independently.

Pilot studies

Two pilot studies were carried out in 2014 and 2016 to determine how useful R2P was in helping students develop clinical decision-making skills, and are reported in full elsewhere (Martini *et al.*, 2015; Martini *et al.*, 2019). In 2014, an anonymous survey - based on the work of Whitton (2007) – was used to assess students' experiences with the simulation and to determine engagement with intended learning from the simulation (Martini *et al.*, 2015). Based on previous theories, Whitton identified five factors that affect student engagement in a learning activity, which were deemed suitable for our study: challenge, control, immersion, interest and purpose (Whitton, 2007). However, not all of the questions in the final validated 18-item questionnaire were applicable or appropriate. A selection of nine questions - with a five-point Likert scale from strongly disagree to strongly agree - were chosen from each category. Adapting this questionnaire for R2P helped to provide targeted feedback, but resulted in questionable reliability (Cronbach's 0.63) and limiting generalisability to other simulations.

Reflective questions were added to determine if decision-making processes were improved, worsened or stayed the same; a question on whether or not participants thought they were likely to be motivated to learn with simulations; and a scale of 1 to 100 on how valuable the simulation was for student learning. Open-text questions were included for additional qualitative information. Students who took part in the study believed R2P improved their ability to make effective use of clinical resources, make decisions quickly, and improved their constructive decision-making skills. However, most experienced some difficulty with interpreting diagnostic aspects such as the electrocardiogram (ECG). As diagnostic monitoring and imaging do not form part of formal pharmacy education, this was seen as an opportunity to pilot test the design of the simulation with medical students in interprofessional learning (IPL) study (Martini *et al.*, 2019). This study made use of the Readiness for

Interprofessional Learning Scale (RIPLS) and interviews to gather student feedback.

Integration of simulation into the curriculum

The next round of studies (2017 and 2018) were done to inform/test the implementation of the VP simulation in the pharmacy curriculum. Based on prior feedback and subsequent design changes, we also wanted to assess whether there were any differences in learning in students who completed the simulation in the classroom (2017) versus those who did it in their own time (2018).

Both pilot studies conducted with final year pharmacy students completing their degree under the former curriculum, suggested that students were more confident in completing the simulation if they had recently completed coursework that covered the learning components. In this former curriculum, students had covered diabetes in their third year, and renal failure in the first term of their final year, equipping them with the prerequisite knowledge they needed for the simulation. In the revised curriculum, the modules were reorganised to include both the Renal module (term one) and the Endocrine module (start of term two) in the third year of the B.Pharm programme. It was therefore considered appropriate for the simulation to be implemented in the third-year curriculum after students had completed both of these prerequisite modules, but not within these modules. The rationale for later implementation was so that students could still draw on recent knowledge, thereby consolidating their learning, but they were less likely to be influenced by confirmation bias by learning the material at the same time as completing the simulation.

In 2017, third year Pharmacy students were invited to complete the simulation as part of their course requirements. The simulation was scheduled to take place in two concurrent one-hour in-class simulation sessions in a designated computer laboratory, which could accommodate one computer per student. Students were able to complete the simulation on their own laptop computers if they so wished. Students were informed that the activity was not part of the module they were completing at that time and was intended to provide an interactive learning experience in which they could practice their clinical decision-making skills and put their learning into practice. It was also an opportunity to self-assess their readiness to practice. The session was structured to allow for a five-minute introduction, 20-25 minutes for the simulation task, ten minutes for discussion, and five minutes to complete the survey. For comparative purposes, the same survey was used as in the 2014 pilot study. Students were provided with an open-text field to note any additional

comments. Links to the simulation and survey were provided the morning of the session.

In 2018, in an introductory lecture at the start of the second term, students were informed that they would be taking part in a simulation later that term. In October, students were directed to a link and were given three days in which to complete the simulation task. The purpose of the activity was said to provide students with an opportunity to practise their clinical skills and knowledge that they had already acquired. Students were advised to complete the simulation on their own, at a quiet time and space, and with the sound on. They could complete the simulation as many times as they wanted but could only complete the survey once. In the survey, four additional questions were added asking students to reflect on how confident they were working through the case, and whether there was anything that would have helped them answer the case more efficiently/effectively; if they did not complete the simulation on their own, how working with someone else helped them answer the case more efficiently/effectively; a reflection on the effectiveness of the virtual simulation in their learning; and whether students had any recommendations to improve the simulation. All data were collected and entered into a Qualtrics spreadsheet for processing. Two weeks post simulation, feedback based on students' responses were collated and summarised, and posted in an announcement to students via the Learning Management System (LMS).

Qualitative and quantitative survey data were entered into Microsoft Excel for analysis. Qualitative data were analysed using a general inductive approach (Thomas, 2006). Open-ended questions were coded, consistent with the questions asked, and individual codes were grouped on the basis of similarity to form themes. Survey questions from one to nine and the scale were treated as interval data; negatively scored items (questions five and six) were reversed for analysis and analysed using t-tests. Reflective questions were analysed using chi-square.

Evaluation

Student evaluation of the simulation

Across the two evaluations, 87% of the student cohort participated in the survey (67/77 in 2017; 85/98 in 2018). Both populations were demographically similar in terms of gender, age and ethnicity (Table II). The first nine questions of the evaluative survey covered student engagement in the simulation task (Table III). Overall, chi-square and t-tests showed no statistical differences

between the students who did the task in-class (2017) or in their own time (2018).

Both groups equally wanted to explore all options in the simulation. More students who completed the simulation as an in-class activity versus in their own time knew what they needed to do (73% vs 66%) and believed they had what they required to complete the simulation successfully (85% vs 67%). Irrespective of where students completed the simulation, they were positive they could achieve the goal of the activity (79% vs 81%). Students did not find the activity too complex, nor did they report having too many potential options available to them. More students who completed the simulation in-class felt absorbed in the activity (85% vs 71%) and felt they had to concentrate hard on the activity (76% vs 64%). Both groups felt the feedback they were given was useful (85% vs 84%).

Table II: Age, gender and ethnicity of students in B. Pharm. III

Demographics		2017 N=77 (%)	2018 N=98 (%)
Gender	Female	55 (71.4)	64 (65.3)
	Male	22 (28.6)	34 (34.7)
Ethnicity	Asian	57 (74.0)	67 (68.4)
	European	15 (19.5)	19 (19.4)
	Pacific Islands	4 (5.2)	2 (2.0)
	MELAA ¹	1 (1.3)	7 (7.1)
	Māori		2 (2.0)
	Other		1 (1.0)
Mean age (years)		21 (range 19-31)	21 (range 20-36)

¹MELAA = Middle Eastern, Latin American, African

Table III: Count of responses to questions 1-9 of the evaluative survey (2017 [N=67]; 2018 [N=85])

		SD+D (%)	N (%)	A+SA (%)	Mode
Q1: I wanted to explore all the options available to me	2017	2 (3)	3 (4.5)	62 (92.5)	4
	2018	1 (1.2)	5 (5.9)	79 (92.9)	5
Q2: I knew what I had to do to complete the activity	2017	7 (10.4)	11 (16.4)	49 (73.1)	4
	2018	14 (16.5)	15 (17.6)	56 (65.9)	4
Q3: I felt that I could achieve the goal of the activity	2017	5 (7.5)	9 (13.4)	53 (79.1)	4
	2018	6 (7.1)	10 (11.8)	69 (81.2)	4
Q4: I had all the things I required to complete the activity successfully	2017	5 (7.5)	5 (7.5)	57 (85.1)	4
	2018	12 (14.1)	16 (18.8)	57 (67.1)	4
Q5: The activity was too complex	2017	24 (35.8)	26 (38.8)	17 (25.4)	3
	2018	29 (34.1)	44 (51.8)	12 (14.1)	3
Q6: I had too many potential options available to me	2017	27 (40.3)	26 (38.8)	14 (20.9)	3
	2018	28 (32.9)	36 (42.4)	21 (24.7)	3
Q7: I felt absorbed in the activity	2017	1 (1.5)	9 (13.4)	57 (85.1)	4
	2018	10 (11.8)	15 (17.6)	60 (70.6)	4
Q8: I had to concentrate hard on the activity	2017	4 (6)	12 (17.9)	51 (76.1)	4
	2018	6 (7.1)	25 (29.4)	54 (63.5)	4
Q9: The feedback I was given was useful	2017	0 (0)	10 (14.9)	57 (85.1)	4
	2018	2 (2.4)	12 (14.1)	71 (83.5)	4

SA=strongly agree; A=somewhat agree; N=neither agree nor disagree; D=somewhat disagree; SD=strongly disagree

Overall, more students who worked in-class felt the activity improved their understanding of how to make good clinical decisions more quickly (69% vs 57%), use clinical resources more effectively (63% vs 58%), and constructive ways of making decisions (64% vs 51%) (Figure 3). There were no significant differences in the engagement questions between the years ($p > 0.05$).

In both student groups, over 70% of students found the simulation valuable for their learning, and only 15%

were not motivated to learn using simulations. Eight students who completed the simulation in their own time, admitted to working with a third-year pharmacy peer. These students said the collaboration helped to aid their understanding and made them more at ease when confirming the diagnosis. Their peer gave them hints when they were going in the wrong direction, and they could discuss alternative options when making clinical decisions.

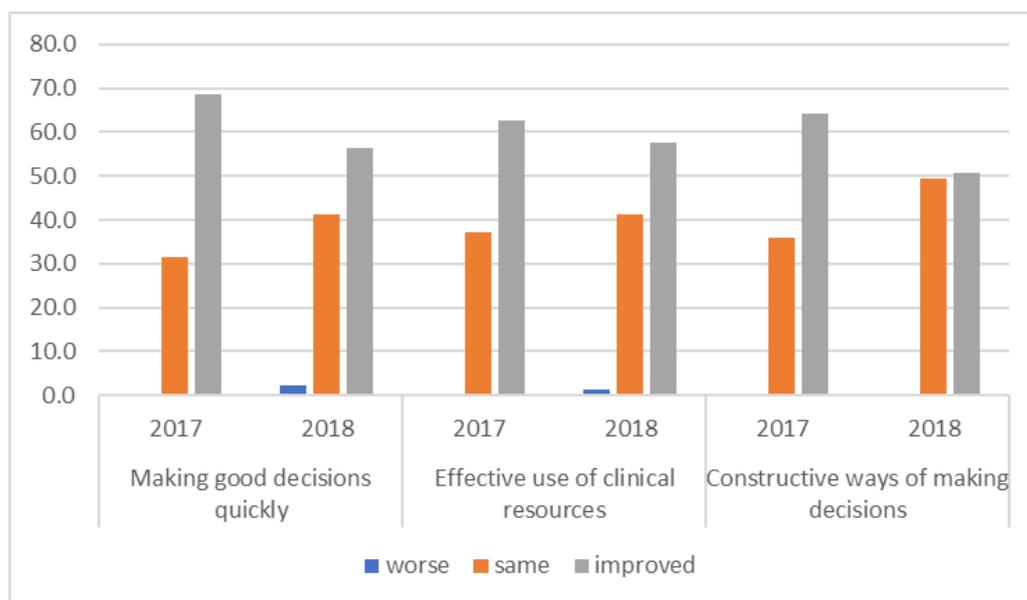


Figure 3: Student views on whether R2P assisted with clinical decision-making

Confidence in clinical decision making

Students who worked independently were asked how confident they were working through the case in their own time. The majority said that they were not confident. The main factors relating to confidence in achieving the task were clarity with the burden of time pressure, prior knowledge, and availability of resources.

Clarity with burden of time pressure

For some, confidence increased as they progressed through the simulation or after they had a better understanding of what they needed to do. Due to the time limit in Part I of R2P, some students felt under pressure to make fast decisions.

“At first, I was not confident at all so I didn't know what buttons to press... I also would have liked to know that there was no time limit on prescribing drugs and that I had time to open up another tab to decide what medicines suited the patient.”

“[I]didn't realise you had to look at all the sources to progress in the activity so my patient died first time round. This wasn't clear and I thought I should just look at the best one to move quickly.”

The time limit created stress for some students who felt the patient's life was in their hands.

“Not that confident because I took it serious[ly] and I felt pressured that someone's life was on my hands. I didn't want to make a mistake but the time pressure got to me.”

However, others felt the time pressure was useful as it helped them to “*think on [their] feet*”, focus and exercise faster decision-making.

“I was not confident the first time because I did not know there was a time limit, and it pressured me. The second time, I knew the patient's health would deteriorate fast, so I made decisions faster and focused more.”

Prior knowledge

For most students, their confidence was associated with their pre-existing knowledge of the medical condition and interpretation of clinical laboratory results. Those who were confident had studied the work previously and recognised what they needed to do and found the case to be a good revision of that knowledge.

“I was confident because it was a topic we had learnt before although I had forgotten some details, it was good to get a reminder and have the chance to get feedback and try again.”

Moreover, many students recognised that their knowledge was not adequate for the task and realised the importance of understanding the material before applying it to a case. Several students admitted they were more confident in some aspects of the task than in others.

“I was confident in answering most of the activity - just when it was asking for me to identify the ECGs, this was difficult as pharmacy students are not

required to know this kind of stuff in too much detail!!"

Availability of resources

Confidence increased in most students as they explored the options in the simulation, and realised that they had the resources needed to answer the case.

"I got more confident as I had explored the options a little more and settled in on a diagnosis. Everything that was required to solve the case was given in the scenario."

External online resources were used by some students to assist in aspects of the task, guiding them through areas that they were not confident in.

"The case was ok to work through. The main benefit was having a webpage open when answering questions about ECG changes."

"I had to NZF and Micromedex search the clearance route of the drugs, also we didn't know anything about ECG in hyperkalaemia though."

A few students suggested that having help, ideas and opinions from others would have helped them to make decisions faster and easier.

"I felt that perhaps having a second opinion on what I thought I should do next would be helpful in making the correct treatment changes sooner."

Learning effectiveness

Most students thought that the simulation mimicked a 'real-life' hospital scenario or found it similar to what they had experienced during their hospital placement. They believed this gave them an opportunity to apply their knowledge and clinical decision-making skills, helping them to think faster and more constructively.

"I think this stimulation was really effective at seeing how our clinical skills and the things we have been taught are applied in the real world to real patients and it really helped me improve my time management skills."

"It was useful to help put prior learning into practice and actually apply it to a 'real' case. It's all well and good to learn the information and even discuss it in workshops but it is far more satisfying to put it all into real life context."

Some students, however, questioned the realism of the scenario. They didn't think that pharmacists would be involved in diagnostic decision making, nor did they believe that it was a substitute for real-life learning.

"In reality I was not aware that pharmacists help make the diagnosis and speak to the patient etc. In many hospitals, especially small ones, they are not part of the multidisciplinary team meetings so I was unsure of this relevance..."

Most students felt the simulation was an effective tool to identify gaps in their learning, prompting them to recall what they had previously learnt, and it helped to tie concepts together.

"It helped me to identify gaps in my knowledge because I forgot the medicines that were renally excreted and it refreshed the topic for me. It also provided an opportunity to use skills that I learnt last semester. It was a really good simulation and was a lot of fun to practice in a clinical setting."

Making decisions under pressure provided much needed practice for what students may encounter in stressful clinical situations and made them realise they needed to practice their clinical decision-making and time management skills.

"I enjoyed this virtual simulation learning approach, it helped me identify my strengths and any gaps in my knowledge, and helped me see how I was able to quickly make clinical decisions in a time pressured setting."

Although a small number of students believed the simulation was not specific to pharmacy, wasn't clear, and made them feel unprepared for practice, the majority believed their learning had been challenged in positive ways as they were able to interact in ways they couldn't in more traditional ways.

"VERY EFFECTIVE, I felt like I was challenged in so many ways, almost like when we do case studies at university but more interactive because we had to interact with the patient, nurse, doctor and their notes and resources. This simulation was very lifelike."

"This simulation was amazing. Honestly, this should be the way we learn in pharmacy. I have so many gaps in my knowledge and skill set in terms of application. I've always struggled with the application aspect and I have no idea why, but I feel like everything I learned here will stick more than when I read my notes 5 times. I know my drugs and how they work, but I don't know how to customise it to a patient with multiple disease states in an emergency situation and I should especially because I have learnt these things."

"It was very intellectually stimulating as it allowed me to recite back to my prior knowledge that I haven't visited in a while. Also interactive and fun."

Many students who completed the activity in-class, requested the simulation to be available for the remainder of the term so that they could go through it again, and several students requested more simulations with which to practice applying their clinical knowledge.

Critical analysis of the VP simulation

Careful consideration and planning are needed to integrate VPs with other learning modalities, and to ensure VPs do not result in cognitive overload where learners have not yet grasped core knowledge and are not ready to apply it in a simulated clinical encounter (Baumann-Birkbeck *et al.*, 2017). Implementing R2P in the curriculum was neither resource-intensive nor challenging once a decision had been made in which year and module to include it. However, a number of students questioned this placement, recommending the Endocrine module as a more suitable place. Although students may have been more confident to work through R2P in the module where they had most recently covered the content, it is unlikely that this would have translated in superior competence as the VP learning objectives were not specific to endocrinology or renal disease, which was the biggest challenge laid in the development of the simulation.

This required expert input from clinicians, pharmacists, a learning designer, and a professional game company to effectively simulate a multidisciplinary clinical environment, and resources that mimic those found in a real hospital. While R2P is not a high-fidelity simulation, this did not affect student engagement. In fact, most students found R2P comparable to what they had previously encountered during their hospital placements, and the realism of the scenario, coupled with the time constraint, saw many students feeling pressured to save the VP's life. The time pressure made the scenario seem real and focused their attention, which is not readily mimicked with a paper-based scenario. As such, pharmacy students appreciated R2P as an interactive, authentic representation of a clinical case that challenged them to apply their clinical knowledge in a way they had not previously experienced and helped identify gaps in their learning. Context authenticity is an essential feature of simulation-based clinical education (McGaghie *et al.*, 2010).

The ability of the simulation to provide immediate and directed feedback is a distinct advantage of R2P and of VPs in general. In the classroom, a post-simulation debriefing exercise further helped to reinforce learning objectives and can provide both individual and team-oriented feedback, where relevant. Yet, if learning is to

occur outside of the classroom and/or in the student's own time, careful consideration needs to be given to the delay between the task and debriefing. In the absence (or delay) of feedback, learners could face a lack of self-discipline and enthusiasm for learning (Combs & Combs, 2019).

When designed well, VPs have the ability to provide learners with focused, repetitive practice, that coupled with clear learning objectives and formative feedback can lead to mastery of a particular skillset (McGaghie *et al.*, 2010). Outcome measurements based on interviews, direct observation, and students' reflection and responses through pilot study data, demonstrated the ability of the R2P to facilitate clinical decision making. However, as the current version of R2P includes only one scenario, this does not offer learners an opportunity to practice clinical reasoning across a range of diverse clinical areas and patients. To address this, more simulation scenarios that address key learning in the pharmacy undergraduate curriculum need to be developed.

Future plans

Future research direction

The authors believe that ongoing evaluation of R2P needs to be centred on its potential for peer-led and interprofessional education. Pilot studies have already effectively demonstrated the ability of R2P to engage learners in clinical decision making and teamwork across pharmacy and medicine. For interprofessional learning to be possible, further development of the VP simulation is needed. This could see virtual student teams exposed to different versions of the VP, allowing them to focus on their specific disciplinary learning objectives whilst appreciating the skillset that other disciplines bring to patient care. By allowing multiple students (care teams) to use the simulation asynchronously, the need for co-location and synchronous operation is removed, and interprofessional learning can occur with more flexibility in already busy timetables. This also allows for greater scalability in the number of teams who are able to access the VP at the same time. More research is needed to determine the quantity and quality of feedback that is needed in interprofessional VPs and how outcomes measures are defined within and across disciplines.

Additional VP scenarios need to be developed, the greater the diversity of clinical cases, the more opportunities students have with which to practice clinical reasoning. Further care episodes of the same VP patient could offer longitudinal insights into healthcare that cannot easily be replicated with mannequins and/or real patients. These scenarios could address key aspects

of learning in undergraduate students as well as post-graduate or continuing education. With research focusing largely on short-term outcomes, R2P has not been able to demonstrate for how long learning was retained. Further work is needed to determine whether VPs are superior to other modalities in skill maintenance and also whether skills learnt to translate into real practice.

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