UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Transforming Errors into Learning Opportunities in Simulation-Based Learning

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Thesis submitted in fulfilment of the requirements for the degree of

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Under the supervision of

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Certificate of original authorship

I, Evelyn Palominos, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in the School of Nursing and Midwifery, Faculty of Health at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research was supported by the Australian Government Research Training Program.

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Dedication

I dedicate this thesis to:

Paola, whose love knows no limits. My parents, Ana Maria and Raul, for giving me the strength to chase my dreams. My sisters, Claudia and Ana Maria, for always being there for me. My nieces and nephews, Daniela, Benjamin, Valentina and Ricardo, for their unconditional love. My second family, Lizzie and Ricardo for their unyielding support since I commenced this journey. My friends, Ely, Norma, Jane, Mariana, Genaro, Cecilia, Jorge and Rodrigo, for the treasure of their friendship.

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I certify that the format of this thesis is by compilation, which comprises papers that follow a sequential order. A written declaration from each co-author certifying my contribution to the authored manuscripts is included.

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Glossary of Terms

> "When I have eliminated the ways that will not work, I will find the way that will work."
>
> — Thomas A. Edison

Declarative knowledge

refers to knowledge about facts (Ohlsson, 1996). Declarative questions often start with the word “what” (Jacobson et al., 2017). For example, “what are the sign and symptoms of …?”

Delayed instruction

“… includes minimal structured activities followed by pedagogical guidance” (Jacobson et al., 2015, p. 716). Westermann and Rummel (2012) refer to it as a delay in the content-related instruction until a subsequent phase. In other words, the educator does not provide content-related support before students participate in practical learning activities.

Desirable difficulties

refers to providing challenging activities to learners (Bjork, 1994). Unguided problem-solving tasks and delayed feedback or instruction are examples of desirable difficulties (Kapur, 2016).

Direct instruction

is an approach that provides pedagogical information and support needed (e.g., explanation of concepts and procedures) for students to achieve learning outcomes (Kirschner et al., 2006). In terms of timing of instruction, direct instruction combines instruction followed by problem-solving activities (Cao et al., 2020).

Direct instruction simulation

is a form of simulation that starts with instruction about the simulation topic, followed by the simulation activity (Zendejas et al., 2010).

Errors

"encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcomes and when these failures cannot be attributed to the intervention of some chance agency" (Reason, 1990, p. 9).

Error management training

(EMT) aims to minimise the potential negative outcomes of making errors (Frese & Keith, 2015) and develop coping strategies for responding to errors effectively (Keith, 2011). EMT engages trainees in active exploration of the learning tasks and explicitly encourages error making (Keith, 2011).

Explanatory knowledge

measures students' understanding of a particular event (Coleman, 1998; Jacobson et al., 2017). "Why" or "how" words are often used as a preface to these types of questions (Jacobson et al., 2017).

Failure

refers to students' inability to generate correct solutions by themselves (Kapur, 2016).

Mistakes

occur when the plan to achieve a desirable goal is inadequate (Reason, 1990). "In a mistake, the action proceeds as planned but fails to achieve its intended outcome because the planned action was wrong" (Institute of Medicine, 2000, p. 54).

Normalisation of errors

refers to accepting errors as a natural occurrence of the learning process.

Positive error framing

involves making errors evident and prompting individuals to visualise them as learning opportunities (Steele-Johnson & Kalinoski, 2014). Positive error framing is employed in statements such as "The more errors you make, the more you learn!" or "You have made an error? Great! Because now you can learn something new!" (Keith & Frese, 2008, p. 60).

Productive failure

is described as "a learning design that affords students opportunities to generate representations and solutions to a novel problem that targets a concept that they have not learned yet, followed by consolidation and knowledge assembly where they learn the targeted concept" (Kapur, 2015, p. 52).

Productive failure simulations

are experiences that allow students to participate in a simulation activity before receiving instruction about the content or concepts of the session.

Simulation

"… is a technique—not a technology—to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner" (Gaba, 2004, p. i2). Simulation-based learning enables students to practice nursing care in simulated settings that mimic the situations encountered in real clinical contexts (Cant & Cooper, 2017).

Psychologically safe environment

refers to: 1) the opportunity of making mistakes without consequences for the leaner, the patient or both; 2) the qualities of the facilitator, such as being approachable, being honest and flexible and admitting mistakes; and 3) the use of foundational activities embedded within the simulation such as orientation, objectives and expectations (Turner & Harder, 2018).

Timing of instruction

refers to when the instruction is provided, namely, before or after problem-solving activities (Jacobson et al., 2015).

Transfer of learning

is "the ability to appropriately apply information and skills learned in one setting to a similar or different setting" (Thomas, 2007, p. 5).

Abbreviations

CVC	Central venous catheter
CO	Correct only
CE	Correct plus error
DI	Direct instruction
DI-GBL	Direct instruction game-based learning
EAT	Error avoidance training
EMT	Error management training
LE	Learning from Errors [conceptual model]
PF	Productive failure
PF-GBL	Productive failure game-based learning
SSE	Satisfaction with Simulation Experience
SBL	Simulation-based learning
TI	Traditional instruction
UTS	University of Technology Sydney
VE	Vicarious error

Abstract

This thesis explores how productive failure simulations influence nursing students' learning, perceptions and satisfaction compared with traditional simulations. Simulation-based learning enables learners to make mistakes and learn from them without compromising real patients' safety. Productive failure is a pedagogical approach that allows students to make mistakes as they solve novel learning tasks before receiving instruction. Productive failure simulations comprise a simulation followed by instruction, which contrasts with direct instruction simulations that begin with instruction followed by the simulation. Productive failure has facilitated meaningful learning outcomes in diverse educational settings, but no previous studies have examined the impact of productive failure in nursing simulation. To fill this research gap, an exploratory, sequential mixed-methods design with a three-stage approach was used.

The first stage of the study, an integrative literature review, explored healthcare students' perceptions of making errors in simulation. It identified that supporting students to take responsibility for their mistakes is critical to moderating the negative impact of making errors and transforming them into learning opportunities.

The second stage of this study resulted in the Learning from Errors conceptual model. Building on productive failure and error management training approaches, the model was designed to inform healthcare simulations that explicitly embrace learning from errors. This model includes the following elements: normalisation of errors, challenging simulation scenarios, self-directed learning, collaborative teamwork, and comparison with best practice.

The third stage of this study evaluated nursing students’ learning from and satisfaction with productive failure simulations compared to direct instruction simulations and explored students’ perceptions of productive failure simulations. Participants were randomly allocated to either a productive failure group (n = 181) or a direct instruction group (n = 163). Quantitative data included knowledge tests measuring declarative knowledge, explanatory knowledge and transfer of learning, and the Satisfaction with Simulation Experience scale. Qualitative data involved interviews with students in the productive failure group.

For explanatory knowledge and transfer of learning, the productive failure group outperformed the direct instruction group. This group also scored significantly higher on the satisfaction items related to reflection on practice and clinical learning. The qualitative results identified the following themes: the benefits of simulation prior to instruction; the value of performing a second simulation; and the importance of normalising errors.

This doctoral study demonstrated that productive failure simulations improve nursing students’ learning, perceptions and satisfaction levels. The thesis concludes with implications for nursing education, directions for further research, and recommendations for future practice.

Chapter 1. Overview

1.1 Introduction

> Success which comes easy is not likely to be as highly valued as success which is difficult to achieve.
>
> — Margaret Clifford

Errors in healthcare organisations can be psychologically devastating for clinicians and cause serious harm to patients (Conn, 2018; DaRosa & Pugh, 2012). Consequently, instructing students on the importance of avoiding mistakes is common practice in healthcare education (Conn, 2018; Warner, 2016). Simulation-based learning (SBL) presents opportunities for students to make and learn from their mistakes, because the physical and psychological safety of real patients (Gardner et al., 2015; King et al., 2013) and students are not compromised (Turner & Harder, 2018). However, simulation experiences that explicitly use errors to facilitate learning should integrate the principles of pedagogical approaches that support learning from errors. In this study, a novel form of simulation that used productive failure (PF) principles was designed, implemented and evaluated.

Productive failure is a pedagogical method that encourages students to solve learning tasks before they are provided with the correct solution (Kapur & Bielaczyc, 2012). This inevitably leads them to make mistakes, because the tasks they are given are both novel and challenging. When applied to SBL, a PF simulation requires students to participate in the simulation activity and subsequently receive instruction about the topic of the session. This is a radical departure from traditional simulations (or direct instruction simulations), which typically commence with instruction followed by the simulation activity. Previous research suggests that students exposed to PF approaches exhibit greater flexibility and are able to adapt their understandings to solve problems that have not been taught previously (Kapur, 2011; Kapur & Bielaczyc, 2012).

This aspect of flexibility is vital in contemporary healthcare, which requires clinicians to have the capacity to meet the demands of increasingly complex and unpredictable healthcare settings (Andersen & Vedsted, 2015; Moss, 2008). In order to work effectively in such healthcare environments, clinicians need to be agile and able to adapt to novel and ambiguous circumstances (Mylopoulos et al., 2016). This way of functioning refers to the flexible application of knowledge (Baroody, 2003) or the development of adaptive expertise (Schwartz & Martin, 2004). In healthcare education, adaptive expertise means “to learn new information, to use resources effectively and innovatively, and to invent new strategies for learning and problem-solving in practice” (Steenhof et al., 2020, p. 1100). As a result, there is a need to introduce novel pedagogical approaches, such as PF, that prepare healthcare graduates with the requisite knowledge and skills to manage diverse, complex, and rapidly changing clinical situations.

Despite a growing body of evidence demonstrating the effectiveness of PF in a wide range of content topics and pedagogical settings, there is little understanding of the impact of PF simulations on learning and students’ satisfaction levels compared with direct instruction (DI) simulations, and students’ perceptions of being exposed to PF simulations. The research presented in this thesis by compilation of publications, was designed to fill these research gaps.

1.2 Background

> I have not failed. I've just found 10,000 ways that won't work.
>
> — Thomas A. Edison

This background section is organised into four sections. The first explores errors in education in general and in SBL in particular. Section two is concerned with students' responses to errors in simulation experiences. Section three describes how errors can be used to enhance learning, and the final section examines the effectiveness of errors in terms of learning in different educational settings. Each of these sections highlights the gaps in the literature that led to the development of the research questions for this doctoral study.

1.2.1 Errors in education and in simulation-based learning

The term "error" has been defined in various disciplines. In cognitive psychology, errors "encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcomes and when these failures cannot be attributed to the intervention of some chance agency" (Reason, 1990, p. 9). This definition provides important insights into some characteristics of errors. First, an error emerges when there is a deviation from something else, such as a standard or external goal (Ellis & Davidi, 2005; Hofmann & Frese, 2011). Second, an error occurs when there is a failure to achieve an intended goal; therefore, errors are commonly unplanned (Hofmann & Frese, 2011). Third, errors are generally avoidable, because they occur when an individual has total or partial control over an action (Reason, 1990); therefore, unforeseen events beyond an individual's control cannot be classified as errors (Zapf et al., 1992).

The terms “error” and “failure” are often used interchangeably. In educational psychology, error and failure constructs have a similar conceptual meaning and refer to “incorrect responses to a task or situation” (Clifford, 1979, p. 44). From the learning sciences point of view, Kapur (2014a) defined failure as individuals’ inability to generate correct solutions to learning tasks. In SBL, error and failure are also commonly used interchangeably (Bearman et al., 2018; Bould et al., 2012; Helyar et al., 2013; Kneebone et al., 2004; Young et al., 2016). In the same vein, the concepts of errors and mistakes in SBL are undifferentiated (Bould et al., 2012; Gaba, 2000; Helyar et al., 2013; INACSL, 2016; Young et al., 2016). However, Reason (1990) argued that these constructs are ontologically different, claiming that an error is an action that fails to achieve the desired outcome, whereas a mistake occurs when the plan to achieve a goal is inadequate.

Based on these definitions, it is apparent that there is a subtle distinction between error and failure, and this may partly explain why they are often used interchangeably. Given the definitions mentioned above, in this thesis the terms “error”, “mistake” and “failure” are used to refer to an individual’s inability to provide correct solutions to a novel learning activity.

To better understand the concept of error in education, it is also essential to explore its counterpart: success. Success refers to a situation in which an intended goal is achieved (Clifford, 1984). Success is beneficial for a variety of reasons. It improves short-term performance when the environmental conditions are predictable and expected (Sitkin, 1992). For instance, students who receive methodical instructions about how to solve a learning task may improve their performance because they followed a “recipe” (Heims & Boyd, 1990). Success allows individuals to build optimism and translate it into future actions (Weick, 1984). However, successful experiences may prevent individuals from taking risks and exploring new alternatives, leading to complacency (Sitkin, 1992).

Conversely, an impasse or error can promote the need to search for alternative solutions or new strategies (Roll et al., 2011). The PF approach has demonstrated that students who solve learning tasks before receiving instruction generate more ideas and possible solutions than those students who receive instruction first (Kapur, 2014b). Although these solutions are often incorrect, the PF approach helps students acquire a deeper understanding of the concepts of an educational session (Kapur & Bielaczyc, 2012) and transfer the skills learnt to new situations (Cao et al., 2020; Jacobson et al., 2017). This highlights the importance of errors in facilitating meaningful learning outcomes (Keith et al., 2020). Thus, it is essential to explore relevant learning theories and their relation to errors to understand the role of errors in learning.

Behaviourism and constructivism are two well-known learning theories with opposite views about errors (Santagata, 2005). Behaviourists believe that errors can become ingrained when they are made, so an individual is more likely to repeat them in future situations (Metcalfe, 2017). The behaviourist perspective also views errors as a distraction from the given learning task, and in this sense, they are often seen as a waste of time (Keith, 2011). Therefore, to avoid errors and their potential negative effects, learners are asked to adhere to a set of instructions when undertaking practical activities (Dormann & Frese, 1994). However, this approach limits opportunities to explore possible solutions (Lorenzet et al., 2005) that can lead to the development of flexibility and the knowledge and skills needed to complete unfamiliar tasks (Kapur & Bielaczyc, 2012). Teaching psychomotor skills, where the educator provides a comprehensive explanation of how to perform a particular skill, is an example of applying a behaviourist approach (Shibinski & Martin, 2003).

In contrast to the behaviourist approach, the constructivist paradigm posits that learners construct their knowledge and understandings from their own experiences and interactions with the world (Boghossian, 2006). In this approach, errors are visualised as feedback tools that help learners acquire “insight into how they are organising their experiential world” (Murphy, 1997, p. 8). From this perspective, errors are considered pivotal components of learning (Santagata, 2005) that play a crucial role in assessing students’ understanding (Wilson & Cole, 1991). What is less well understood is the impact of making errors in SBL experiences.

1.2.2 Errors in simulation-based learning

Contemporary healthcare simulation originates from the evolution of simulators in different fields, such as aviation and the military. Knowledge distilled from these disciplines have been applied to simulation-based learning (Rosen, 2013). Simulation-based learning is a learner-centred approach based on social constructivism (Ross, 2021). In this approach, students engage in exploratory learning that inevitably results in errors (Bell & Kozlowski, 2008). When errors are not identified, acknowledged and addressed in SBL experiences, students are likely to repeat the same mistakes in future simulations or clinical practice (Satava, 2007). However, some studies have documented how educators prefer to stop a simulation activity when learners reach an impasse, rather than allowing the situation to unfold and giving them the opportunity to try and solve the problem by themselves (Brown, 2011). Turton et al. (2019) pointed out several reasons why mistakes are not commonly identified and addressed in simulation debriefs. First, educators care for students' wellbeing and want to make sure they feel comfortable and safe. Second, making mistakes visible could trigger feelings of discord and isolation, which can disrupt the simulation session. Third, students could argue that their errors are caused by the simulation itself and miss the opportunity to visualise them as learning tools. Finally, educators and students may share the implicit or explicit belief that harm should always be avoided in SBL experiences. Therefore, the notion of trying to be perfect can result in students focusing on things that go right and avoiding errors (Young et al., 2016).

In addition, avoiding errors is aligned with the general perception that errors in education are adverse events that should be prevented at all costs (Manalo & Kapur, 2018). To err is human (Institute of Medicine, 2000). However, errors in health service delivery can cause severe consequences to patients and be career-ending for clinicians (Warner, 2016). To prevent these potential outcomes, SBL has evolved to allow learners to explore beyond the limits of their knowledge and skills and make and learn from their mistakes (Pollock & Biles, 2016). However, little is known about healthcare students' perceptions of making mistakes in simulation. The following section explores this issue in more detail.

1.2.3 Students' perceptions of making errors in simulation-based learning

> A study group resident failed to place the pulse oximeter on the patient and conducted the entire anaesthetic without saturation monitoring. Needless to say he never detected the hypoxic event, but to this day Ken has never forgotten about his mistake and brings it up frequently and every time we get together to conduct a PBL session together at annual anaesthesia meetings. Recognizing the power of mistakes, errors, and failure was born from such early experiences and has set the tone of our simulation scenarios and our research efforts to this day.
>
> — [Rosen, 2013, p. 36]

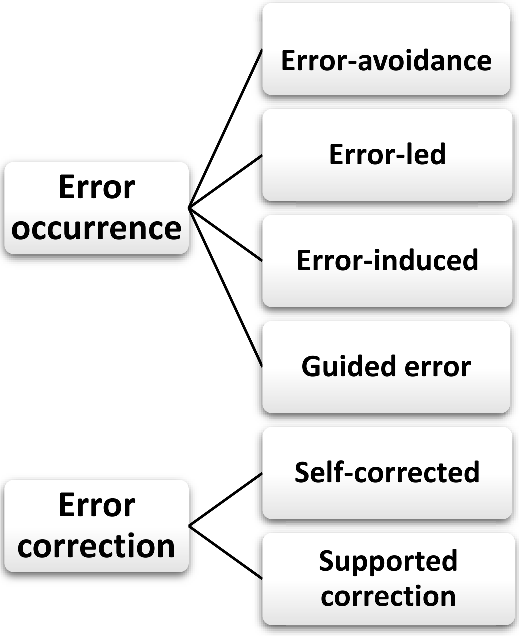
SBL "offers permission to fail, encouraging learners to deliberately experience and learn from such failure in a way that would be inconceivable with actual patients" (Kneebone et al., 2004, p. 1098). However, errors in simulation can have negative consequences (Shearer, 2016). Several studies emphasise how errors can be emotionally detrimental for some students (Cato, 2013; Cordeau, 2012), and they may feel too intimidated to reveal their mistakes (Aubin & King, 2015). Moreover, emotions such as anxiety or fear caused by errors may lead to more errors (Cordeau, 2012; Savoldelli et al., 2005) and affect clinical performance (Cheung & Au, 2011). Despite the emotional distress that errors may cause in SBL experiences, students also recognise that making errors in simulation is critical for their learning (Harder, 2012; Young et al., 2016). Simulations experiences that allow students to reflect on their errors and the potential consequences for their clinical practice are considered meaningful and memorable (Bearman et al., 2018). In recognition of the potentially positive and negative impacts of errors on students and their learning, a deeper exploration of healthcare students' views and experiences of making mistakes in SBL was warranted and led to the first stage of this study (see the publication in Chapter 2).

1.2.4 The use of errors in education

The use of errors in education requires the implementation of instructional strategies and error correction mechanisms that allow students to learn from their mistakes. Lorenzet et al. (2005) proposed a typology for the use of errors in education, emphasising two key components: error occurrence and error correction (see Figure 1).

Figure 1

A Typology for the Use of Errors in Education



Error occurrence can be categorised into the following instructional strategies: error-avoidance, error-led, error induction, and guided error (Lorenzet et al., 2005). In error-avoidance strategies, learners receive comprehensive explanations of how to perform practical learning tasks, which prevents them from making errors (Dormann & Frese, 1994). In medical education, this type of instructional strategy is common (DaRosa & Pugh, 2012; Satava, 2007).

In an error-led approach, there is no predetermined strategy for eliciting errors, but they are not prevented (Lorenzet et al., 2005), whereas in error induction or error encouragement instruction (DaRosa & Pugh, 2012) error-making is actively promoted. In this approach, specific conditions are created for students to elicit errors. Examples of these conditions include providing complex learning tasks without pedagogical guidance (Dormann & Frese, 1994; Kapur & Bielaczyc, 2012; Keith, 2011) or delaying instruction about the learning task (Jacobson et al., 2015; Kapur, 2012). Although it is not possible to ensure learners will always make the same errors (Ivancic & Hesketh, 2000), the likelihood of committing them increases considerably (Frese et al., 1991).

In guided errors, individuals learn by analysing examples of errors and their possible solutions (Ivancic & Hesketh, 2000). Kapur (2014a) defined this way of learning as vicarious failure, in which students learn from their peers' errors. Although this approach can minimise the negative emotional effects of eliciting errors (Lorenzet et al., 2005), it does not enable learners to develop metacognitive skills (Ivancic & Hesketh, 2000).

The second component of Lorenzet et al.'s (2005) typology for the use of errors is error correction, which refers to how errors are addressed. The authors proposed two alternatives to error correction: self-correction and guided correction (Lorenzet et al., 2005). In the former, learners correct their errors without external facilitation (Dormann & Frese, 1994; Frese et al., 1991). In the latter, external facilitation, such as the educator's feedback (Kapur & Bielaczyc,

2012) or computer-based support (Lorenzet et al., 2005) is used to rectify errors (Debowski et al., 2001).

This section has described how errors can be used in education. The key message of this section is that the use of errors in education requires a careful plan that involves the implementation of instructional strategies (e.g., error-led, error-induced) and the mechanism with which errors will be corrected (guidance or self-correction). Consequently, simulation experiences that explicitly use errors as learning tools should integrate the principles of pedagogical approaches that support learning from errors. The importance of acquiring a deeper understanding of the pedagogical methods that embrace errors as learning opportunities and how such approaches can inform simulation design meant the exploration of this topic was essential; the second stage of the study (see the manuscript in Chapter 3) addresses this topic.

1.2.5 The impact of errors on learning

This section explores the impact of errors on students' learning based on pedagogical approaches that support learning from errors, namely error management training (EMT) and PF, in the context of occupational training, health-related disciplines, and SBL.

Error management training

Error management training has been widely implemented in many occupational training settings (Frese, 1995; Keith & Frese, 2005). This training method minimises the negative outcomes of making errors (Frese & Keith, 2015) and develops healthy coping strategies for responding to them (Keith, 2011). EMT engages trainees to actively explore learning tasks and explicitly encourages error-making (Keith, 2011).

The effectiveness of EMT has been explored for more than three decades (Dormann & Frese, 1994; Frese et al., 1991). Frese et al. (1988) conducted a series of studies comparing two types of training approaches: error training (designed to elicit errors) and error-avoidant training (designed to induce error-free performance).

In one study, Frese et al. (1991) allocated participants to either an error training group (n = 15) or an error-avoidant group (n = 9). The training was designed for participants to learn computer skills. Both groups completed a pre-test and received a mini-lecture about basic computer concepts before the study intervention. Participants in the error-avoidant group received written specifications for each step of the given learning task, reducing the opportunity to make mistakes. In contrast, participants in the error training group did not receive guidance on how to solve the learning task and were instructed to solve the problem by themselves; therefore, this group was more exposed to making errors. This group also received positive statements about the benefits of errors, intending to minimise negative emotions in the face of errors. Both groups completed a post-test the day after the intervention. The findings indicated that the error training group scored higher than the error-avoidant group in solving complex learning tasks. In addition, the researchers suggested that participants from the error training group had developed emotional strategies to cope with errors under stressful circumstances. It was postulated that without pedagogical support from trainers, deep mental processing was activated, which led participants to gain a better understanding of the content to be learnt. Although the error training group was demonstrated to be superior in terms of completing challenging learning tasks, the results of this paper should be interpreted with caution because of the small sample size. In addition, the study was conducted in a single setting, limiting the representativeness and generalisability of the results.

Ivancic and Hesketh (2000) explored the impact of making errors (error training) compared to error avoidance training (EAT, designed to avoid making errors) in the context of an automobile driving simulation. The researchers found that learners exposed to an error training approach were better able to transfer what they had learned to an analogous driving test than those who received an error avoidance approach. The error training participants also demonstrated better strategies for coping with a novel driving problem. Further research is needed to establish whether the findings of this study can be translated to real-world driving conditions.

Joung et al. (2006), working with firefighters (N = 59), investigated whether an “error-story training group” who received case studies with common errors committed in firefighting events and were instructed about the consequences of such mistakes, improved adaptive performance compared with an “errorless-story group”, who received the same case studies but with successful firefighting practices. The findings indicated that the error-story training group enhanced adaptive performance and adopted a more active approach in reviewing strategies and exploring alternatives, all pivotal to developing adaptive behaviour. Evidence-based interventions conducted in real-world settings are needed to support the findings of this study.

Although the above studies demonstrate the superiority of error training compared to EAT in facilitating learning, some studies have documented inconsistent findings. For instance, Loh et al. (2013), in the context of an air traffic control simulated environment, allocated 164 participants to three groups: error encouragement, error avoidance, or control training. The findings suggested that the error encouragement group performed better than the error avoidance group; however, the control training and error encouragement groups were equally effective. This finding may be explained because participants in the latter two groups had the same opportunities for active exploration of the learning tasks, leading them to achieve better learning outcomes. In addition, Loh et al. (2013) found that higher-ability participants benefit from error training more than lower-ability students, suggesting that learning from errors is cognitively demanding. The error encouragement training was more beneficial than EAT for participants who were more open to new experiences, suggesting that personal attributes should also be considered when designing error training activities.

Meritet et al. (2020) compared the impact of EMT and EAT with veterinary students learning to tie surgical knots. There were no statistically significant differences between groups on the transfer assessment. In addition, overall, both EMT and EAT groups exhibited a decline in performance at seven weeks after training. However, there was a significant difference between EAT and EMT groups in one of eight outcomes measured. Although further research is needed to confirm and expand on these results, the authors suggested that EMT is at least comparable to EAT for surgical knot training.

The effectiveness of EMT has also been explored in SBL. For example, Gardner and Rich (2014), in a pilot study, randomly assigned first year radiology technology students (N = 22) into either traditional instruction (TI) or vicarious error (VE) management training. The TI group (n = 11) watched a case scenario in which radiology technicians performed correct procedures, whereas the VE group (n = 11) watched the same case scenario, including the errors committed. Subsequently, both groups participated in discussion sessions. In the TI group, the discussion consisted of students reflecting on what went well and specifying the reasons why. In contrast, VE participants were asked to identify the errors committed in the case scenario. Subsequently, both groups participated in a performance test, on which the VE participants outscored TI participants. Gardner and Rich (2014) concluded that in order to learn from errors, educators should facilitate a discussion about students' mistakes and how to correct them. The findings cannot be generalised easily, because this was a small-scale study conducted in one site.

Gardner et al. (2015), facilitating central venous catheter (CVC) placement skills, randomly allocated medical interns (N = 30) to either the correct only (CO) group (n = 16) or the correct plus error (CE) group (n = 14). Both groups completed a pre-test that measured knowledge and skills related to internal jugular and subclavian CVC placement. Subsequently, the CO group watched a 10-minute video displaying the correct CVC placement procedure. The CE group watched the same video and additionally the typical errors when performing this procedure and how to address them. This group also received positive error framing, which refers to making errors evident and prompting individuals to visualise errors as learning resources (Steele-Johnson & Kalinoski, 2014). Both groups completed a post-test and a transfer test 30 days after finalising the training. The findings indicated that both groups improved their knowledge and skills in the post-test. However, the CO group had significantly worse skill retention for the CVC placement technique in the transfer test than the CE group. These findings suggest that errors can be used to facilitate learning. Further research is needed to confirm whether the findings of this study can be transferred to larger populations at different locations.

Dyre et al. (2017) compared the effectiveness of EMT and EAT in a simulated ultrasound activity with medical students. Whereas EAT participants (n = 28) were instructed to make as few errors as possible, EMT participants (n = 32) were allowed to make errors and received positive feedback when an error occurred. Examples of these positive error statements were: “The more errors you make, the more you learn!” and “You have made an error? Great! Because now you can learn something new!” (Keith & Frese, 2008, p. 60). The results demonstrated that EMT students obtained higher scores on the transfer test than the EAT group, suggesting that positive error framing minimises the potential negative effects of making errors and promotes learning. Further research is required to confirm the results of this study in different sites and with multiple cohorts. In addition to the EMT approaches outlined previously, PF studies have contributed to advancing the understanding of the effectiveness of errors in education.

Productive failure

Productive failure is a pedagogical method that comprises an exploration phase in which students attempt to solve novel and challenging learning tasks before being taught how to approach them, followed by a consolidation or instruction phase, in which the educator provides instruction on the concepts or content to be learnt based on students' responses to the given problem/s (Sinha & Kapur, 2019). Although the exploration phase can lead students to generate erroneous solutions (make mistakes), it prepares them to receive subsequent instruction (DeCaro & Rittle-Johnson, 2012; Kapur, 2014b, 2015). This is because the exploration of learning tasks leads to trial and error, and the errors provide the feedback needed for students to realise their knowledge and skills deficits, and therefore pay closer attention to the educators' explanations in the instruction phase (Loibl & Rummel, 2014).

Productive failure has been compared with a more traditional approach, referred to as DI, that commonly starts with instruction on the concepts or content of the educational session, followed by problem-solving activities (Cao et al., 2020; Jacobson et al., 2017; Kapur, 2010, 2012; Kapur & Bielaczyc, 2011, 2012). As a consequence of this conventional approach, students know in advance how to solve the learning tasks (Kirschner et al., 2006) and therefore tend to make fewer mistakes.

The effectiveness of PF has been explored in secondary education and higher education through the measurement of learning outcomes such as declarative knowledge, explanatory knowledge, and transfer of knowledge (Cao et al., 2020; Jacobson et al., 2017). Declarative knowledge refers to knowledge about facts (Ohlsson, 1996). Common approaches to measuring declarative knowledge include questions about the signs and symptoms of a particular disease or the equipment required for a specific clinical procedure. Declarative questions are often preceded by the word "what" (Jacobson et al., 2017), for example, "what are the sign and symptoms of …?"

In explanatory knowledge, students explain their understanding of a particular event (Coleman, 1998; Jacobson et al., 2017). Explanatory knowledge is demonstrated, for example, when students provide the rationale for choosing a particular nursing action or clinical procedure. “Why” or “how” words are often used as preliminaries to these types of questions (Jacobson et al., 2017).

Transfer of learning refers to students’ ability to apply what they have learned to novel problems (Loibl et al., 2017). This knowledge is assessed, for example, by challenging students to apply their learning to novel clinical problems that were not addressed in a given educational session.

Several researchers have compared the effectiveness of PF and DI approaches. For instance, Jacobson et al. (2017) worked with students to learn complex systems and climate change concepts in the context of an agent-based computer simulation. The researchers assigned 110 students to either a PF group or a DI group. The PF group worked with agent-based computer models before receiving instruction, while the DI group received instruction followed by problem-solving tasks using computer-based models. The results revealed that the PF group significantly outperformed the DI group on explanatory knowledge and the transfer of learning without compromising the acquisition of declarative knowledge. Due to the small sample size of this study, conducted at one single setting, further research could explore the impact of PF in multiple settings and with diverse student cohorts and topics.

Cao et al. (2020) randomly allocated 148 students to either a PF game-based learning (PF-GBL) group or a DI game-based learning (DI-GBL) group (to learn mathematics and genetics concepts). The study consisted of three intervention sessions and a pre-test and post-test. The PF-GBL participants outperformed DI-GBL participants on the test items measuring explanatory knowledge and transfer of learning.

Chowrira et al. (2019) demonstrated that first-year university students (n = 295) who learned biology concepts using a PF approach increased their scores by five percentage points in a follow-up test (midterm exam) compared to students (n = 279) who received a more conventional instructional approach. Interestingly, the benefits of PF were particularly evident in students with a history of poor performance; these students improved approximately seven points in a second follow-up test (final exam).

Although the studies outlined above support the effectiveness of PF in terms of knowledge improvement and transfer of learning, there are also conflicting findings.

For example, Nachtigall et al. (2020) conducted two quasi-experimental studies to explore the effectiveness of PF in learning social science research methods. Students (N = 212) were allocated to either a PF group (n = 121) or a DI group (n = 91). PF students began with a challenging learning task, and subsequently received guidance on how to solve the problem. In contrast, the DI group received instruction and then the learning task. The results demonstrated that the DI approach was superior to PF for learning social science research methods.

Productive failure in healthcare education

Steenhof et al. (2019) randomly allocated first-year Doctor of Pharmacy students to either a PF group (n = 21) or a DI group (n = 22) to learn the concept of creatinine clearance. Learning outcomes measured were knowledge acquisition, knowledge application and preparation for future learning (the ability to generate new solutions or strategies for solving problems). The findings demonstrated no significant difference between the groups with respect to the knowledge acquisition and knowledge application assessments. However, the PF group outperformed the DI group on the preparation for future learning assessment, suggesting that PF facilitates new learning. The findings of this study should be interpreted with caution due to the small sample size, single site and the use of unvalidated instruments.

Similarly, Steenhof et al. (2020) compared the effectiveness of two pedagogical approaches: PF and indirect failure (in which students compare their peers' mistakes to a correct solution). In the exploration phase, students in the PF group (n = 21) were instructed to create a formula to estimate creatinine clearance without pedagogical guidance, which inevitably elicited mistakes. The indirect failure group (n = 21) compared the correct solution with their peers' erroneous solutions and received the Cockcroft–Gault formula (for creatinine clearance) as instructional support. Subsequently, both groups received an instruction phase and a practice phase, followed by tests of knowledge acquisition, knowledge application, and preparation for future learning immediately after the session and again after one week of finalising the activity. There were no significant differences between groups with respect to knowledge acquisition and knowledge application. However, the PF students outperformed indirect failure students on the preparation for future learning test, both in the immediate post-training test and one week later.

There are some conflicting findings regarding the effectiveness of PF in healthcare education. Dubovi (2018), in an online computer-based simulation, allocated 103 nursing students to either a PF group or a simple-to-complex group (in which pedagogical facilitation is gradually reduced according to students' progress) (Frerejean et al., 2019). Participants from each group individually completed two online clinical simulation scenarios. The findings suggested that the simple-to-complex approach was more effective than the PF approach for learning clinical reasoning skills. However, in this study, participants were not debriefed after the simulation activity. PF theory posits that incorporating an instruction phase (provided in the debrief session of a simulation experience) is pivotal for students to learn from their mistakes. This phase allows students to make sense of their errors (and knowledge gaps) and consolidate their knowledge into more complete schemas (Jacobson et al., 2020; Kapur, 2016; Kapur & Bielaczyc, 2012).

In summary, the studies outlined above highlight that both PF and EMT approaches have the potential to promote meaningful learning outcomes in different settings, subjects and cohorts of students. Although the effectiveness of EMT has been assessed in the context of simulation-based medical education, there is a need for further research on the impact of PF on students' learning, satisfaction levels (discussed in Chapter 4) and perceptions of this novel learning experience (discussed in Chapter 5) in the context of simulation-based nursing education.

1.3 Problem statement

The literature review revealed the following research gaps:

1. Poor understanding of healthcare students’ perceptions of making errors in SBL
2. A lack of understanding of how pedagogical approaches that use errors as learning tools can inform the design of SBL experiences that explicitly support learning from errors
3. A lack of empirical evaluations of the effectiveness of and student satisfaction with productive failure simulations compared to direct instruction simulations
4. A dearth of studies examining students’ views about being exposed to productive failure simulations.

1.4 Research questions

The following research questions were formulated based on the research gaps outlined above:

1. What are healthcare students' perceptions and experiences of making errors in SBL? (see Chapter 2)
2. How can SBL experiences be informed by pedagogical approaches that promote learning from errors? (see Chapter 3)
3. How are nursing students' learning and satisfaction levels influenced by PF simulations compared with DI simulations? (see Chapter 4)
4. What are nursing students' perceptions of participating in PF simulations? (see Chapter 5).

1.5 Research paradigm: Pragmatism

In research, a paradigm refers to a set of beliefs, values, and assumptions commonly shared by a community of researchers (Creswell & Plano Clark, 2011). A paradigm represents worldviews based on philosophical positions about, for instance, the nature of reality (ontological beliefs), ways of knowing (epistemological beliefs), and the nature of ethical actions and values (axiological assumptions) (Johnson et al., 2007; Patton, 2002). The selection of a paradigm allows researchers to clarify their philosophical and methodological positions and justify the research design, strategies of inquiry and research methods for a particular study (Creswell, 2009). Research can be guided by postpositivist (Panhwar et al., 2017), constructivist (Mertens, 2014), transformative (Creswell, 2009), and pragmatic (Morgan, 2007) paradigms. This doctoral study was based on the philosophical assumptions of pragmatism.

Pragmatism, as a research paradigm, became popular in the United States in the early 20th century from due to the work of pragmatists such as William James, Charles Pierce and John Dewey (Leavy, 2017). Pragmatism can be defined as a “way to fit together the insights provided by qualitative and quantitative research into a workable solution” (Johnson & Onwuegbuzie, 2004, p. 16). The pragmatic paradigm has the following characteristics.

- Individuals have a unique and personal interpretation of reality (Mertens, 2014), and knowledge is constructed by multiple world realities (Leavy, 2017). In this sense, pragmatism supports different worldviews and perspectives on a research problem (Andrew & Halcomb, 2009; Creswell & Creswell, 2017).
- Pragmatism supports a value-oriented approach drawn from cultural values such as freedom, equal opportunity and progress (Johnson & Onwuegbuzie, 2004).
- Pragmatists adopt research methods and strategies of inquiry (Creswell, 2009) based on the specific research questions and aims of the research (Andrew & Halcomb, 2009; Morgan, 2007).
- Pragmatism supports fallibilism, which holds that beliefs and research conclusions cannot be completely certain (Johnson & Onwuegbuzie, 2004).
- Pragmatism rejects the traditional standards of truth as permanent and objective (Andrew & Halcomb, 2009). From this philosophical position, truth is “what works” in a particular circumstance (Creswell & Creswell, 2017, p. 332). In other words, pragmatism emphasises the outcomes of action rather than the underlying philosophy (Leavy, 2017).

- Pragmatism recognises the natural/physical world and the social and psychological world (Leavy, 2017), involving aspects such as language, culture and subjective thoughts (Johnson & Onwuegbuzie, 2004).
- Pragmatism rejects the dichotomy between qualitative and quantitative methods (Andrew & Halcomb, 2009). It supports mixed methods research, in which quantitative and qualitative approaches are integrated for a more holistic understanding of the phenomena of interest (Creswell & Creswell, 2017).

1.6 Research design: Mixed methods

As outlined previously, mixed methods research has its foundations in the philosophy of pragmatism (Johnson et al., 2007). Mixed methods research moves away from the perpetuated conflict of purist paradigms (qualitative and quantitative) towards a more logical and integrated approach (Johnson & Onwuegbuzie, 2004). Mixed methods research is defined as an approach that "employs quantitative research assessing magnitude and frequency of constructs and rigorous qualitative research exploring the meaning and understanding of constructs" (Creswell et al., 2011, p. 4). Mixed methods research involves the use of inductive and deductive reasoning (Creswell & Creswell, 2017). Inductive reasoning moves from specific observations and measures to general conclusions or theories (Mitchell, 2018). Qualitative researchers commonly use this way of thinking as a bottom-up approach, from collecting and analysing data to proposing emerging themes (Creswell & Creswell, 2017). In contrast, quantitative researchers often use deductive reasoning, which adopts a top-down approach that begins with a theory of interest to be tested, confirmed or rejected (Mitchell, 2018).

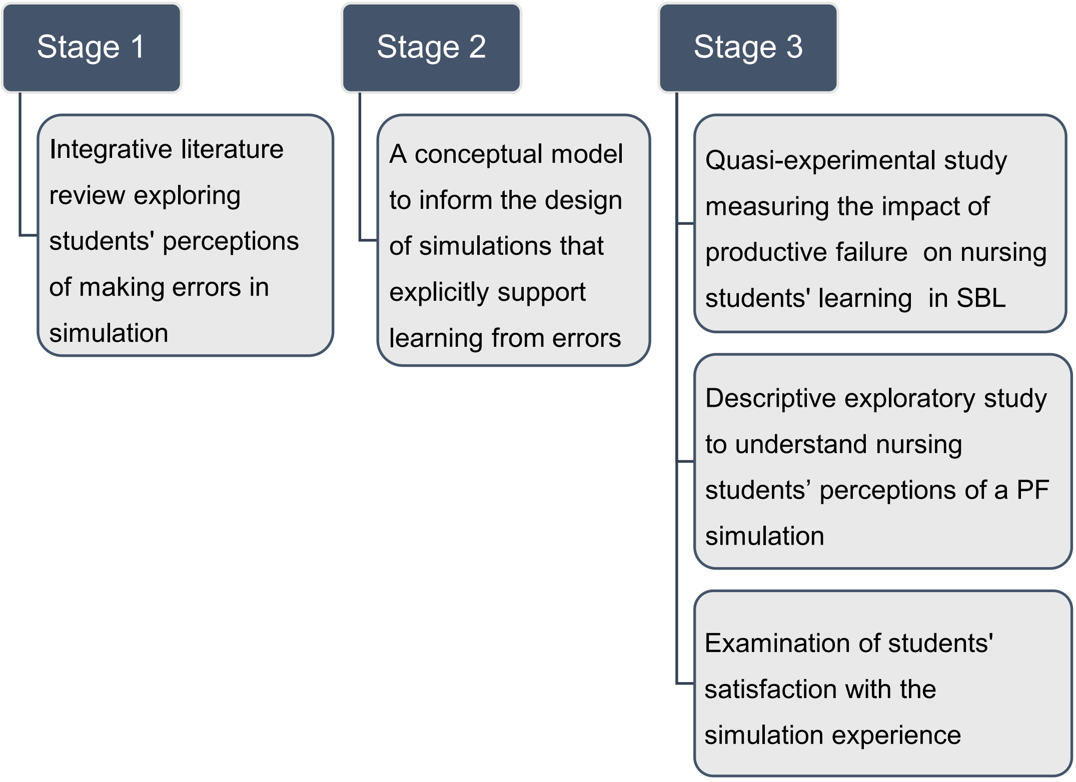
Advocates of mixed methods research recognise that qualitative and quantitative research can contribute to knowledge (Johnson & Onwuegbuzie, 2004), employing both approaches in a single study to provide a more in-depth understanding of a research inquiry (Creswell, 2009). Incorporating insights from both approaches can produce more integrated outcomes (Johnson & Onwuegbuzie, 2004). An exploratory, sequential, mixed-methods design with a three-stage approach was used in this doctoral study and is described in the following section.

1.7 Research stages

The first stage of this doctoral research (see Figure 2) highlighted the controversy over the use of errors in simulation due to their potential positive and negative impact on students and their learning. An integrative literature review was conducted to explore healthcare students' views about their experiences of making errors in simulation.

Figure 2

Stages of this Doctoral Research



The second stage of the study addressed the lack of understanding of how pedagogical approaches that promote learning from errors can inform simulation design. Thus, in this stage, a Learning from Errors (LE) conceptual model was developed to inform the design of healthcare simulations that use errors as learning tools. This novel conceptual model is based on key principles of PF and EMT, along with the pedagogical features of high-quality healthcare simulations. The LE model includes the following elements: normalisation of errors, challenging simulation scenarios, self-directed learning, collaborative teamwork, and comparison with best practice.

The third stage of the study evaluated nursing students' learning and satisfaction with a PF simulation compared to a DI simulation and explored students' perceptions of PF simulations. Consenting participants were randomly allocated to either a PF group (n = 181) or a DI group (n = 163). The intervention consisted of two paediatric closed head injury simulations interspersed with a debrief. The learning outcomes measured were declarative knowledge, explanatory knowledge and transfer of knowledge. The Satisfaction with Simulation Experience (SSE) scale (Levett-Jones et al., 2011) was used to measure participants' satisfaction with the learning experience. Semi-structured interviews were conducted with students in the PF groups to fully explore their experiences and views. Table 1 displays a summary of each research stage and its corresponding publication. Details of each stage and its results are presented in the following chapters.

Table 1

Research Stages and Resulting Publications

Stage	Research aim	Participants/ included papers	Chapter	Citation
1	Integrative literature review exploring healthcare students' perceptions of making errors in simulation	n =11 (papers)	2	**Palominos, E.,** Levett-Jones, T., Power, T., & Martinez-Maldonado, R. (2019). Healthcare students' perceptions and experiences of making errors in simulation: An integrative review. *Nurse Education Today, 77*, 32-39.
2	Conceptual model to inform the design of simulations that explicitly support learning from errors	-	3	**Palominos, E.,** Levett-Jones, T., Power, T., & Martinez-Maldonado, R. A conceptual model to inform the design of healthcare simulations that promote errors as a catalyst for learning: A discussion paper. *Nurse Education in Practice,* 65, 103500.
3	Quasi-experimental study measuring the impact of PF on nursing students' learning in simulation	n = 344 (participants)	4	**Palominos, E.,** Levett-Jones, T., Power, T., Alcorn, N., & Martinez-Maldonado, R. (2021). Measuring the impact of productive failure on nursing students' learning in healthcare simulation: A quasi-experimental study. *Nurse Education Today*, 101, 104871.
	Descriptive exploratory study exploring nursing students' perceptions of a PF simulation	n = 66 (participants)	5	**Palominos, E.,** Levett-Jones, T., Power, T., & Martinez-Maldonado, R. (2022). 'We learn from our mistakes': Nursing students' perceptions of a productive failure simulation. *Collegian: The Australian Journal of Nursing Practice, Scholarship and Research.*

1.8 Ethical considerations

This research project was conducted according to ethical standards determined by University of Technology Sydney (UTS) research policies and procedures and the National Health and Medical Research Council ethical requirements (National Health and Medical Research Council, 2007, updated 2018). Ethics approval was only required for stage 3, and was obtained from the UTS Human Research Ethics Committee (protocol no. ETH19-3425) (see Appendix 1). The ethical principles embedded in this study included respect for persons, research merit and integrity, justice and beneficence (Anderson & Corneli, 2018), and are discussed below.

Respect for persons recognises that “each human being has value in himself or herself, and that this value must inform all interaction between people” (National Health and Medical Research Council, 2007, updated 2018, p. 9). Respect for persons recognises participants’ opinions and the value of human autonomy. Autonomy refers to the individual’s right to make their own decisions based on adequate and comprehensive information (Shahriari et al., 2013). Informed consent promotes trust between participants and researchers and serves as a way to demonstrate the researchers’ commitment to protecting participants’ autonomy, rights and welfare (Resnik, 2018). Therefore, written informed consent was sought from participants prior to commencing data collection (see Appendix 2). Potential participants were given a participant information statement (see Appendix 3) that included information about the study, such as the aim of the study, the reasons to conduct the research, time commitment, type of activity and the risks and benefits of participating (O'Leary, 2021). This also involved answering participants' questions until they were satisfied (Schneider, 2013). Autonomy was ensured by allowing potential participants the freedom to decide whether to participate in the study, and advising them that they possessed that right. Those who were willing to participate in the study signed the consent form. It was emphasised that participation was voluntary, and that participation or non-participation would not affect participants' course progression or any assessments.

Respect for persons also involves participants' anonymity and confidentiality (National Health and Medical Research Council, 2007, updated 2018). Anonymity refers to protecting participants' identities, even from the researchers if possible (O'Leary, 2021). To ensure anonymity, participants' personal information was deidentified by removing their names from the class attendance list and replacing them with randomly generated identification numbers (see Appendix 4). The randomisation was conducted by a researcher who was not associated with the study, using an online random number generator (Haahr, 2010). In addition, it was ensured that the data from the various sources used in the study (demographic survey, pre- and post-simulation knowledge tests, and a satisfaction survey) were collected anonymously.

Confidentiality was ensured by presenting and publishing research findings in such a way that participants cannot be identified. Additionally, data collected from this research project was securely stored on password-protected computer files for a period of five years, after which time it will be destroyed (National Health and Medical Research Council, 2007, updated 2018). UTS requirements regarding the storage of data have been complied with, and a UTS Stash account was created to manage the research data.

To be ethical, research must have merit. The findings presented in this thesis have already made useful contributions to knowledge; to date, the four papers included in this doctoral study have been published in high-quality Q1 peer-reviewed nursing journals, and two of them have received multiple citations. It is expected that the findings from this doctoral research will inform the design of simulations that embrace errors as learning resources that facilitate meaningful learning outcomes that ultimately improve patient outcomes.

Research integrity and honesty are crucial in conducting, reporting and publishing research findings (Schneider, 2013). Research integrity refers to the responsible conduct of research (Resnik, 2018) according to recognised regulations and ethical guidelines (Schneider, 2013). This doctoral study complied with ethical requirements for the conduct of research as well as the research protocol and consent process approved by the UTS Human Research Ethics Committee. The data obtained from the study were analysed accordingly, and the results were published and disseminated truthfully.

The principle of justice recognises that individuals must be treated equally (National Health and Medical Research Council, 2007, updated 2018). In research, this involves the fair recruitment of participants and equal distribution of the benefits and burdens of research (Anderson & Corneli, 2018). In terms of recruitment, this study was embedded in a scheduled, in-class simulation session.

To avoid any perception of coercion, the study was introduced to students at the beginning of the simulation session by an external researcher who was not involved in teaching or the research project, and students were told that their decision to participate or not would have no impact on their course progression or assessment results. Students who declined to participate still undertook the simulation but did not complete the demographic survey, pre- and post-simulation knowledge tests or satisfaction survey. Regarding the equal distribution of the benefits and burdens of research, the study involved two groups: the PF group and the DI group. Both groups were taught by the same simulation facilitator and exposed to the same simulation scenarios and instructional materials. The main difference between groups was that the DI group received instruction before the simulation activity, while the PF group received the inverse instructional sequence (simulation activity followed by instruction).

The ethical value of beneficence refers to ensuring no physical/emotional harm to participants (Anderson & Corneli, 2018). Despite direct risks to participants being unlikely, this study involved participants performing challenging simulation scenarios without the immediate guidance of the simulation facilitator, which could have caused emotional distress. In the participant information statement, it was emphasised that the exposure to challenging simulation activities would be in an environment of trust and respect, and the simulation process would be similar to previous simulation sessions in which they had been involved. The participant information statement also included the candidate’s contact phone number and contact details of the Human Research Ethics Secretariat in case of complaints, concerns, or further questions.

1.9 The researcher's situatedness within the study

This section presents the foundations from which my situatedness may have influenced the interpretation of the research reported in this thesis.

I studied for my Bachelor of Nursing at a Chilean university, and started to develop a passion for understanding how people learn with the support of technologies. I was interested in exploring novel teaching and learning approaches beyond the well-known teacher-centred approach and the rote memorisation method. In order to pursue my passion for this topic, after completing my undergraduate studies, I studied a graduate diploma in teaching in Biomedical Sciences and subsequently a Master of Education in Health Sciences. I also dedicated half of my work schedule to serving as a clinical nurse educator. My interactions with new graduate nurses in the clinical setting made me realise that despite obtaining good scores in their assessments at university, some nurses struggled to apply their "learning" to clinical practice. Why did this happen? What were we, as nurses' educators, missing? These questions motivated my decision to undertake a Master's degree in Learning Sciences and Technology in Australia. My Master's supervisor, Professor Michael Jacobson, introduced me to a novel pedagogical approach named productive failure. Studies of PF had begun to produce promising results in terms of the transfer of learning to novel problems in mathematics and physics. However, there was little exploration of this pedagogical approach in nursing simulation. I also found that the pedagogical sequence of simulations commonly involved "instruction followed by the simulation activity", which falls in the traditional teaching approach, and PF employs the inverse pedagogical order. Hence, I identified research gaps that deserved to be filled. This thesis offers an alternative novel pedagogical approach to simulations that may improve nursing students' learning, satisfaction levels and perceptions.

Conclusion

Chapter 1 provided an overview of the role of errors in education and in SBL. It also explored healthcare students' perceptions of making errors in simulation and the effectiveness of errors in terms of learning in different educational settings. Finally, this chapter presented the research gaps, research questions, research design, research stages, the ethical considerations for the study and the researcher's situatedness within the study. The next chapter answers the first research question by presenting an integrative review of the literature on healthcare students' views and experiences of making errors in SBL.

Chapter 2. Integrative literature review (stage 1)

> Failure is success if you learn from it.
>
> — Unknown

2.1 Introduction

The overview of the literature presented in the previous chapter emphasises the importance of SBL providing a safe learning environment in which students can make and learn from errors (Felton & Wright, 2017; King et al., 2013; Lendahls & Oscarsson, 2017; Reime et al., 2016; Schoening et al., 2006; Ziv et al., 2005). Nevertheless, for some students, making mistakes in simulation can trigger unpleasant feelings (Shearer, 2016; Yockey & Henry, 2019). Paradoxically, students also recognise that things that went wrong in simulation and the emotions that emerged from these experiences are crucial for their learning (Bearman et al., 2018). In response to these controversial findings and recognising the potential positive and negative impacts of errors on students and their learning, the candidate conducted an integrative review of the literature on healthcare students' views and experiences of making errors in SBL.

2.2 Published paper

The paper presented in this chapter is:

Palominos, E., Levett-Jones, T., Power, T., & Martinez-Maldonado, R. (2019). Healthcare students' perceptions and experiences of making errors in simulation: An integrative review. *Nurse Education Today, 77*, 32-39. https://doi.org/10.1016/j.nedt.2019.02.013

2.3 Aim

The aim of this review was to:

Explore healthcare students' perceptions of making errors during SBL experiences.

2.4 Ethics approval

Not applicable

2.5 The impact of this publication

By the end of November 2022, this integrative literature had been cited 29 times (Source: Google Scholar), tweeted 19 times and retweeted 74 times. Attention score: 50, placing it in the top 5% of all research outputs scored by Altmetric (Altmetric, 2015).

2.6 Publication copyright

Elsevier® authorises authors to include their articles in full or in part in a thesis or dissertation (Elsevier, 2022).

2.7 Appendices

The following appendices are related to Chapter 2:

- Appendix 4—literature search outcomes
- Appendix 5—the Critical Appraisal Skills Programme checklist of the selected studies

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Review

Healthcare students' perceptions and experiences of making errors in simulation: An integrative review

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ABSTRACT

Background: Research literature suggests that learning from mistakes facilitates news insights and leads to professional development. The significant growth in the use of simulation-based learning is premised on the understanding that in this context learners can make and learn from their errors without negatively impacting real patients. However, studies also suggest that making errors can be emotionally detrimental to learners. Given these contradictory findings, this literature review explores learners' views about this phenomenon.

Objective: The objective of this integrated review was to explore healthcare students' perceptions of making errors during simulation-based learning experiences.

Design: Whittemore and Knafl's framework for integrated reviews was used to structure this review.

Data sources: Five electronic databases MEDLINE, CINAHL, PsycINFO, ProQuest, and SCOPUS and the search engine Google Scholar were searched. The initial terms used were nursing students, medical students, health professionals, error*, mistake*, and simulation.

Methods: The original search resulted in 2317 potential records. After screening against the inclusion/exclusion criteria, 11 articles were critically appraised using The Critical Appraisal Skills Program (CASP) checklist and were included in the review.

Results: The two overarching themes to emerge from the analysis were *the impact of errors on learners* and *the impact of errors on learning.*

Conclusion: Despite the negative feelings experienced by some students regarding making mistakes in simulation, there were key factors that moderated the impact of these feelings and transformed the errors into learning opportunities. These included: the provision of a safe learning environment where constructive feedback was provided by skilled educators, and where students were supported to take responsibility for their mistakes. Although the findings suggest that making mistakes in simulation-based learning can be beneficial, optimising learning from mistakes requires a deliberate and thoughtful approach in which educators plan for and support learners to recognise, acknowledge and respond effectively to errors.

1. Introduction

Healthcare errors represent a major source of morbidity and mortality globally. It is estimated that internationally patients experience approximately 16.8 million adverse events each year (Jha et al., 2013), making healthcare errors the third leading cause of death in developed countries (Makary and Daniel, 2016). In recognition of the need to address these concerning patient safety statistics, simulation based-learning (SBL) has emerged as an almost ubiquitous educational approach for healthcare students and practising clinicians.

SBL is defined as an educational method designed to replace or replicate real experiences with authentic learning opportunities in a fully interactive manner (Gaba, 2004). The key premise of healthcare SBL is that it is a way to develop healthcare student's and clinician's professionals' knowledge and skills, whilst protecting patients from unnecessary risks (Lateef, 2010). With reference to this ethical mandate, the literature also asserts that SBL is an opportunity to make and learn from mistakes without compromising the care of 'real' patients (Gardner et al., 2015; King et al., 2013; Ziv et al., 2005).

However, this assertion may be rhetorical as students do not always feel 'safe' making errors in SBL, and sometimes express concerns that failure can be prejudicial for them (Ganley and Linnard-Palmer, 2012). In some situations, this has led to students adopting defensive attitudes, such as denigrating the SBL activity or denying that the error was committed (Ziv et al., 2005). Given these contradictory findings, and in recognition of the potentially positive and negative impact of errors on students and their learning, this integrative literature review sought to explore healthcare students' perceptions of making errors during SBL experiences.

2. Background

The term *error* has been defined in a variety of ways across various disciplines. In educational psychology, error refers to 'incorrect responses to a task or situation' (Clifford, 1979, p. 44). Error and *failure* constructs have a similar conceptual meaning. Kapur (2014) defined

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failure as individuals' inability to generate correct solutions or address problem-solving tasks. In SBL, with the exception of Bearman et al. (2018, p. 8), who refer to failure as '*things going wrong*', several authors commonly use the constructs error and failure interchangeably (Bould et al., 2012; Helyar et al., 2013; Kneebone et al., 2004; Young et al., 2016).

In the same vein, the concepts of *error* and *mistake* in SBL are undifferentiated (Gaba, 2000; Helyar et al., 2013; INACSL, 2016; Young et al., 2016). However, Reason (1990) argued that these constructs are ontologically different. *Error* is an action that fails to achieve a desired outcome, whereas a *mistake* occurs when the plan to achieve a goal is inadequate (Reason, 1990). Based on these definitions, the subtle distinction between these terms becomes evident and may explain, in part, the reasons why they are often inextricably intertwined. For the purpose of this review, these constructs will be used interchangeably as the concept of mistake by far is the most used in SBL literature.

2.1. Contextualising the use of errors in SBL

It is argued that the introduction of *desirable difficulties* during learning activities facilitates learning (Bjork and Bjork, 2011; Bjork, 1994). Desirable difficulties are, for instance, those that seem to slow the learning process and elicit errors (Kevin, 2009). Examples of desirable difficulties include complex problem-solving tasks, and unguided learning activities (Kapur, 2016). Research literature suggests that by addressing desirable difficulties, students are more likely to develop durable and flexible learning (Bjork and Bjork, 2011; Bjork, 1994). On the contrary, when students do not address desirable difficulties while solving learning tasks they tend to believe that subject-content was fully understood; however, this knowledge may not be retained and applied in future learning situations (Bjork, 1994; Kevin, 2009).

In the context of SBL, an example of a desirable difficulty is when students engage in a complex SBL scenario where multiple unpredictable clinical issues unfold. However, during many SBL activities, learners are instructed to follow sequential steps to avoid making errors (King et al., 2013). There is the notion that errors are detrimental for learners and should be prevented at all cost. In some occasions, facilitators 'rescue' students when they make an error by stopping the scenario or providing hints to change the direction of the activity (Brown, 2011). Satava (2007) argued that instead of only instructing medical trainees to develop skills correctly in simulation, they should also learn the meaning of errors and how to address them effectively.

A recent study on ultrasound simulation training suggested that the use of error management strategies, such as framing errors positively and instructing students to make errors during a SBL activity, allowed students to transfer what they learned from the simulation to clinical settings, compared with those who were instructed not to make errors (Dyre et al., 2017). Although there are several issues associated with the use of error management training in SBL (Heitzmann et al., 2017), one aspect that needs more understanding is students' views and experiences of making mistakes in SBL, and how these mistakes impact their personal responses and professional development. Consequently, this integrative literature review sought to explore healthcare students' perceptions of making errors during SBL experiences.

3. The review

3.1. Design

Whittemore and Knafl's (2005) framework was used to guide the integrative review as it provides a rigorous, comprehensive and methodological approach.

Table 1
Literature searching conducted in MEDLINE.

1. Nursing students.mp. or Students, Nursing/
2. Medical students.mp. or Students, Medical/
3. Health professionals.mp. or Health Personnel/
4. (error* or mistake*).mp. [mp = title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
5. SIMULATION TRAINING/ or simulation.mp.
6. 1 or 2 or 3
7. 4 and 5 and 6
8. limit 7 to (English language and yr = "2000–2018")

3.2. Aim

The aim of this review was to explore healthcare students' perceptions of making errors during SBL experiences.

3.3. Search methods

The MEDLINE database was consulted to become familiar with terms related to the topic of interest. The initial search terms were nursing students, medical students, health professionals, error*, mistake*, and simulation (see Table 1). Subsequently, a more narrowed searching was carried out using the following electronic databases CINAHL, PsycINFO, ProQuest and SCOPUS and the search engine Google Scholar. Finally, additional articles were manually identified through review of the reference lists of included articles.

3.4. Search limits

The literature search was limited to records published in English from 2000 to 2018. This period was included due to the exponential increase in the use of simulation in healthcare education during the last two decades (Motola et al., 2013).

3.5. Inclusion criteria

This review considered primary data sources that documented students' perceptions of making mistakes during the simulation activity. Articles that reported students' perceptions of making mistakes in the findings reported were included in the review.

3.6. Exclusion criteria

Unpublished and non-English records were excluded from the review.

3.7. Search outcomes

The original search resulted in 2317 potential records. EndNote® software was used to manage the records and eliminate duplicate papers. Four records were added through hand searching from the reference list of the included articles. Titles and abstracts were then examined, resulting in the exclusion of 2249 records. Reasons for exclusions mainly were articles did not describe students' perceptions of making mistakes and did not include making mistakes in the findings reported. The 72 remaining records were screened against the inclusion/exclusion criteria by the first author (EP) and discussed with the other authors (TP and TL-J), to reach consensus. This left 11 articles for critical appraisal and inclusion in this literature review. Fig. 1 illustrates the selection process.

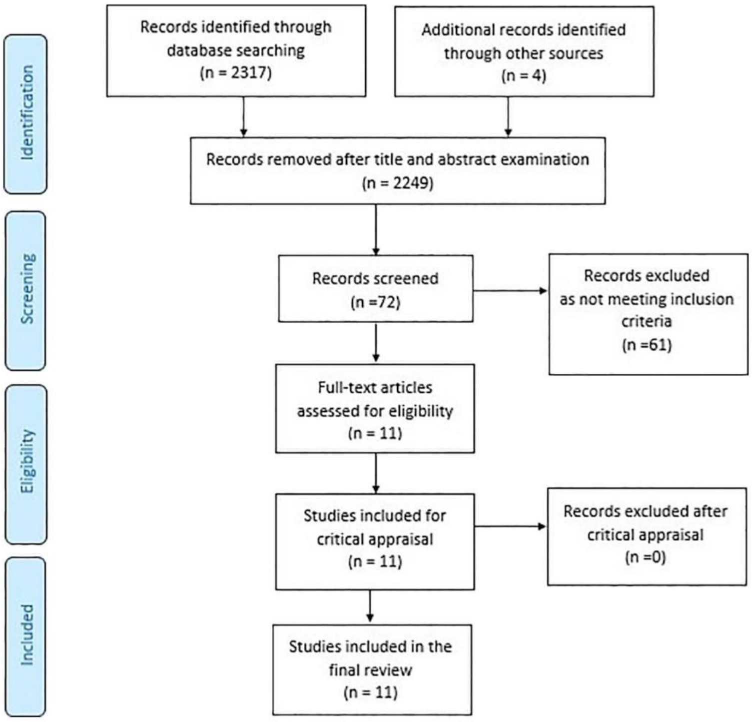

Fig. 1. Flow diagram of study selection process. Adapted from Moher et al. (2009).

3.8. Data analysis

The data analysis process began by tabulating the features of each study (see Table 2). The features for the tabulation were taken from (van der Riet et al., 2018) and included citation, location, quality, aim, design, sample, analysis, results, and limitations. Open coding was initially used to identify emergent codes (Draucker et al., 2007). Then, using NVvivo® software, codes were allocated to data 'chunks' (categories) to identify recurring patterns (Miles et al., 2014), and subsequently condensed into overarching themes.

3.9. Data evaluation

The included studies were appraised using the Critical Appraisal Skills Program (CASP) checklist (Critical Appraisal Skills Program, 2017). The items included in this checklist include aim, methodology, research design, recruitment strategy, data collection, the relationship between the researcher and the participants, ethical issues, data analysis, findings, and overall value. Each item scores one point with an overall score of 10.

4. Results

4.1. Quality of included studies

The results of the critical appraisal undertaken using CASP (Critical Appraisal Skills Program, 2017) checklist indicated the majority of studies scored 8–10 for most criteria. However, some studies had limitations. For instance, apart from Reime et al.'s (2016) interprofessional study, each of the studies included only a single group of participants. Additionally, only one study measured the potential long-term impact of making mistakes in SBL.

4.2. Characteristics of included studies

The included studies originated from seven countries: the United States of America (*n* = 4), Sweden (*n* = 1), United Kingdom (*n* = 2), New Zealand (n = 1), South Korea (n = 1), United Arab Emirates (n = 1) and Norway (n = 1).

4.3. Characteristics of participants

Four studies included nursing students (Bussard, 2015; Harder, 2012; Helyar et al., 2013; Song and Jeong, 2015), three included medical students (Bond et al., 2004; Botezatu et al., 2010; Young et al., 2016), one included midwifery students (Hughes et al., 2014), and another study involved medical imaging students (Elshami and Abuzaid, 2017). One study (Reime et al., 2016) was interprofessional and included both nursing and medical students. The participant sample size for the 11 included studies ranged from 9 to 262 (mean *n* = 102). The overall number of participants was 609.

4.4. Study designs

Seven of the studies were qualitative (Bond et al., 2004; Botezatu et al., 2010; Bussard, 2015; Harder, 2012; Helyar et al., 2013; Song and Jeong, 2015; Young et al., 2016), and four used a mixed methods approach (Elshami and Abuzaid, 2017; Hughes et al., 2014; Reime et al.,

Table 2
Included studies.

Citation/location/quality	Aim/purpose	Design	Sample	Analysis	Results	Limitations
Young et al. (2016) NZ Quality rating: 10/10 (CASP)	To identify core components of students' SBL experiences.	Qualitative, phenomenology	Medical students (n = 77)	Thematic analysis	Participants perceived mistakes as learning opportunities. Feedback was crucial to learn from mistakes.	
Bussard (2015) USA Quality rating: 10/10 (CASP)	To examine students' experiences of simulated encounters to develop accountability skills.	Qualitative	Nursing students (n = 15)	Thematic analysis	Students learnt from their mistakes. Taking responsibility for own errors was crucial for learners.	
Song and Jeong (2015) South Korea Quality rating: 9/10 (CASP)	To explore the experiences of nursing students in a clinical simulation encounter.	Qualitative, phenomenology	Nursing students (n = 9)	Thematic analysis	Students understood the importance of taking responsibility for their mistakes.	Ethical aspects were not addressed
Harder (2012) USA Quality rating: 10/10 (CASP)	To explore values and beliefs about HPSMs.	Qualitative, ethnography	Nursing students (n = 11), Instructors (n = 20)	Thematic analysis	Even though some students reported emotional distress making mistakes, they valued committing errors in simulation and not with real patients.	
Bond et al. (2004) USA Quality rating: 9/10 (CASP)	To explore emergency medicine residents' perceptions using challenging simulation scenarios.	Qualitative, in-depth interviews	Emergency medicine residents (n = 15)	Thematic analysis	Making mistakes caused reflection/motivation. The simulation was stressful, but it was not possible to establish that errors were the cause of stress.	Content validity was not addressed
Botezatu et al. (2010) Sweden Quality rating: 10/10 (CASP)	To examine medical students' opinions on the use of virtual patients.	Qualitative, exploratory	Undergraduate Medical students (n = 16)	Thematic analysis	Students' comments highlighted that once an error is committed it is less likely to commit the same mistake in a clinical setting.	Students were randomly selected
Helyar et al. (2013) UK Quality rating: 10/10 (CASP)	To determine if a low-fidelity simulation provides a realistic learning experience for pre-registration nursing students.	Qualitative, in-depth interviews	Pre-registration nursing students (n = 12)	Thematic analysis	Making errors should be an active component in simulation experiences.	
Elshami and Abuzaid (2017) United Arab Emirates Quality rating: 8/10 (CASP)	To examine students perceptions of a Magnetic Resonance Imaging simulation training.	Mixed methods	Medical imaging students (n = 29)	Content analysis, descriptive statistics	60% of participants recognised that they learnt from their mistakes.	
Sullivan et al. (2016) USA Quality rating: 7/10 (CASP)	To investigate students and faculty engagement using simulated patient scenarios.	Mixed methods	Medical students (n = 98)	Content analysis, descriptive statistics	Students valued addressing the clinical cases by themselves and seeing the consequences of their decisions. Participants did not feel embarrassed making mistakes in a safe environment, even though they lost points for their mistakes	Ethical issues were not addressed
Reime et al. (2016) Norway Quality rating: 8/10 (CASP)	To explore students' experience of an interprofessional simulation activity and its impact on patient safety.	Mixed methods	Bachelor, postgraduate nursing students, and medical students (n = 262)	Content Analysis, descriptive statistics	Making mistakes seems to improve the quality of patient care, as students become more alert in clinical settings	Relationship between researcher and participants was not specified
Hughes et al. (2014) UK Quality rating: 8/10 (CASP)	To examine the midwifery students' perceptions of self-efficacy after a simulated maternal obstetric emergency.	Mixed methods	Midwifery students (n = 65)	Content Analysis, descriptive statistics	Participants learnt from their mistakes. The support and constructive feedback provided by instructors was crucial.	

2016; Sullivan et al., 2016).

4.5. Study findings

It should be noted that only one of the included studies was conducted specifically with a focus on mistakes in simulation. Instead, the analysis of students' views about their experiences typically included reference to the impact of and learning from the errors they had made. Indeed, this was a key finding in each of the eleven studies included in the review. Thus, the two overarching themes to emerge from the analysis were the **impact of errors on learners** and **the impact of errors on learning**.

4.5.1. The impact of errors on learners

4.5.1.1. Negative feelings - frustration, guilt and fear. While students' perceptions of making mistakes during SBL were often positive, intense feelings of frustration were described in several studies. For example, in Helyar et al.'s (2013) study, almost all participants reported the detrimental emotional effects of making mistakes with reference to negative feelings such as frustration, guilt and fear. However, the participants still regarded making mistakes during the SBL activity to be critical for their learning. Harder (2012) and Young et al. (2016) referred to how, in the debriefing that followed the simulation, both nursing and medical students expressed frustration at the mistakes they had made. However, students typically recognised the benefits of making mistakes, and to some extent, this helped to offset some of the associated distress.

> 'I was frustrated with myself for not being more complete in my examination and for missing a "red flag" but I learnt from this case the importance of being thorough when doing examinations'.
> (Young et al., 2016, p. 70)

> 'I remember being a bit peeved that I made an error, and I then when I looked back on it, it was like the whole point… it really made you aware of how important it is not to make errors'.
> (Helyar et al., 2013, p. 14)

4.5.1.2. The comfort of knowing that mistakes made during SBL do not present a risk for 'real' patients. Despite the negative feelings experienced by some students in response to the errors they made during SBL, there were key factors that lessened the impact of these feelings and transformed the mistakes into learning opportunities. One factor included a SBL experience where students could focus on learning without the concern of 'real' patients being harmed.

SBL experiences are designed to replicate the real world of clinical practice in an immersive and authentic manner (Gaba, 2004), and several studies included in this review described how students felt safe in and valued SBL experiences because the care of 'real' patients was not compromised. For example, in Hughes et al.'s (2014) study, where midwifery students ($n = 65$) were exposed to a simulated maternal obstetric emergency, participants attributed their enhanced learning and self-efficacy to the comfort of knowing that the mistakes they made during the simulation activity did not present a risk for 'real' women or babies. In another study examining medical students' ($n = 16$) views about virtual patients, Botezatu et al. (2010) found that students reported feeling less '*stressed*' making mistakes with simulated patients because the consequences were not as severe as in clinical practice. Similarly, in a study exploring nursing students' ($n = 11$) perceptions of high-fidelity manikin-based simulations, Harder (2012) noted that, although some students reported emotional distress from making mistakes, they nevertheless valued the opportunity to do so during a SBL activity rather than in a clinical setting with 'real' patients.

> 'And that would be the time to make a mistake, not with the patient. So that part is good that you can do a mock stuff without worrying about doing any harm'.
> (Harder, 2012, p. 75)

4.5.1.3. Viewing mistakes as positive learning experiences due to the feedback received. One of the key factors that appeared to offset negative feelings associated with making mistakes was receiving constructive feedback following the simulation. For example, Young et al. (2016) described how meaningful feedback provided 'a safety net' and helped participants view their mistakes as learning opportunities. Similarly, in Hughes et al.'s (2014), study, students felt that the negative impression of their SBL performance and their confidence was ameliorated, to some extent; by the positive feedback and reinforcement they received in the debrief.

> 'I think we got some very positive feedback on things as well and sort of boosted your confidence and made you think 'well I did do that bit ok and' it's this that I need to work on'.
> (Hughes et al., 2014, p. 204)

When students did not feel 'judged' or threatened, and where their mistakes were discussed constructively they were more positive about their SBL experiences.

> 'I believe that the [simulations] were a very non-judging environment where you could have mistakes brought to your attention in a constructive as opposed to a confrontational way…'
> (Young et al., 2016, p. 70)

4.5.2. The impact of errors on learning

4.5.2.1. Taking responsibility for mistakes. Mistakes made during simulations helped many participants recognise that seemingly minor issues or omissions can result in significant harm to patients (Bussard, 2015). Assuming responsibility for their mistakes also helped participants become cognizant of their role in the prevention of adverse patient outcomes in the future (Helyar et al., 2013; Song and Jeong, 2015).

> 'Making even a small mistake, could endanger or be lethal for a patient. Now I feel burdened and understand my responsibility'.
> (Song and Jeong, 2015, p. 150)

> 'As a nurse, bearing in mind the professional code of practice you operate under, …you have to make sure your practice is safe… it [the simulation] really … embedded it'.
> (Helyar et al., 2013, p. 16)

In a study that explored medical students' ($n = 98$) views of using virtual surgical patient cases to develop decision-making and diagnostic skills, Sullivan et al. (2016) identified that, despite being penalised by losing points for making mistakes during the simulation activities, students still felt it was a positive learning experience. They valued being independent and responsible for the patient cases; they did not feel embarrassed by making mistakes, but instead suggested that it helped them to realise that their decisions, right or wrong, have consequences.

4.5.2.2. Recognition of the potential impact of learning from mistakes on patient safety. Four of the included studies described how the errors made during SBL were a catalyst for learning and potentially, improved clinical practice. In Botezatu et al.'s (2010) study, medical students ($n = 16$) discussed how committing an error with virtual patients meant that they were less likely to make the same mistake in a clinical setting. Similarly, in a study of magnetic resonance imaging students ($n = 29$), Elshami and Abuzaid (2017) described how the majority (60%) valued SBL as it gave them an opportunity to learn from their mistakes and prevent future errors with real patients.

> 'I believe that simulation training decreases mistakes that I'm making in clinical training as I'm trying not to repeat the same

> mistakes again'.
> (Elshami and Abuzaid, 2017, p. 156)

In a study with pre-registered nursing students ($n = 15$), Helyar et al. (2013) found that making mistakes helped students become knowledgeable about the importance of safe clinical practices.

> '…it really confirmed how important safety is. You have to do everything you possibly can to ensure your practice is safe… it is something that I took away from that and still practice, is still with me today'.
> (Helyar et al., 2013, p. 15)

The findings from an interprofessional patient safety simulation with 262 undergraduate and postgraduate nursing and medical students illustrated how the emotions provoked by making a mistake alerted the participants to issues associated with patient safety and their own fallibility (Reime et al., 2016). Further, these emotions triggered the memory of the mistake following SBL and helped students recall similar experiences from both previous simulations and clinical practice (for example failing to check a patient's identification, which resulted in a blood transfusion error). Importantly, participants described how the negative feelings associated with making a mistake made the learning both meaningful and memorable and by so doing, facilitated transfer of learning to clinical practice.

> 'I really got hit, I had even checked the name, I thought, but had not done it well enough. This experience was a real wake-up call. It is so easy to make mistakes. I have become more aware overall since, and have been more thorough when checking IDs'.
> (Reime et al., 2016, p. 79)

Similarly, in Helyar et al.'s (2013) study, nearly all participants ($n = 9$ of 12) discussed how making mistakes helped to connect theory and practice, especially in checking procedures and its potential use in future clinical practices.

> 'They [errors] were ones where I obviously hadn't realised how important some of the theory is, obviously about identification and things…We had always been told, but obviously the simulation brought it to my attention just that much more'.
> (Helyar et al., 2013, p. 15)

4.5.2.3. Testing abilities and developing humility. Harder (2012) found that nursing students preferred to make and independently correct their mistakes rather than being guided by a simulation educator, as this gave them an opportunity to test their abilities. Similarly, in Young et al. (2016) study of medical students, the mistakes made during simulation activities helped participants develop humility, recognise the limits of their abilities and be more willing to ask for help.

> 'After all medical students and doctors are humans so we are not expected to know everything but we are expected to be able to practice safely and be able to appreciate the limits of our abilities and seek help when appropriate'.
> (Young et al., 2016, p. 70)

> 'I soon realised this was an amazing learning opportunity where we didn't have to get everything right'.
> (Young et al., 2016, p. 70)

4.5.2.4. Errors as a stimulus for developing confidence. Lendahls and Oscarsson (2017) and Song and Jeong (2015) described how making mistakes in SBL followed by opportunities for deliberate practice, improved nursing and midwifery students' confidence. The findings also indicated that the errors provided a stimulus for learning, both by observation and through repeated practice.

> 'At first, we really messed up. I left after my team's performance and watched all the other teams. And I think the more I saw, the more I could build my confidence. I watched our second performance with my friends and while it was not excellent, it was better than earlier'.
> (Song and Jeong, 2015, p. 151)

Young et al. (2016) documented similar findings with medical students.

> 'Throwing us in the deep end was great for my confidence in the long run'.
> (Young et al., 2016, p. 70)

4.5.2.5. Developing cognitive and metacognitive skills. Bond et al. (2004) described how emergency medicine residents ($n = 15$) reflected on their mistakes after the SBL activity, which facilitated a deeper understanding of the patient scenario and acted as a motivation for further learning. Participants also recognised that their mistakes provoked the use of cognitive and metacognitive strategies as they learned to '*step back*' and '*reassess their thought process*' (Bond et al., 2004). Helyar et al. (2013) also reported students' cognitive processes while reflecting on their mistakes.

> 'It made you think more about things that could go wrong'.
> (Helyar et al., 2013, p. 15)

5. Discussion

This integrative literature review sought to explore students' perceptions and experiences of making mistakes in SBL. Despite the lack of detailed impact assessment and to the depth of research about SBL on this area of learning, this integrative review presented research evidence that allowed a comprehensive understanding of the topic. The two overarching themes to emerge from the analysis of the included studies were the impact of errors on learners themselves and the impact of errors on their learning.

Literature has suggested that students, particularly those in the early stages of a healthcare degree, sometimes perceive or are taught that errors are negative experiences that should be avoided (Aubin and King, 2015; Conn, 2018; Warner, 2016). Consistent with these notions, this review identified that many students' held negative views about the errors they made during SBL (Harder, 2012; Helyar et al., 2013; Young et al., 2016). However, although feelings of frustration, guilt and fear were often reported by students, skilled educators were able to transform the mistakes into learning opportunities (Harder, 2012; Helyar et al., 2013; Hughes et al., 2014; Lendahls and Oscarsson, 2017; Song and Jeong, 2015; Young et al., 2016). Factors that students considered key to minimising the negative impact of errors and using them as stimuli for learning included the provision of a psychologically safe learning environment (Botezatu et al., 2010; Harder, 2012; Hughes et al., 2014; Young et al., 2016) where, instead of punitive responses from educators and/or peers, they were provided with meaningful feedback (Hughes et al., 2014; Young et al., 2016). These findings align with simulation literature suggesting that a safe learning experience is not limited to patient safety (Ganley and Linnard-Palmer, 2012), but involves the establishment of a supportive learning environment where students feel safe to take risks, to express feelings of vulnerability and to openly disclose their errors (Rudolph et al., 2014).

This review identified that debriefing sessions where mistakes were discussed in a constructive manner allowed students to perceive errors as learning opportunities (Harder, 2012; Helyar et al., 2013; Hughes et al., 2014; Lendahls and Oscarsson, 2017; Song and Jeong, 2015; Young et al., 2016) and promoted the development of emotional strategies that allowed them to respond to errors positively (Harder, 2012; Hughes et al., 2014; Sullivan et al., 2016; Young et al., 2016). This may be particularly important for performance-oriented individuals who try to avoid making mistakes (Van-Dyck et al., 2010).

The capacity to take responsibility for errors was frequently reported in the papers reviewed (Bussard, 2015; Helyar et al., 2013; Song and Jeong, 2015; Sullivan et al., 2016). In order to learn from mistakes, students must recognise and take ownership of their errors (Fischer et al., 2006), as this helps them understand the personal impact of errors and their role in the prevention of adverse patient outcomes in the future (Helyar et al., 2013).

It is suggested in some studies that the negative feelings associated with making errors in SBL cannot and should not be completely removed (Rudolph et al., 2014), as the emotional consequences of errors make the learning experience both meaningful and memorable. Indeed, as some of the studies in this review have pointed out, students who commit errors and learn from them in SBL may be less likely to repeat the same mistakes in clinical settings (Elshami and Abuzaid, 2017; Helyar et al., 2013; Reime et al., 2016).

6. Limitations and implications

Grey literature and unpublished records were beyond the scope of this integrative review, and only studies published in English were included. Consequently, some relevant studies could have been missed. This review focused on healthcare students' views of making mistakes in simulation and other stakeholders were not included (for example, simulation educators), an issue which may limit insights into the current topic as a whole.

7. Conclusion

Despite the negative feelings experienced by some students regarding making mistakes in SBL, there were key factors that minimised the impact of these feelings and transformed mistakes into learning opportunities. These included: the provision of a safe and non-threatening learning environment where constructive feedback was provided by skilled educators, and where students were supported to take responsibility for their mistakes. The take-home message from this review is that it cannot be assumed that SBL is a safe experience where learners are able to make and learn from their mistakes. Optimising learning from mistakes in SBL requires a deliberate and thoughtful approach in which educators plan for and support learners to recognise, acknowledge and respond effectively to errors. Although the findings from this review indicate that students believe that making mistakes, under certain conditions, has potential learning benefits, how to incorporate errors as a deliberate teaching strategy in SBL and how to optimise learning from those errors should be the subject of future studies.

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Conflict of Interest

None declared.

Ethical Approval

Not applicable.

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Chapter 3. A conceptual model to inform the design of healthcare simulations that promote errors as a catalyst for learning: A discussion paper (stage 2)

> Mistakes have the power to turn you into something better than you were before.
>
> — Unknown

3.1 Introduction

The integrative literature review outlined in Chapter 2 explored healthcare students' perceptions of making errors in SBL (Palominos et al., 2019). The review identified that the use of errors in simulation can be beneficial for students. However, this review also concluded that optimising learning from errors in simulation requires a deliberate and thoughtful approach informed by pedagogical approaches that use errors as learning resources. In particular, the need for simulation design, implementation and evaluation to be guided by relevant educational principles has been recognised as a critical feature of SBL (Levett-Jones & Guinea, 2017; Parker & Myrick, 2009). This chapter presents a manuscript that proposes a conceptual model that can assist educators in the design of simulations that explicitly support the use of errors to facilitate learning.

3.2 Published paper

The manuscript provided in this chapter is:

Palominos, E., Levett-Jones, T., Power, T., & Martinez-Maldonado, R. (2022). A conceptual model to inform the design of healthcare simulations that promote errors as a catalyst for learning: A discussion paper. Nurse Education in Practice, 65, 103500. https://doi.org/https://doi.org/10.1016/j.nepr.2022.103500

3.3 Aims

The aims of this paper were to present the LE model, an evidence-based approach that can be used to inform the design of simulations that explicitly promote learning from errors and provide a practical simulation example of how educators can use this model.

3.4 Ethics approval

Not applicable

3.5 Publication copyright

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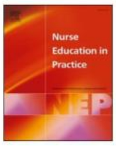

A conceptual model to inform the design of healthcare simulations that promote errors as a catalyst for learning: A discussion paper

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ABSTRACT

Background: Previous studies have demonstrated that students who are engaged in learning tasks and make errors before receiving instruction on how to complete them, achieve better learning outcomes than students who first receive instruction and then complete the learning activities with the aim of avoiding errors. Although simulation literature often refers to errors as learning opportunities, to date, there is limited understanding of how pedagogical approaches that promote learning from errors can guide the design of simulation-based learning in healthcare education.
Aims: To (a) present the Learning from Errors conceptual model; and (b) provide an example of how educators can use this model.
Design: The Learning from Errors model is drawn from critical elements of two pedagogical approaches, productive failure and error management training and pedagogical features of high-quality healthcare simulations.
Methods: We describe the Learning from Errors model, which emphasises the need for adopting pedagogical methods that explicitly use errors as learning opportunities and ultimately inform simulation design. We then illustrate the application of this model to a simulation example.
Results: The model includes the following elements: i) normalisation of errors, ii) challenging simulation scenarios, iii) self-directed learning, iv) collaborative teamwork and v) comparison with best practice.
Conclusion: This discussion paper presents the Learning from Errors conceptual model, an evidence-based approach that can assist educators in the design of simulations that embrace errors as a catalyst for learning.

1. Introduction

Previous studies have demonstrated that students who are engaged in novel learning tasks and make errors before receiving instruction achieve better learning outcomes compared with students who receive instruction prior to solving learning activities (Cao et al., 2020; Jacobson et al., 2017; Kapur and Bielaczyc, 2012). Although simulation literature often refers to errors as learning opportunities (Helyar et al., 2013; Turner and Harder, 2018; Ziv et al., 2005) or puzzles to be addressed (Rudolph et al., 2014), little is known about how to operationalise learning from errors in healthcare simulation (Heitzmann et al., 2017). There is a need for explicit pedagogical principles that can be used to guide the design of simulation-based learning (SBL) experiences that explicitly promote errors as learning opportunities.

The effectiveness of two pedagogical approaches that promote the use of errors to facilitate learning have been recently explored in SBL experiences: productive failure (PF) in nursing simulations (Dubovi, 2018; Palominos et al., 2021) and error management training (EMT) in medical simulations (Dyre et al., 2017; Gardner et al., 2015). Despite the exploration of the potential impact of PF and EMT on students' learning in SBL, there is limited understanding of how these pedagogical approaches can inform healthcare simulation design. Thus, this paper intends to fill this research gap by presenting a conceptual model that can assist educators in designing simulations that explicitly promote errors as a catalyst for learning.

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2. Background

In this section we describe the main characteristics of PF and EMT approaches and examine the effectiveness of these pedagogical methods in the context of healthcare education and SBL.

2.1. *PF: there is not learning without failure*

PF approach comprises two main stages (Kapur and Bielaczyc, 2012). The first stage (or exploration phase) involves active exploration of novel learning tasks, during which errors commonly occur because students have not previously been taught how to address these practical problems. The second stage (or instruction phase) involves students comparing their solutions to the learning tasks with the correct solutions provided by the educator (Kapur and Bielaczyc, 2012; Loibl and Leuders, 2018). In SBL, a PF simulation involves students working on the simulation activity followed by instruction on the simulation topic in the debrief that follows (Fig. 1).

Previous studies have compared PF approaches with a more conventional teaching method named direct instruction (DI) (Cao et al., 2020; Jacobson et al., 2017). In the DI approach, students are protected from making mistakes because the educator monitors their progress and provides feedback prior to and during practical learning activities (Kapur and Bielaczyc, 2012). In SBL, a DI simulation involves students receiving instruction on the simulation topic before participating in the simulation activity (Fig. 2).

2.2. *EMT: embracing errors to facilitate learning*

EMT is an approach that seeks to minimise the potential negative outcomes of making errors (Frese and Keith, 2015) and to promote the development of effective strategies to cope with errors (Keith, 2011). EMT has been compared with a more traditional training approach called error avoidance training, where learners do not engage in active exploration of learning tasks and instead receive explicit instructions on how to solve the learning activities, thereby limiting the possibility of making errors (Keith and Frese, 2008).

2.3. *Effectiveness of PF and EMT*

When applying PF and EMT key elements to SBL, it is important that educators understand the benefits and impact of these pedagogical methods on learning. Both PF and EMT have proven to facilitate meaningful learning outcomes, such as the transfer of learning (knowledge and skills learned) to novel problems in different content topics and educational (Cao et al., 2020; Jacobson et al., 2017) and training settings (Keith and Frese, 2008).

In the context of healthcare education, recent studies have also explored the effectiveness of PF and EMT in terms of learning. Steenhof et al. (2019) randomly allocated Doctor of Pharmacy students to either a PF group or a DI group to learn the concept of creatinine clearance. Learning outcomes measured in this study were knowledge acquisition, knowledge application and preparation for future learning, which evaluates the ability to solve unfamiliar learning tasks. The authors found no significant differences between groups regarding knowledge acquisition and knowledge application assessments. However, the PF group outperformed the DI group on the preparation for future learning assessment. Similarly, Steenhof et al. (2020) compared the effectiveness of PF and indirect failure (where students compare their peers' mistakes to a correct solution). The PF group was instructed to create a formula to estimate creatinine clearance and make as many attempts as possible to solve this learning task without the involvement of the educator. The indirect failure group was given the same problem along with incorrect solutions generated by their peers in a previous study and were instructed to compare these solutions with a correct solution. The results indicated that the PF group performed significantly better than the indirect failure group on the preparation for future learning assessment. In the context of nursing simulation, Palominos et al. (2021) randomly allocated nursing students to either PF groups (n = 181) or DI groups (n = 163). Students in the PF groups participated in a simulation activity followed by a debriefing session that included a discussion about the simulation topic and video demonstration of registered nurses performing the same simulation activity. Students in the DI groups engaged in a discussion of the simulation topic, watched the same video demonstration and subsequently participated in the simulation activity. The findings indicated that in the posttest, the PF groups outperformed the DI groups on the explanatory knowledge (students' understanding of a particular idea) and the transfer of learning to novel clinical problems. These findings suggest that PF facilitates new learning. However, other studies have documented opposite findings. For example, Dubovi (2018) compared the effectiveness of two pedagogical methods in the context of online computer nursing simulation: PF and simple-to-complex approach, where pedagogical facilitation is gradually reduced according to students' progress (Frerejean et al., 2019). The authors found that the simple-to-complex approach was more effective than PF for learning clinical reasoning skills. It is important to note that in this study, students in the PF group were not debriefed after the simulation activities. In simulations explicitly designed to support learning from errors, the debrief session is critical for the educator to assist students to identify and rectify their errors (Palominos et al., 2019).

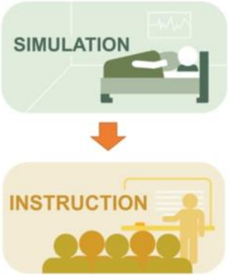

Fig. 1. PF simulation.

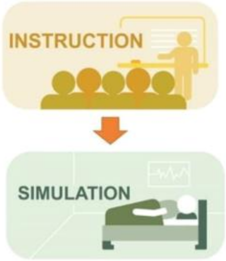

Fig. 2. DI simulation.

The effectiveness of EMT has also been documented in SBL. Gardner and Rich (2014) randomly assigned radiology technology students into either traditional instruction or vicarious EMT (learning from other people's errors). The traditional instruction group was presented a patient scenario with radiology technicians performing correct procedures, whereas the vicarious EMT group received the same patient scenario, including the errors committed. In the discussion session, the traditional instruction group was instructed to reflect on what went well, specifying the reasons why. In contrast, the vicarious EMT participants were asked to identify the errors made in the patient scenario. The findings demonstrated that the participants from the vicarious EMT group outscored traditional instruction participants on the performance test.

Dyre et al. (2017) compared the effectiveness of EMT and error avoidance training in a simulated ultrasound training with medical students. Whereas the error avoidance training participants were instructed to make as few errors as possible, the EMT participants were encouraged to make errors and they received positive statements when an error occurred. The results indicated that the EMT participants outperformed the error avoidance training participants on the transfer test, suggesting that positive error framing facilitates learning and minimises the potential negative effects of making errors.

Despite the potential effectiveness of PF and EMT in terms of learning in SBL experiences, there is limited understanding of how these pedagogical methods can inform simulation design, particularly in nursing education. Therefore, the aims of this paper are to (a) present the Learning from Errors (LE) conceptual model, an evidence-based approach that can be used to guide the design of simulations that explicitly use errors as learning resources; and (b) provide a simulation example of how educators can use this model.

2.4. LE conceptual model

This section describes the LE conceptual model drawn from key elements of PF and EMT and pedagogical features of high-quality healthcare simulations. We explain the elements of the LE model (normalisation of errors, challenging simulation scenarios, self-directed learning, collaborative teamwork and comparison with best practice) and illustrate how these elements can be integrated into the stages of a simulation session (pre briefing, simulation activity and debriefing) (Fig. 3).

3. Elements of the LE model

3.1. Normalisation of errors

The first element of the LE model is the normalisation of errors. Previous studies have identified that making errors can be emotionally detrimental for some students and disrupt their learning (Palominos et al., 2019). Therefore, the normalisation of errors aims to minimise negative emotions in the face of errors. EMT promotes the establishment of positive error framing where the educator employs statements, such as "*The more errors you make, the more you learn!*" "*You have made an error? Great! Because now you can learn something new!*" (Keith and Frese, 2008, p. 60). In PF, the educator creates a supportive environment that helps students persist in solving novel learning tasks despite setbacks (Kapur, 2015; Kapur and Bielaczyc, 2012; Sinha and Kapur, 2021).

Applying the normalisation of errors to SBL experiences that promote learning from errors involves educators stating explicitly that errors are critical for learning. The normalisation of errors can take part during the pre-briefing when expectations and norms of the simulation session are established, and it also should be reinforced during the simulation activity. The educator can use positive statements, such as "*You can make errors in simulation as the safety of real patients is not compromised*"; "*Do not be afraid of making errors in simulation as they are part of the learning process and an opportunity to improve*"; and "*Errors help identify your skills and knowledge deficits so that you can learn and improve.* "' The normalisation of errors not only mitigates the impact of negative feelings of making errors in simulation but contributes to building a psychologically safe environment.

Fig. 3. LE conceptual model.

3.2. Challenging simulation scenarios

The second element of the LE model is the use of challenging learning tasks (Heimbeck et al., 2003; Kapur and Bielaczyc, 2012) that keep students engaged (Keith and Frese, 2008), but not frustrated (Kapur and Bielaczyc, 2012).

Challenging learning tasks are examples of desirable difficulties (Kapur, 2016) that elicit errors in the short term but facilitate learning in the long term (Kevin, 2009). Desirable difficulties are necessary because they promote the activation of mental processes that promote meaningful learning outcomes, such as the transfer of learning to novel situations (Bjork and Bjork, 2019). This aspect is important because one of the aims of SBL is to influence nurses' clinical practice to have a positive impact on patients' outcomes (Bruce et al., 2019).

Further, the provision of challenging learning tasks in a psychologically safe environment, enables students to develop a sense of agency (Sinha and Kapur, 2021), where they become responsible for their learning and demonstrate a willingness to persevere despite struggling to complete the learning tasks (Tishman and Clapp, 2017). This aspect is related to resilience, which helps nursing students manage stressful and complex work-related situations that they will encounter in their practice (Kunzler et al., 2020).

In SBL experiences designed to embrace errors to facilitate learning, students should be introduced to appropriately challenging simulation scenarios (see Fig. 3). It is important to note that to keep students engaged but not frustrated, the simulation activity should be pilot tested to identify common errors and ensure that students have adequate knowledge and skills (prior knowledge) that allow them to learn from desirable difficulties (Bjork and Bjork, 2020). For example, to undertake a paediatric closed head injury simulation session, students should have previously practised skills such as physical assessment of infants and children and recognising and managing patient deterioration (Palominos et al., 2021).

3.3. Self-directed learning

In the LE conceptual model, a self-directed learning approach is used. Both PF and EMT promote active exploration of novel learning tasks without the educator's immediate feedback or direct guidance (Jacobson et al., 2015; Keith and Frese, 2008). This refers to students engaging in the simulation activity without the educator's involvement (LeFlore et al., 2007). In other words, students adopt the role of clinicians and take responsibility for their clinical decisions. Although this may result in errors (and even poor performance), students achieve a deeper understanding of the concepts or content of the simulation when later explored in the debriefing session.

3.4. Collaborative teamwork

The fourth element of the LE model is collaborative teamwork (Kapur and Bielaczyc, 2012). Group-based collaboration can generate debate, constructive engagement and clarification of ideas (Sawyer and Obeid, 2017). Collaborative teamwork also promotes a deeper analysis of the learning activities and critical thinking, which can enhance the students' learning experience (Osborne, 2010).

In PF, collaborative teamwork promotes shared understanding among team members (Kapur and Bielaczyc, 2012). A recent study found that students working collaboratively in a PF environment were able to recognise gaps in their prior knowledge and generate opportunities for clarification in the face of dissimilarities (Kerrigan et al., 2021). King et al. (2013) suggested that EMT provides opportunities for healthcare team members to engage in open discussions about errors, which can improve group performance. Although collaborative teamwork is already inherent in many SBL experiences, this element should also be included in the design of LE simulations.

3.5. Comparison with best practice

The last element of the LE model is the provision of feedback to enable error correction. In simulation literature, feedback refers to "the comparison between a trainee's observed performance and a standard given with the intent to improve the trainee's performance" (van de Ridder et al., 2008, p. 189). Although EMT does not incorporate a comparing activity, this element is crucial for PF simulations to be effective because it facilitates a deep understanding of the concepts or content to be learnt and promotes transfer of learning to novel problems (Jacobson et al., 2017). Further, comparing activities can help students become cognisant of their knowledge and skill gaps and therefore, examine their mental models (Loibl and Leuders, 2019). This aspect is important because mental models play a pivotal role in clinical decision-making (Mazur, 2015). The more accurate the mental model, the more precise the actions (Keith and Frese, 2008), which can contribute to reducing clinical errors and increasing patient safety.

Applying this element to SBL involves the educator providing instruction on the simulation topic, including a demonstration of experienced nurses performing the expected level or standard of care to the simulated patient, through a pre-recorded video or a live presentation. Subsequently, the educator asks students to compare their performance with the standard or expected performance and share their thoughts with the whole class.

To summarise, this section described the elements of the LE conceptual model and how they can be integrated into the main phases of a simulation session to optimise learning (see Table 1).

4. Application of the LE model to a simulation example

This section provides a simulation example of how educators can use the LE model to design simulation sessions that promote learning from errors.

4.1. Simulation example

In the prebriefing, the educator introduces the learning objectives for the simulation session and ensures students are familiar with the simulation environment and the clinical equipment. Confidentiality and privacy are also considered. Subsequently, the educator discusses the expectations of the simulation session, which includes the normalisation of errors. The facilitator can use statements such as "*Errors are part of the learning process. If you make errors in the simulation, you can learn from them.*" The educator also can verbalise these statements during the simulation activity.

In the simulation activity, students work in groups (collaborative teamwork) and are presented with a challenging simulation scenario which is aligned with their prior knowledge and skills. After being allocated roles, students are asked to participate in the clinical simulation without the educator's guidance. This requires the students to adopt the role of a registered nurse and assume full responsibility for the [simulated] patient's care. The educator emphasises that students will need to be self-directed learners throughout the simulation including when they analyse blood tests, check vital signs or perform a clinical procedure.

In the debrief session, that follows the simulation activity, students share their initial impressions of the simulation and their clinical performance. Subsequently, the facilitator provides instruction on the simulation topic which includes a demonstration of the expected level or standard of care for the [simulated] patient and how to overcome the challenges presented. Subsequently, the educator asks students to reflect on the similarities and differences between their performance (comparison with best practice) and the best practice example and the aspects they would like to improve for future simulations or clinical practice. Finally, students share their thoughts with the whole class. For a more specific example of the application of the LE model, please read Palominos et al. (2021).

Table 1
Summary of the elements of the LE model integrated into the main stages of a simulation session.

Simulation session phases	Design element	Description
Prebriefing and simulation activity	Normalisation of errors	The educator states explicitly that errors are an integral part of the learning process.
Simulation activity	Challenging simulation scenarios	The use of challenging simulation scenarios that keep students engaged but not frustrated.
	Self-directed learning	Students work on the simulation activity without the involvement of the educator.
	Collaborative teamwork	Students work in groups on the simulation activity.
Debriefing	Comparison with best practice	Students compare their performance with a standard or expected performance.

5. Conclusion

This paper presents the LE conceptual model, a simulation approach informed by two pedagogical methods that use errors to facilitate learning, PF and EMT. The simulation example provided illustrated how educators can use the LE model to guide the design of simulations that purposefully embrace errors as a catalyst for learning. The LE model emphasises (a) the importance of normalising errors during SBL experiences by explicitly stating that errors are critical for learning; and (b) the provision of content knowledge (instruction) *after* the simulation activity (in the debrief session). The LE conceptual model also highlights the significance of providing challenging scenarios, collaborative learning and a self-directed approach that allows students to activate their prior knowledge and experiences and identify the need for further knowledge and skills. Finally, the LE model advocates that students receive feedback for error correction during the debriefing that includes a *comparing activity* for them to reflect on the similarities and differences between their own performance and the best practice example provided. This enables students to make sense of their errors and consolidate their knowledge. Further research is needed to extend on this work and to examine the effectiveness of the LE model in different sites and with a diverse range of student cohorts.

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Conflict of interest

None.

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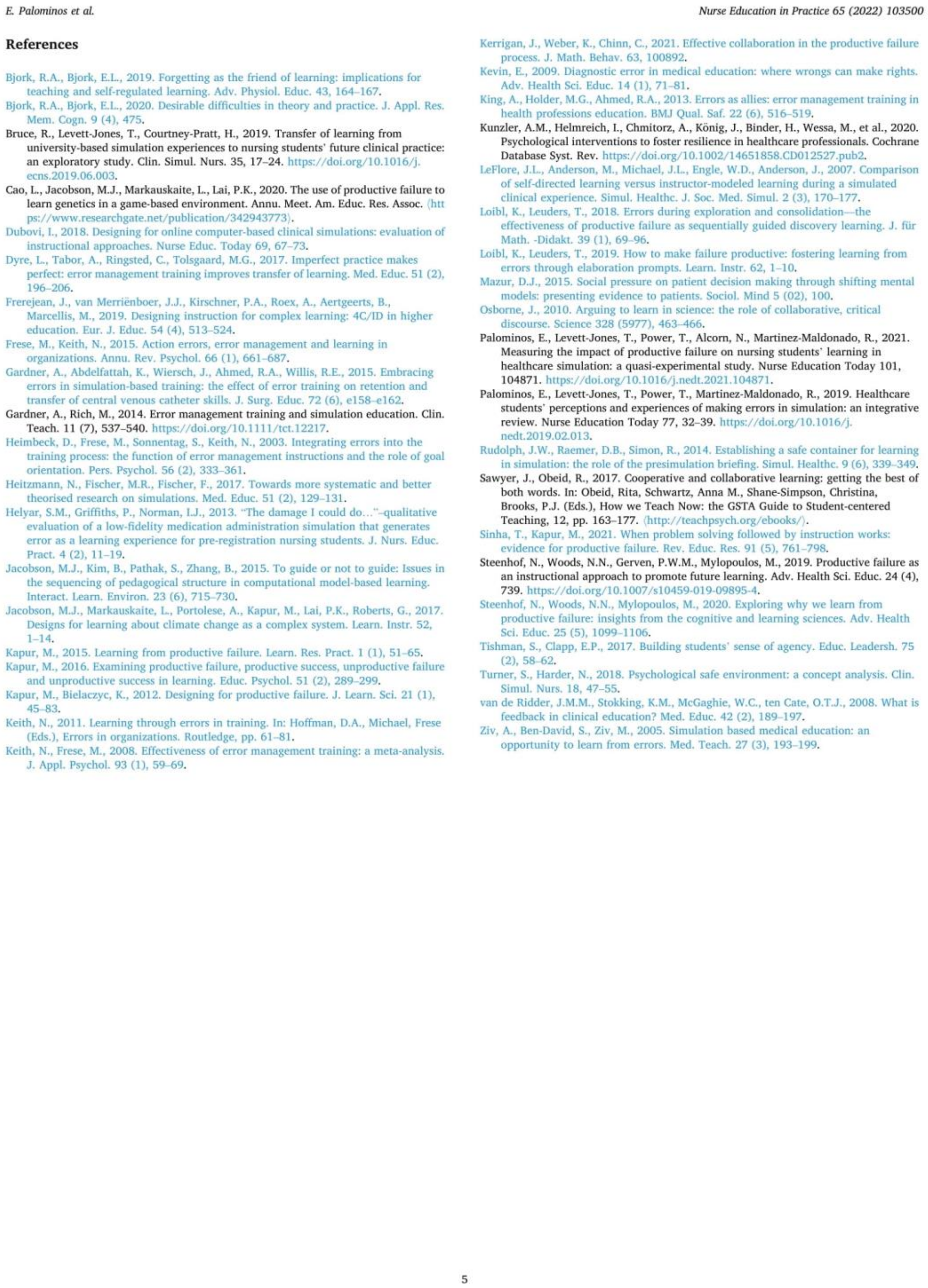

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Chapter 4. Measuring the impact of productive failure on nursing students' learning: A quasi-experimental study (stage 3)

> Figuring something out on our own way may be
> the best way to learn.
>
> — Manu Kapur

4.1 Introduction

The LE conceptual model outlined in Chapter 3 presented critical elements to inform the design of simulation experiences that embrace errors as learning opportunities. To date, the literature identified no studies of the effectiveness of and students' satisfaction with SBL experiences purposely designed to enable students to learn from errors. A quasi-experimental study was conducted to fill this research gap.

This chapter includes a paper about the comparative impact of PF simulations and DI simulations on nursing students' learning. In addition, it presents the key findings of an application of the SSE scale (Levett-Jones et al., 2011) to measure students' satisfaction with the simulation experience, as presented at the 18th National Nurse Educator conference.

4.2 Published paper

The paper provided in this chapter is:

Palominos, E., Levett-Jones, T., Power, T., Alcorn, N., & Martinez-Maldonado, R. (2021). Measuring the impact of productive failure on nursing students' learning in healthcare simulation: A quasi-experimental study. *Nurse Education Today, 101*, 104871. https://doi.org/10.1016/j.nedt.2021.104871

4.3 Aim

The aim of this paper was to measure the impact of PF on nursing students' declarative knowledge, explanatory knowledge, and transfer of knowledge compared to a DI approach in a paediatric closed head injury simulation.

4.4 Ethics approval

Ethics approval was obtained from the UTS Human Research Ethics Committee (protocol no. ETH19-3425) (Appendix 1).

4.5 The impact of this publication

In early November 2022, this paper has been cited three times and tweeted 12 times. Attention score: 9, which is in the top 25% of all research outputs scored by Altmetric (Altmetric, 2015).

4.6 Publication copyright

Elsevier® authorises authors to include their articles in full or in part in a thesis or dissertation (Elsevier, 2022).

4.7 Appendices

The following appendices are related to Chapter 4:

- Appendix 6—The randomisation of study participants
- Appendix 7—The randomisation of study groups
- Appendix 8—Subject matter expert content and face validity of pre-and-post simulation knowledge test
- Appendix 9—Demographic survey
- Appendix 10—Pre-and-post simulation knowledge tests and related rubrics
- Appendix 11—Instructional guideline for the simulations
- Appendix 12—Simulation facilitator guide (PF groups and DI groups)
- Appendix13—PowerPoint presentation slides used in the study intervention
- Appendix 14—Screenshots of the educative video presented in the debriefing

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Measuring the impact of productive failure on nursing students' learning in healthcare simulation: A quasi-experimental study

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ABSTRACT

Background: Previous research suggests that making errors in a non-threatening simulated environment can facilitate learning. Productive failure, which combines problem-solving tasks followed by instruction, enables students to learn from making mistakes. This teaching approach has demonstrated improved learning outcomes such as explanatory knowledge and transfer of knowledge compared to a direct instruction approach where students receive instruction prior to problem-solving tasks. However, no previous studies have examined the impact of productive failure on nursing students' learning in manikin-based simulation.
Objective: To measure the impact of productive failure on nursing students' declarative knowledge, explanatory knowledge, and transfer of knowledge compared to a direct instruction approach in a paediatric closed head injury simulation.
Methods: Second year undergraduate nursing students ($n = 349$) from one Australian university were invited to participate in the study. Consenting participants ($n = 344$) were randomised into two groups: productive failure and direct instruction. The intervention consisted of two paediatric closed head injury simulations separated by a simulation debrief. Knowledge tests were administered before and immediately after the simulation.
Results: Data from 331 participants were analysed. The productive failure group outperformed the direct instruction group in the post-test ($p < 0.001$). Learning gains for participants in the productive failure group were significantly higher than the direct instruction group for both explanatory knowledge ($p < 0.001$) and the ability to apply learning to solve novel clinical problems ($p < 0.001$). The difference in the median scores for declarative knowledge was not significant ($p = 0.096$).
Conclusion: This study demonstrated that a productive failure simulation that leads learners to make mistakes before receiving instruction can facilitate deeper levels of explanatory knowledge and enable the transfer of learning to new clinical situations. These results suggest the need for further exploration of pedagogies that foster learning from errors in simulation-based learning.

1. Introduction

In simulation-based learning experiences, learners can explore the limits of their practice and learn from their mistakes (Yockey and Henry, 2019; Young et al., 2016). Although making errors in simulation may trigger negative feelings, there are key aspects that can mitigate these negative emotions and transform mistakes made into learning opportunities (Hughes et al., 2014; Young et al., 2016). These aspects include the creation of a non-threatening learning environment where skilled educators provide constructive feedback and students are supported to take responsibility for their mistakes (Palominos et al., 2019).

Making mistakes in a realistic but non-threatening simulated environment can help students become cognisant of their responsibilities as future professionals and their role in the prevention of adverse patient outcomes (Helyar et al., 2013). Error experiences followed by opportunities for deliberate practice or observing others perform the task correctly can also heighten students' confidence (Lendahls and Oscarsson, 2017; Song and Jeong, 2015). Simulation-based learning experiences demand a deliberate and thoughtful approach that incorporates suitable pedagogical methods that inform simulation design to maximise

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learning (Nestel et al., 2017).

Productive failure is a pedagogical approach that leads students to commit mistakes before receiving instruction. The learning outcomes assessed in productive failure studies include declarative knowledge, explanatory knowledge, and transfer of knowledge (Cao et al., 2020; Jacobson et al., 2017). For the purpose of this study, declarative knowledge refers to knowledge about facts (Ohlsson, 1996); explanatory knowledge involves providing explanations related to the understanding of a particular event (Coleman, 1998; Jacobson et al., 2017); and transfer of knowledge refers to students' ability to apply what they have learned to a novel situation or problem (Loibl et al., 2017). These learning outcomes have been measured in topics such as genetics (Cao et al., 2020) and complex systems (Jacobson et al., 2017). Cao et al. (2020), in the context of game-based learning, conducted a quasi-experimental study in which students (n = 148) were randomly allocated to one of two study conditions: productive failure game-based learning (PF-GBL) and direct instruction game-based learning (DI-GBL). Students had three intervention sessions and completed a pre-test and a post-test. Descriptive statistics and parametric tests were used for data analysis. Research findings determined that PF-GBL participants outperformed DI-GBL participants on explanatory knowledge and transfer problems.

Jacobson et al. (2017), in the context of agent-based computer simulation, allocated students (n = 110) to either a productive failure condition or a direct instruction condition. Productive failure participants worked with agent-based computer models prior to receiving instruction, whereas direct instruction students received an inverse pedagogical intervention (instruction followed by computer-based models). Findings of this study demonstrated that productive failure participants significantly outperformed direct instruction participants on explanatory knowledge and knowledge transfer. Although productive failure has demonstrated improved learning outcomes, no previous studies have measured the effectiveness of this innovative teaching approach in undergraduate nursing students in the context of manikin-based simulation. Hence, this study aimed to measure the impact of productive failure on nursing students' declarative knowledge, explanatory knowledge, and transfer of knowledge compared to a direct instruction approach in a paediatric closed head injury simulation.

2. Background

Productive failure comprises a generation and exploration phase, followed by a consolidation and knowledge assembly phase (Kapur, 2015). In the exploration phase, students work collaboratively on novel problems without receiving instruction. Students draw on their prior knowledge and ideas to create possible solutions to the given problems, which typically results in errors (Kapur and Bielaczyc, 2012). Although students often struggle to solve the given problem, this phase serves to prepare them to deeper understand critical concepts and explanations provided by the teacher during the consolidation phase (Kapur, 2014).

In the consolidation phase, the teacher provides instruction based on students' solutions, allowing students to compare and contrast their solutions to the given problem with the teacher's correct solutions (Kapur and Bielaczyc, 2012). It is suggested that this process helps learners identify specific knowledge gaps, recognise their mistakes, and pay closer attention to the teacher's explanations (Loibl and Rummel, 2014). Advocates of productive failure argue that learners achieve a better conceptual understanding and are more likely to transfer what they have learned to new situations or problems (Loibl et al., 2017).

In contrast to productive failure, direct instruction approach combines instruction followed by problem-solving activities (Cao et al., 2020; Kapur, 2014). Proponents of direct instruction claim that addressing novel problems without receiving comprehensive explanations may be ineffective as students may develop misconceptions or acquire inaccurate information (Kirschner et al., 2006). Sweller et al. (2011) argued that students may generate significant extrinsic cognitive load when dealing with novel information without receiving direct instructional guidance.

To the best of our knowledge, no previous studies have examined the benefits of productive failure for nursing students engaged in manikin-based simulations. The closest to our research was conducted by Dubovi (2018) in an online computer-based simulation. In this study, nursing students (n = 103) were allocated to either a productive failure group or simple-to-complex group and individually completed online clinical simulation scenarios. The results indicated that the simple-to-complex approach was more effective than productive failure for learning clinical reasoning skills. This result highlights the need for further research exploring the impact of productive failure on nursing students' learning in other contexts such as manikin-based simulation.

3. Methods

3.1. Research design

This paper presents the quantitative results of a quasi-experimental, two-group, pre-test and post-test study.

3.2. Participants and setting

Second year undergraduate Bachelor of Nursing students (n = 349) enrolled in a paediatric clinical subject in one large, urban Australian university were invited to participate in the study. The study was embedded in a scheduled, in-class simulation session. Students who declined to participate still undertook the simulation but did not complete the pre and post-tests.

3.3. Ethical considerations

Ethical approval was granted by the university's human research ethics committee (protocol no. ETH19-3425). Participation was voluntary, and an identification number was used to protect the anonymity of the participants involved. The research was introduced to the students by an external researcher who was not involved in teaching or the research project. It was stressed that participation or non-participation will not adversely affect participants' course progression or assessments.

3.4. Pilot study

A pilot simulation was undertaken to predict the sort of mistakes that students were likely to make in the paediatric simulation. Two second year nursing students and one simulation facilitator participated in this activity and provided critical feedback that was used to develop guiding questions for the debrief that followed the simulation activity.

3.5. Instructional materials

The instructional materials consisted of a 12-minute narrated PowerPoint presentation and a 13-minute video demonstration. The PowerPoint presentation included knowledge and skills related to the simulation topic (paediatric closed head injury), such as classification of head injuries, pathophysiology, clinical manifestations, nursing assessment and management. The video demonstration consisted of a simulation performed by experienced paediatric nurses caring for an infant who has been shaken. Two experienced paediatric academics provided feedback on the content of the PowerPoint presentation and the video demonstration.

Prior to participating in the simulation, students had attended lectures related to the simulation topic. The lectures provided an introduction to conducting a systematic physical assessment of a child (assessment of Airway, Breathing, Circulation Disability, Exposure, Fluids and Glucose). Students attended compulsory laboratory classes where they practised general skills associated with the physical assessment of infants and children and prioritisation of care using simulation manikins. However, students had not practised the specific skills needed for the assessment and management of a paediatric patient with a closed head injury.

3.6. *Randomisation*

Consenting participants were randomised into two groups: The productive failure (experimental) group or the direct instruction (control) group. The randomisation was conducted using a permuted block approach to achieve balance across groups (Follmann and Proschan, 1994). To avoid selection biases, a researcher not associated with the study performed the randomisation.

3.7. *Intervention*

3.7.1. *Productive failure group*

Participants in the productive failure group completed a short demographic survey and answered a knowledge pre-test prior to the simulation. They were also asked to maintain confidentiality about the simulation. The facilitator then briefed students on the simulation environment, the objectives and expectations of the simulation session, its structure, time limits and available roles. Subsequently, participants were divided into groups of six or seven and, after being allocated to roles, participated in a simulation focused on paediatric closed head injury secondary to non-accidental injury (shaken baby syndrome). The clinical scenario required students to demonstrate clinical skills such as systematic physical assessment, prioritisation of care and care planning. Following the principles of productive failure, students could make mistakes as in this activity they did not receive any feedback or instruction. Prior to and during the simulation, it was emphasised that errors are part of the learning process.

Medium fidelity paediatric manikins were used; they were programmed to reproduce parameters such as heart rate, vocal sounds, and lung sounds. To enhance realism, bedside iPad monitors were used to display blood pressure, temperature, respiratory rate, and oxygen saturation level. To facilitate students' performance, a standard paediatric observation chart (New South Wales Health, 2016), paediatric neurological and pain assessment tools, that students were familiar with, were provided. After the simulation, the facilitator offered a short debrief for each group, followed by a full class debrief. In the small group debrief, students shared their first impressions of the simulation and provided a summary of their performance. In the full class debriefing, the facilitator provided instruction about the simulation topic using the PowerPoint presentation, followed by the video demonstration as instructional support. Subsequently, to support the

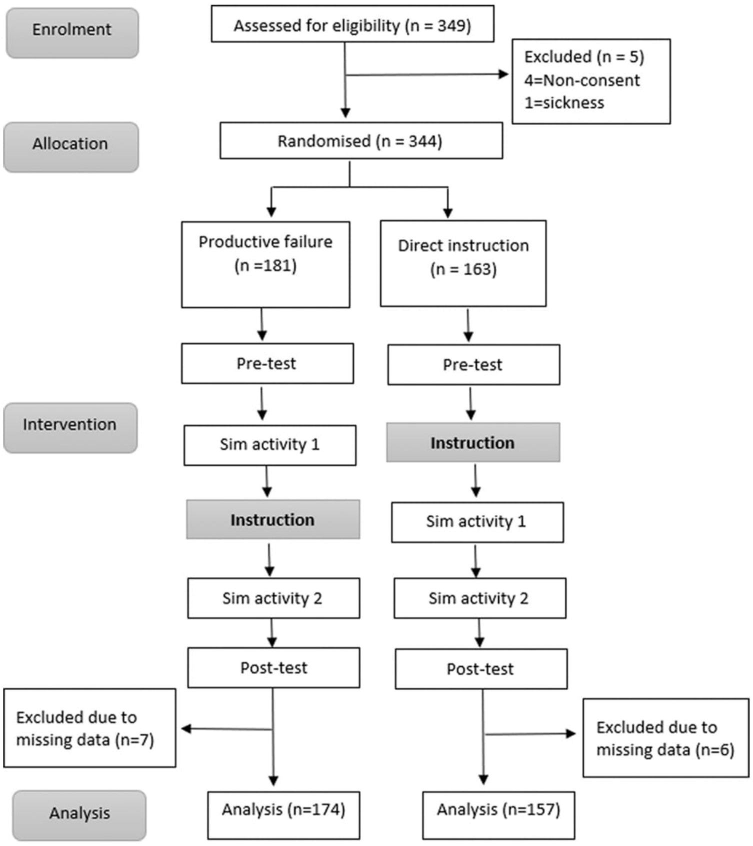

Fig. 1. Study design.

consolidation of knowledge (Kapur and Bielaczyc, 2012), students participated in a contrasting and comparing activity where they were asked to reflect on the following questions: 1) What are the similarities between your performance and the video demonstration? 2) What are the differences between your performance and the video demonstration? 3) What aspects of your performance could you improve?

After the debriefing and to provide an opportunity to apply what they had learned, the students participated in a second simulation of a paediatric patient with a closed head injury as a result of a fall from a 3rd-floor apartment window. They then completed a post-simulation knowledge test. The entire simulation session lasted 3 h.

3.7.2. *Direct instruction group*

After completing the short demographic survey and the pre-test, participants in the direct instruction group were also briefed on the simulation environment, the objectives and expectations, time limits and roles. This group was taught by the same facilitator and exposed to the same simulation scenarios and instructional materials as those in the productive failure group. However, these participants received instruction prior to the first simulation. Fig. 1 illustrates the study design.

3.8. *Instruments*

3.8.1. *Demographic survey*

Baseline characteristics of participants were collected to provide a general description of the study population.

3.8.2. *Pre-test and post-test*

Students' knowledge was assessed using a 14 item-pretest and a 16 item post-test consisting of ten open-ended questions, four short answer questions and two multiple-choice questions. The highest possible score on the pre-test was 30 and 36 on the post-test. The questions were designed to enable students to: a) recall the pathophysiology of closed head injury, b) recall the clinical manifestations of neurological deterioration in children, c) provide rationales for the nursing care of children with closed head injury, and d) apply what they have learned to new clinical problems. These questions measured declarative knowledge, explanatory knowledge, and transfer of knowledge. Table 1 displays examples of pre and post-test questions.

Pre and post-test questions were drawn from Hoffman et al. (2017). Content validity of the questions was evaluated by an expert panel who were asked to assess each item for relevance, clarity, ambiguity, and level of difficulty (Lynn, 1986; Polit and Beck, 2006).

Table 1
Examples of pre-test and post-test questions according to knowledge assessment type.

Knowledge assessment type	Question (Q)
Declarative knowledge	Q1: The rigid cranial cavity contains three elements. What are these three elements? Q2: Which clinical manifestations of increased intracranial pressure from the following list can be present in a 7-year-old patient. Select all that apply. (a) High-pitched cry; (b) blurred vision; (c) bulging fontanelle; (d) nausea
Declarative and explanatory knowledge	Q3: (a) Alex is a six-year old boy who presented to the Emergency Department. He suffered a mild head injury after a pushbike accident, with loss of consciousness of less than 2 min. Write down two nursing interventions to help maintain Alex's intracranial pressure within the normal range. (b) Explain the rationale for each of the nursing interventions
Transfer of knowledge (post-test only)	Q4: Olivia is a two-year old girl who suffered a mild head injury due to a fall from the top of a bunk bed. Careful clinical examination reveals no serious intracranial injury. Before being discharged, what nursing recommendations would you give to parents for the care of Olivia at home?

3.9. *Scoring*

Short answer questions and multiple-choice questions were coded as correct or incorrect. Participants received one to three points per correct answers, depending on the complexity of the question, and zero points for incorrect responses. Open-ended questions were assessed using a four-point rubric scale (Jacobson et al., 2017). Two researchers validated the content of the rubric, one with paediatric clinical nursing experience. Two raters independently scored 20% of randomly selected tests and achieved high inter-rater reliability scores (Kappa 0.96); one rater then scored the remaining tests.

3.10. *Data analysis*

Participants' demographic characteristics were analysed using descriptive statistics. The analysis for normality showed that data were not normally distributed; therefore, non-parametric tests, Mann-Whitney *U* test and Wilcoxon's Signed Rank test, were used. The level for statistical significance was set at $p \leq 0.05$ (two-tailed). Data analysis was conducted using IBM SPSS Statistics, version 26.0.

4. Results

4.1. *Demographic characteristics of all participants*

Second year student nurses agreed to participate in the study (n = 344). Thirteen participants (7 from the productive failure group and 6 from the direct instruction group) were excluded due to missing data. Thus, the data from 331 participants were analysed with most participants (n = 280, 84.4%) being female. Participants' age ranged from 18 to 64. Those in the 18–24 age group comprised the majority of participants (n = 227, 68.5%). Nearly half (n = 150, 45.3%) of the participants were born in Australia, with the remaining participants (n = 154, 46.5%) born in Asia. A variety of other countries were represented by 8.2% of participants (n = 27). For more than half (54%) of the participants, English was their first language (n = 179). The majority of the participants (61.3%) completed their high school studies in Australia (n = 202). Half (n = 168, 50.5%) of the participants had previously participated in simulation sessions.

4.2. *Study groups*

Data from 331 participants were analysed, 174 in the experimental productive failure group, and 157 in the control direct instruction group. There were no significant differences between the demographic characteristics of the two groups (Table 2).

4.3. *Pre-test*

The median pre-test knowledge score of participants in the productive failure group was 7 (5–10), compared to 8 (5–11) for the direct instruction group. This difference was not significant ($p = 0.489$). Regarding knowledge assessment type, there was no significant difference between the groups' median pre-test scores for declarative knowledge ($p = 0.851$) or explanatory knowledge ($p = 0.107$), indicating that both groups were equivalent prior to the study intervention.

4.4. *Post-test*

Median post-test knowledge score of participants in the productive failure group was 19 (14–24), compared to 14 (11–18) for the direct instruction group. This difference was significant ($p < 0.001$). Table 3 shows the overall pre and post-test scores according to study groups.

Table 2
Demographic characteristics of productive failure and direct instruction groups.

	Productive failure group (n = 174)		Direct instruction group (n = 157)		*p*
	Sample	Per cent	Sample	Per cent	
Gender					
Female	151	86.7	129	82.2	0.329
Male	21	12.1	27	17.2	
Transgender female	1	0.6	0		
Indigenous Sistergirl	0		1	0.6	
Different gender identity	1	0.6	0		
Age					
18–24	121	69.5	106	67.5	0.364
25–34	43	24.7	36	22.9	
35–44	4	2.3	10	6.4	
45–54	5	2.9	5	3.2	
55–64	1	0.6	0		
Country of birth					
Australia	74	42.6	76	48.6	0.068
Asia[a]	90	51.7	64	40.5	
Other[b]	10	5.7	17	10.9	
Country of completion of high school					
Australia	98	56.3	104	66.2	0.065
Other	76	43.7	53	33.8	
English as first language					
Yes	90	51.7	89	56.6	0.366
No	84	48.3	68	43.4	
Number of times practiced in-class simulation					
1–3	97	55.8	71	45.3	0.253
4–6	38	21.8	40	25.4	
7–9	9	5.2	13	8.3	
>10	30	17.2	33	21.0	

[a] Asia: Bangladesh, Bhutan, Cambodia, China, India, Iran, Iraq, Indonesia, Israel, Japan, Korea Malaysia, Nepal, Pakistan, Philippines, Singapore, Thailand, Vietnam.

[b] Other: Canada, Colombia, Ecuador, Fiji, Ireland, Italy, Kenya, Liberia, New Zealand, Nigeria, Portugal, South Africa, Sweden, Switzerland, UK, Zimbabwe.

Table 3
Overall pre-test and post-test scores per study groups.

Test scores	Productive failure	Direct instruction	*p*
	Median (IQR)	Median (IQR)	
Overall pre-test score	7 (5–10)	8 (5–11)	0.489
Overall post-test score	19 (14–24)	14 (11–18)	**0.001**

4.5. Learning outcomes according to knowledge assessment type

Both groups improved scores on declarative knowledge; however, the difference in the median scores was not significant ($p = 0.096$) (Fig. 2).

When examining each group separately, pre to post-test, non-parametric test analysis indicated that both productive failure and the direct instruction groups showed learning gains on declarative knowledge ($p < 0.001$ and $p < 0.001$, respectively) and explanatory knowledge ($p < 0.001$ and $p < 0.001$, respectively). However, when comparing both groups, learning gains were significantly higher in the productive failure group than the direct instruction group for both explanatory knowledge ($p < 0.001$) (Fig. 3) and transfer of knowledge ($p < 0.001$) (Fig. 4). Table 4 compares pre and post-test median scores according to learning outcomes and group conditions.

5. Discussion

Substantial research has demonstrated the efficacy of productive failure in domains such as sciences and mathematics (Jacobson et al., 2017; Kapur and Bielaczyc, 2012). However, no studies were identified that examined the impact of productive failure in manikin-based simulation. This is one of the first studies to measure the effectiveness of productive failure compared to direct instruction in undergraduate nurses, with previous research being limited to assessing clinical reasoning skills in computer-based simulation environments (Dubovi, 2018).

The current study aimed to measure the impact of productive failure on nursing students' declarative knowledge, explanatory knowledge, and transfer compared to a direct instruction approach. The results indicated that overall, the productive failure group outperformed the direct instruction group in the post-test. A more specific analysis per knowledge assessment type revealed that learning gains for participants in the productive failure group were significantly higher than the direct instruction group for explanatory knowledge and the ability to apply learning to solve novel clinical problems. Although both groups improved scores on declarative knowledge, the difference in the median scores was not significant. These results are supported by recent studies conducted in different topic areas, such as genetics (Cao et al., 2020) and complex systems (Jacobson et al., 2017). Results from these studies indicate that productive failure appeared to improve explanatory knowledge and transfer of knowledge compared to direct instruction without compromising the acquisition of declarative knowledge (Cao et al., 2020; Jacobson et al., 2017).

Previous studies suggest potential reasons why productive failure seems to be more effective than direct instruction. It is theorised that during the exploration phase, students activate their prior knowledge and intuitive ideas to solve unfamiliar learning tasks (Kapur and

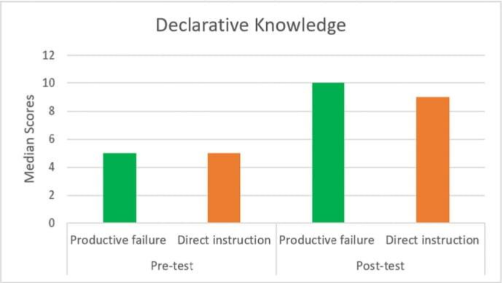

Fig. 2. Differences in the median scores between the two groups for declarative knowledge.

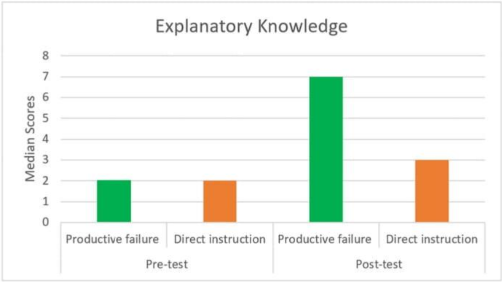

Fig. 3. Differences in the median scores between the two groups for explanatory knowledge.

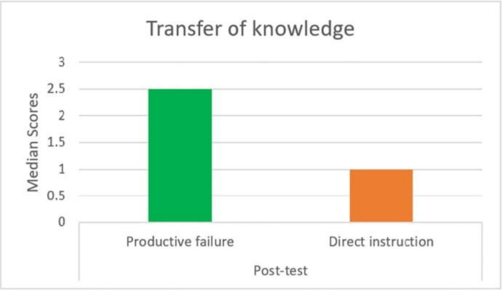

Fig. 4. Differences in the median scores between the two groups for transfer of knowledge.

Table 4
Comparison of pre and post-test median scores according to learning outcomes and study groups.

Learning outcome	Test	Study groups		*p*
		Productive failure	Direct instruction	
		Median (IQR)	Median (IQR)	
Declarative knowledge	Pre-test	5 (4–7)	5 (4–7)	0.851
	Post-test	10 (8–13)	9 (7–11)	0.096
Explanatory knowledge	Pre-test	2 (0–3)	2 (1–4)	0.107
	Post-test	7 (4–9)	3 (2–5)	**<0.001**
Transfer of knowledge	Post-test	2.5 (1–4)	1 (1–2)	**<0.001**

Bielaczyc, 2012). Conversely, students exposed to direct instruction fail to draw on their prior knowledge and adopt a more passive approach to receiving information rather than actively engaging in the learning tasks (Jacobson et al., 2017). Although the activation of prior knowledge forms the basis upon which to integrate new information, a pivotal element to learning from errors is providing students with the opportunity to reflect on the errors committed (Loibl et al., 2017).

Allowing students to compare their erroneous solutions to the teacher's correct solutions helps them detect inconsistencies in their mental models or schemas (Loibl and Leuders, 2019). Consequently, it is more likely that students build a more generalised and complete schema facilitating the application of learning to new problems or contexts (Jacobson et al., 2020).

This study has shed light on the effect of instruction timing (simulation activity prior to or after instruction) on learning outcomes. The results demonstrated that learning gains were higher for students who first practised the simulation activity and then received instruction than those who undertook the activities in the reverse order (instruction followed by simulation activity). Previous studies have reported inconsistent findings in regards to the outcomes of the timing of instruction. For example, in a study with medical residents (n = 123) in the context of web-based learning, Cook et al. (2009) found that learning outcomes were similar whether students addressed problem-solving tasks prior to or after instruction. In contrast, healthcare simulation studies appear to support our findings, suggesting that performing a simulation activity prior to receiving instruction was more effective for knowledge acquisition (Stefaniak and Turkelson, 2014; Zendejas et al., 2010). However, these studies did not explore which types of knowledge are most impacted. Additionally, in a study with medical students (n = 36), Kulasegaram et al. (2018) found that students who practised suturing skills before receiving instruction outperformed on the transfer test those who received instruction followed by the simulation activity.

The present study has some limitations. Firstly, this is a single-site study, which limits its generalisability. Secondly, we did not include follow-up tests to assess the effect of the simulation experience on knowledge retention. This provides an opportunity for future research to evaluate the long-term impact of productive failure in different contexts and with different cohorts as well as students' perceptions and satisfaction levels of the simulation experience.

6. Conclusion

This is one of the first studies to measure the effectiveness of productive failure compared to a more conventional pedagogical approach in undergraduate nursing students in the context of manikin-based simulation. This study demonstrated that a productive failure simulation that leads learners to make mistakes before receiving instruction can facilitate deeper levels of explanatory knowledge and enable the transfer of learning to new clinical problems. Our study also suggests that addressing a simulation scenario prior to instruction may be beneficial to learning. The potential application of this study to other simulation experiences in different contexts and with different cohorts would allow us to confirm the current research findings and progress this line of research.

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CRediT authorship contribution statement

All authors meet at least one of the following criteria: 1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; 2) manuscript writing and revisions for important intellectual content. All authors gave final approval of the version to be published.

Declaration of competing interest

Nil.

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Satisfaction with Simulation Experience scale: Key findings

In addition to the paper outlined previously, this chapter provides the key findings from an application of the SSE scale (Levett-Jones et al., 2011), which were disseminated at the 18th National Nurse Education Conference.

Context of the study

Second-year nursing students (n = 349) were invited to participate in the study. Consenting participants (n = 344) were randomised either to a PF group or a DI group. The PF group participated in the simulation activity before receiving instruction about the topic of the simulation. In contrast, the DI group experienced the intervention in the reverse order (instruction followed by the simulation activity). For further information about the study intervention, please see the paper provided previously in this chapter.

Once the simulation session ended, participants from the PF group and the DI group were asked to complete the SSE scale. The validity and reliability of the SSE scale have been demonstrated in previous studies (Levett-Jones et al., 2011; Levett-Jones et al., 2018). The SSE scale consists of 18 items and three subscales: debrief and reflection, clinical reasoning, and clinical learning (Levett-Jones et al., 2011). Students were asked to report their level of agreement with each statement on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree).

Data analysis

Quantitative data were analysed using the Statistical Package for the Social Sciences Statistical Software package version 22.0 (IBM Corp, Released 2013).

Demographic characteristics and item responses from the SSE scale were summarised using descriptive statistics. An independent samples *t*-test was used to compare differences in satisfaction scores between study groups. A p-value of less than 0.05 was considered statistically significant.

Participant demographics

A total of 312 nursing students responded to the SSE scale from a population of 331 (response rate of 94%), 163 from the PF condition and 149 from the DI condition. Participants were predominantly female (84%), and most (68%) were aged 18-24 years. Forty-five per cent of the participants were from Australia, 46% were born in Asian countries, and the remaining (8%) were from other countries such as Canada and New Zealand.

Quantitative findings

The overall mean satisfaction score on the SSE scale was 4.31/5.0 (SD = 0.55), indicating a high level of participant satisfaction with the simulation. The mean scores for debrief and reflection, clinical reasoning, and clinical learning were 4.25 (SD = 0.60), 4.38 (SD = 0.58), and 4.37 (SD = 0.57), respectively. The PF participants scored significantly higher than the DI participants on five satisfaction questions related to reflection on practice and clinical learning (Table 2, questions 3, 6, 15, 16 and 18).

Table 2

SSE Scale with Mean and Standard Deviations for Study Groups

SSE scale items	PF group (N = 163)	DI group (N = 149)	
	Mean ± SD	Mean ± SD	*P*
Subscale 1: Debrief and reflection			
Q1: The facilitator provided constructive criticism during the debriefing	4.03 ± 0.98	3.93 ± 0.92	0.368
Q2: The facilitator summarised important issues during the debriefing	4.30 ± 0.75	4.17 ± 0.82	0.160
Q3: I had the opportunity to reflect on and discuss my performance during the debriefing	4.36 ± 0.69	4.05 ± 0.87	**0.000***
Q4: The debriefing provided an opportunity to ask questions	4.44 ± 0.66	4.42 ± 0.70	0.809
Q5: The facilitator provided feedback that helped me to develop my clinical reasoning skills	4.25 ± 0.84	4.09 ± 0.88	0.124
Q6: Reflecting on and discussing the simulation enhanced my learning	4.55 ± 0.56	4.36 ± 0.70	**0.012***
Q7: The facilitator's questions helped me to learn	4.25 ± 0.78	4.30 ± 0.76	0.566
Q8: I received feedback during the debriefing that helped me to learn	4.07 ± 0.97	3.99 ± 0.85	0.476
Q9: The facilitator made me feel comfortable and at ease during the debriefing	4.49 ± 0.57	4.39 ± 0.70	0.161
Subscale 2: Clinical reasoning			
Q10: The simulation developed my clinical reasoning skills	4.40 ± 0.68	4.40 ± 0.66	0.959
Q11: The simulation developed my clinical decision-making ability	4.43 ± 0.59	4.33 ± 0.69	0.170
Q12: The simulation enabled me to demonstrate my clinical reasoning skills	4.39 ± 0.07	4.29 ± 0.68	0.187
Q13: The simulation helped me to recognise patient deterioration early	4.37 ± 0.64	4.30 ± 0.70	0.346
Q14: This was a valuable learning experience	4.51 ± 0.63	4.45 ± 0.68	0.424
Subscale 3: Clinical learning			
Q15: The simulation caused me to reflect on my clinical ability	4.50 ± 0.53	4.30 ± 0.70	**0.004***
Q16: The simulation tested my clinical ability	4.47 ± 0.59	4.30 ± 0.68	**0.024***
Q17: The simulation helped me to apply what I learned from the case study	4.39 ± 0.67	4.30 ± 0.66	0.228
Q18: The simulation helped me to recognise my clinical strengths and weaknesses	4.49 ± 0.54	4.27 ±.073	**0.002***

*There was a statistically significant difference between groups.

Discussion

Quantitative data analysis indicated that participants from both the PF group and the group were highly satisfied with the simulation experience. However, the PF group scored significantly higher in five satisfaction questions related to reflection on practice and relevance to clinical learning. This result suggests that participants recognised the value of the PF simulation in supporting reflection. Simulation literature highlights the importance of errors for reflection, and that educators play a crucial role in encouraging students to visualise them as resources for improvement instead of mistakes to be punished (Rudolph et al., 2014). Things that went wrong in simulation can support meaningful reflection among students (Bearman et al., 2018), and reflecting on mistakes in simulation experiences can help learners to accept and learn from their mistakes to improve future practice (Peddle et al., 2020).

Conclusion

The SSE scale findings support the notion that PF simulations can facilitate reflection on practice and improve clinical learning. Further research is needed to expand on this study in different sites and with a diverse range of student cohorts.

Appendices

Appendix 15 contains the abstract submitted at the 18th National Nurse Education Conference and Appendix 16 shows the PowerPoint presentation slides used in the conference, which includes the key results from the SSE scale.

Chapter 5. "We learn from our mistakes": Nursing students' perceptions of a productive failure simulation (stage 3)

> We learn from our mistakes and failures. The error of the past is the wisdom and success of the future.
>
> — Tryon Edwards

5.1 Introduction

The quasi-experimental study presented in Chapter 4 examined the effectiveness of and students' satisfaction with PF simulations in relation to DI simulations (Palominos et al., 2021). It is important to note that PF simulations are radically different to conventional simulations (Zendejas et al., 2010), and the integrative literature review presented in Chapter 2 found no in-depth studies of nursing students' perceptions of this type of learning experience. Therefore, in this stage of the study, a descriptive exploratory approach was used to gain a better understanding of students' views and experiences of the PF simulation.

This chapter presents one manuscript that profiles some of the findings of stage 3, which involved an exploration of nursing students' perceptions of a PF simulation.

5.2 Published paper

The manuscript presented in this chapter is:

Palominos, E., Levett-Jones, T., Power, T., & Martinez-Maldonado, R. (2022). ‘We learn from our mistakes’: Nursing students’ perceptions of a productive failure simulation. *Collegian: The Australian Journal of Nursing Practice, Scholarship and Research*. https://doi.org/https://doi.org/10.1016/j.colegn.2022.02.006

5.3 Aim

The aim of this paper was to explore nursing students’ perceptions of a productive failure simulation.

5.4 Ethics approval

Ethics approval was obtained from the UTS Human Research Ethics Committee (protocol no. ETH19-3425) (Appendix 1).

5.5 The impact of this publication

In early June 2022, this paper has been tweeted 12 times (Altmetric, 2015).

5.6 Publication copyright

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Original article

‘We learn from our mistakes’: Nursing students’ perceptions of a productive failure simulation

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ABSTRACT

Background: Productive failure simulations require students to participate in a simulation before receiving instruction. This approach contrasts with traditional simulations that typically begin with instruction followed by the simulation. Although previous studies have demonstrated that productive failure facilitates meaningful learning outcomes, students’ perspectives after being exposed to this approach have not been examined in simulation-based learning.
Objective: To explore nursing students’ perceptions of a productive failure simulation.
Design: Descriptive exploratory study.
Participants: Undergraduate nursing students from one large metropolitan Australian university.
Methods: Students involved in a productive failure simulation were invited to participate in semi-structured interviews on completion of their simulation experience. The interviews were audio-recorded, transcribed and the qualitative data were subjected to thematic analysis.
Findings: Fifteen small group interviews and seven individual interviews were conducted (n = 66). Three themes emerged from the analysis of the qualitative data: (i) the benefits of simulation prior to instruction; (ii) the value of performing a second simulation; and (iii) the importance of normalising errors.
Conclusion: The productive failure simulations helped students identify their knowledge and skill deficits and this acted as a catalyst for their learning. The normalisation of errors by the educator minimised the stress of trying to be “perfect” and assisted students to persevere despite setbacks. The provision of a second simulation helped the students rectify their errors in preparation for their future clinical practice. These aspects were considered essential for a meaningful productive failure simulation experience.

Summary of relevance

Problem

Previous studies have not explored students’ perspectives of productive failure simulations.

What is already known

Evidence from previous research has demonstrated that a productive failure pedagogical approach facilitates meaningful learning outcomes.

What this paper adds

This qualitative study found that three main components, namely simulation prior to instruction, the normalisation of errors by the educator, and students’ participation in a second simulation were important for students to experience a meaningful productive failure simulation.

Introduction

Productive failure is a pedagogical approach designed to engage students in problem-solving tasks before receiving instruction (Kapur & Bielaczyc, 2012). A novel adaptation of this approach is the productive failure simulation in which students participate in the simulation prior to receiving in-depth instruction about the concepts involved (Palominos, Levett-Jones, Power, Alcorn, & Martinez-Maldonado, 2021). This approach differs from many traditional simulations whereby students are provided with content knowledge before participating in the simulation activity (Zendejas, Cook, & Farley, 2010).

Previous studies have demonstrated that productive failure, compared to more traditional teaching approaches, improves meaningful learning outcomes such as explanatory knowledge

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and the transfer of learning to novel problems (Cao, Jacobson, Markauskaite, & Lai, 2020; Jacobson et al., 2017; Palominos et al., 2021). However, there is a dearth of studies about productive failure simulations and that explore students' perceptions of this approach. Thus, this study sought to address this research gap.

Background

Productive failure is a teaching method that consists of two main phases: an exploration phase and a consolidation phase (Kapur, 2014). In the exploration phase, students address novel problem-solving tasks, which can lead to mistakes as they have not been provided with instruction on how to solve them. The exploration phase can help students activate their prior knowledge to address the given learning tasks (Kapur & Bielaczyc, 2012) and identify their knowledge gaps (Loibl & Rummel, 2014). In the consolidation phase, the educator provides solutions to the problems presented. This phase is an opportunity for students to compare and contrast their solutions with the educator's solutions. This approach has been demonstrated to lead to deeper conceptual understanding and application of learning to future problems (Kapur & Bielaczyc, 2012). Productive failure contrasts with the more traditional teaching method known as direct instruction.

In direct instruction, students receive comprehensive explanations about the concepts to be learnt before addressing problem-solving tasks (Kirschner, Sweller, & Clark, 2006). This approach can diminish students' determination to seek alternative solutions and may limit their capacity to address novel problems (Kapur & Bielaczyc, 2012). In training and organisational contexts, this method has also been shown to cause learners to overestimate their abilities (Lorenzet, Salas, & Tannenbaum, 2005) and believe that no improvement is necessary (Sitkin, 1992).

The concept of learning from errors in simulation based-learning (SBL) is not new (Ziv, Ben-David, & Ziv, 2005). SBL offers 'permission to fail, encouraging learners to deliberately experience and learn from such failures in a way that would be inconceivable with actual patients' (Kneebone, Scott, Darzi, & Horrocks, 2004, p. 1098). SBL aims to improve patient safety as making and learning from errors in simulation can minimise the occurrence of similar mistakes in clinical practice (Ziv et al., 2005). For example, recent studies suggest that when students identify, acknowledge, and correct their mistakes, it is less likely that they repeat them (Palominos, Levett-Jones, Power, & Martinez-Maldonado, 2019). Simulation activities that "go wrong" can generate opportunities to discuss the errors made and their implications for clinical practice (Peddle, Bearman, McKenna, & Nestel, 2020).

The provision of a safe learning environment is crucial for students to feel comfortable enough to openly discuss their errors and vulnerabilities in simulation. In SBL, a safe learning environment involves: (i) the use of foundational activities embedded within the simulation such as the provision of briefing/orientation, which includes clear articulation of expectations and objectives; (ii) the skills and attributes of the educator and in particular, being approachable, honest, flexible and willing to admit their ownmistakes; and (iii) the opportunity to make mistakes without negative consequences for the learner and the patient (Turner & Harder, 2018). Further, when exploring students' perceptions of making mistakes in SBL, Palominos et al. (2019) identified key aspects that can help students overcome negative feelings about making errors and visualise them as opportunities to improve. These included skilled educators who were able to provide meaningful and constructive feedback designed to support students to identify and acknowledge their errors.

Inherent in productive failure pedagogical design is the provision of affective student support (Kapur, 2019; Kapur & Bielaczyc, 2012). This is because solving learning tasks before receiving instruction about the key concepts or content can cause students to struggle and make errors during the learning activities. By contrast, in activities informed by direct instruction, students learn about the targeted concepts before addressing the learning tasks, so it is less likely they will make mistakes.

Although a growing body of literature has demonstrated that productive failure facilitates meaningful learning outcomes, few studies have explored productive failure simulations or students' perceptions of this approach. As productive failure simulations entail a radically different approach to more conventional simulations (Zendejas et al., 2010), further exploration of this topic is warranted.

Context of the study

This study is part of a larger study from which some findings have been previously published (Palominos et al., 2021). The study was conducted at one large metropolitan Australian university. Following ethics approval from the university's human research ethics committee, second year Bachelor of Nursing students enrolled in a core paediatric subject were recruited for the study. The simulation session was part of the routine nursing curriculum; however, only those students who provided voluntary informed consent were included as participants in the study. The intervention was conducted in 14 simulation sessions over one week and facilitated by the same educator. Each simulation session included 24-28 students divided into groups of five to seven.

Participants ($n = 344$) were randomly allocated to one of two groups: the productive failure group ($n = 181$) or direct instruction group ($n = 163$). Randomisation was conducted using a permuted block approach (Follmann & Proschan, 1994). This technique randomises participants to study conditions to ensure that each group contains a similar number of participants (Efird, 2011). An external researcher conducted the randomisation to avoid selection biases using a website generated random number (Haahr, 2010).

Productive failure group

Participants in the productive failure group were briefed on the objectives and expectations of the simulation session, time frames and roles. As outlined previously, productive failure students may struggle during the simulation as the concepts to be learned are new. Thus, the pedagogical design of productive failure highlights the importance of normalising errors and providing affective support to lessen students' fear of making mistakes and their willingness to persevere with solving the given learning task (Kapur & Bielaczyc, 2012). Consistent with this approach, the educator included the following statement in the briefing: "*During the simulation activity, you may make mistakes. Errors are part of your learning and opportunities to improve.*" Note: in this paper, normalising errors refers to the acceptance of errors as a natural occurrence of the learning process.

After the briefing, participants in the productive failure group engaged in a paediatric closed head injury simulation activity with medium fidelity paediatric manikins programmed to replicate vital signs and respiratory sounds. The simulation was designed to allow students to demonstrate skills such as patient assessment, prioritisation of patient care and care planning. During the simulation activity, students did not receive instruction on the targeted concepts or feedback regarding their performance.

Following the simulation activity, students participated in a debriefing session. The model of debriefing proposed by Rudolph, Simon, Raemer, and Eppich (2008) was used, which includes a reaction phase, analysis phase and a summary phase. In the reaction phase, the educator explored students' feelings about the simulation. In the analysis phase, the educator facilitated a discussion about the simulation topic (paediatric closed head injury) and showed a video of paediatric registered nurses caring for a child who had been shaken. In the summary phase, students reflected on how their learning received could be applied to their clinical practice. The session finished with a second paediatric closed head injury simulation activity about a child falling from a 3rd-floor apartment window. The simulation scenarios included in the study were reviewed by an expert panel consisting of three paediatric registered nurses with experience in healthcare simulation. The simulations were also pilot tested with two second year nursing students and one simulation educator to ensure the simulation outline flowed as expected.

Direct instruction group

Participants in the direct instruction group had the same pre-simulation briefing, participated in the same simulation scenarios, and received the same instructional materials as the productive failure group. The only difference was that students in the direct instruction group received instruction (discussion of the simulation topic and video) before participating in the first simulation, and the educator did not refer to making errors. For further information about this aspect of the study, please see Palominos et al. (2021).

Participant demographics

Most of productive failure participants were female (n = 151, 86.7%), and 121 (69.5%) were in the 18–24 age group. Seventy-four (42.6%) of the participants were born in Australia, and 100 (57.4%) were international students. All participants had previously been involved in SBL sessions, 97 (56%) had participated in 1-3 simulations, 38 (22%) in 4–6 simulation sessions, 9 (5%) in 7–9 simulations, and 30 (17%) in >10 simulations.

Research design and methods

Aim

The aim of this study was to explore nursing students' perceptions of a productive failure simulation.

Design

A descriptive exploratory study using semi-structured interviews methods was used.

Data collection

Students involved in the productive failure simulation and who had agreed to participate in the study were invited to participate in either small group interviews or individual interviews, according to their preference and availability, at the end of the simulation session. As outlined previously, the decision to only interview students from the productive failure simulation was based on the premise that students' perspectives of this novel simulation approach had not previously been explored. Six open-ended questions were used to guide the interviews (see Table 1).

Data analysis

Qualitative data were thematically analysed according to Gibbs' (2018) framework and using NVivo, version 12 (QSR International Pty Ltd, 2020). After immersion in the data, one researcher (EP) generated the initial codes, and a second researcher (RMM) interrogated and confirmed the codes. The research team met regularly to develop, review, and define the confirmatory themes and data interpretation. Consensus on the final themes was reached through ongoing deliberation. Individual interviews and collective group interviews were considered as two separate units of analysis.

Table 1
Semi-structured interview guide.

1. How did you feel about making errors in this simulation session?
2. What did you learn from making mistakes in this session?
3. What do you think of making errors in this simulation instead of a clinical placement?
4. How did your peers and the facilitator help you address the errors made in this simulation?
5. Did you find it useful to perform two separate simulations scenarios?
6. Do you think it was useful to receive instruction and watch the video after the simulation? Why?

Findings

Emergent themes

Sixty-six participants from the productive failure group agreed to participate in the study. A total of 15 small group interviews of three–five students and seven individual interviews were conducted, each interview format lasted approximately 10–15 minutes. From the data analysis, three distinct themes emerged: (i) the benefits of simulation prior to instruction; (ii) the value of performing a second simulation; and (iii) the importance of normalising errors.

The benefits of simulation prior to instruction

In 13 small group interviews (87%) and all of the individual interviews (100%), participants expressed a preference for receiving instruction following the simulation rather than in the inverse order (instruction, followed by the simulation). To justify their views, the participants described a number of perceived benefits of this pedagogical approach. For example, they believed that this approach allowed them to compare their performance with the optimal standard of performance illustrated in the video:

'By doing a simulation and making the mistakes and then watching how it should be done, you are kind of comparing your performance with the standard of care in the video' (Participant T2).

In 13 small groups (87%) and three individual interviews (43%), participants also suggested that doing the simulation before instruction helped them identify their knowledge and skill deficits:

Í think we probably would have done better in the first scenario if we had watched the video, but that probably would not have highlighted the gaps in our skills and knowledge between the first and the second one [scenarios]' (Participant R2).

In 11 small groups (73%) and one individual interview (14%), participants also described how engaging in the simulation prior to instruction allowed them to better understand the mistakes they committed and the reasons why; this was considered a valuable learning process:

'I definitely preferred doing the simulation and then watching the video and the lecture, because the video and the lecture allowed me to understand the mistakes I made, and then why I need to correct them. I think if we watched a video first and then gone straight into the simulation, I wouldn't have been able to learn from my mistakes, and it wouldn't have been an effective learning experience' (Participant V2).

Conversely, in two small groups interviews (13%), participants were of the view that they would have preferred to watch the video before the simulation as they would know what to do beforehand:

'Personally, I would prefer the video first, just so that I know what I have to go into and so I could just do it' (Participant F2).

The value of performing a second simulation

In 12 small groups (80%) and three individual interviews (43%), participants valued the opportunity to perform the second simulation after the simulation debrief. This activity helped them correct and remember the mistakes they had made:

'It is good to then consolidate what you learned and what you didn't do right do it again [in the second simulation], so I'll do it this time and that's just like makes it keeps it more in your memory' (Participant O2).

In 2 small group interviews (13%) and one individual interview (14%), participants also viewed the second simulation as an opportunity to achieve a better understanding of the simulation:

'I definitely prefer doing two [simulations] because the first time you make the mistakes, you don't realise you are making mistakes. Then you debrief, you watch the video, you get talked to about what you need to do. Then the second time, you can rectify those mistakes and you understand what you actually have to do' (Participant V2).

A number of the participants from 6 small groups (40%) and one individual interview (14%), indicated that participating in the second simulation improved their confidence:

'It was good to do the first one [simulation], because you were going in there a bit blind just on your own nursing skills. And then to come back the second time and to be more aware and have more confidence of what you didn't do in the first one' (Participant G3).

In three small group interviews (20%) and four individual interviews (57%), participants described how the second simulation was an opportunity to improve their clinical practice:

'It actually shows yourself you can learn through your mistakes. You're actually going back… [to the second simulation] knowing that you can improve your practice and show that you're better (Participant L2).

The importance of normalising errors

In 13 small groups (87%) and all individual interviews (100%), participants provided insights into how the educator encouraging them to accept errors as part of the learning process helped them minimise negative emotions about the errors, feel more comfortable, and persevere despite setbacks:

'It I was like, okay, I can be comfortable. I do not have to try so hard… I try my best' (Participant K2).

It just creates a welcoming environment to make errors. You know that if you're going to fail, no one's going to get angry at you, and you are more willing to try (Participant O2).

The normalisation of errors also created a non-threatening, less stressful and more enjoyable experience:

'The pressure was released. I was more comfortable learning from it' (Participant K4).

'It makes you feel better because you know you are not being judged on anything' (Participant M4).

[Normalising errors] helped massively because I think sometimes, we can put a bit of pressure on ourselves (Participant B4).

Discussion

This study was designed to explore nursing students' experiences of participating in a productive failure simulation. The findings identified that the majority of participants found this approach beneficial to their learning as it allowed them to identify aspects of their performance that went well and areas that needed improvement. The latter is associated with the identification of skill and knowledge gaps or inconsistencies in individuals' mental models that need to be rectified (Chi, 2000). This is an important finding because students who are not aware of the errors they make are at risk of repeating them in the future (Satava, 2007).

The instruction provided during the simulation debrief was an opportunity for students to bridge the theory practice gaps and consolidate their learning. The video allowed students to discuss and compare their performance with the optimal standard of performance demonstrated. This learning strategy can help students acquire a deeper understanding of the key concepts (Kapur & Bielaczyc, 2012) and to transfer their learning to novel situations. Previous studies support these findings in broad fields such as genetics (Cao et al., 2020) and complex systems (Jacobson et al., 2017), but until recently, this has not been studied in nursing (Palominos et al., 2021).

It should be noted that learning experiences that elicit errors are not necessarily valued by all students (Hesketh, 2012), as evident in this study with the small number of students who indicated that they would have preferred to receive instruction prior to simulation. In the context of SBL, requiring students to practice the simulation before receiving instruction can be perceived as challenging. However, SBL provides opportunities for learners to practice responses to unpredictable and challenging clinical situations in a safe learning environment (Young, Williamson, & Egan, 2016). These learning experiences are examples of 'desirables difficulties' as they trigger cognitive processes that support learning (Bjork & Bjork, 2019). Further, challenging learning experiences are easily recalled and can be used to prevent errors in future simulations or real clinical situations (Palominos et al., 2019).

The participants in this study found that the normalisation of errors by the educator was helpful to their learning as it allowed them to feel more comfortable without the stress of trying to be perfect. This is an important finding as a number of previous studies have reported on the stress associated with making errors in SBL experiences and that some students feel intimidated and reluctant to reveal their mistakes (Aubin & King, 2015). Indeed, negative emotions such as anxiety or fear can significantly increase the potential for making mistakes (Savoldelli, Naik, Hamstra, & Morgan, 2005) and affect clinical performance (Cheung & Au 2011). Therefore, the normalisation of errors in simulation can play a crucial role in changing students' negative beliefs about mistakes and turning them into learning tools.

Studies undertaken in nursing have emphasised the importance of errors for reflection and improvement. Peddle et al. (2020) found that despite the potential negative effects of errors, academics are inclined to expose students to mistakes as a strategy to generate discussion and acquire a better understanding of clinical practice. Learning from errors is a complex cognitive process that demands purposeful reflection on, analysis of the errors committed, and application of new knowledge to improve future performance and decision making (Zhao, 2011). For example, Bearman, Greenhill, and Nestel (2018) explored healthcare professionals' narratives about what constitutes powerful learning experiences in SBL and found that things that "go wrong" can be a catalyst for meaningful reflection. In this study, the provision of a second simulation after the debrief allowed students to demonstrate how they had learnt from their errors in the first simulation and improve their confidence. This approach is supported by adult learning principles regarding the need for immediate application of learning (Knowles, 1980).

Limitations

This is a relatively small-scale study conducted at only one site; this limits both the representativeness and generalisability of the findings. Additional work could explore potential differences between group interviews and individual interviews. Further mixed methods studies and comparisons between productive failure and direct instruction groups would be valuable for better understanding the implications of productive failure simulations.

Conclusion

Three take-home messages emerged from this study. First, simulation educators should normalise errors by explicitly emphasising that they are intrinsic components of the SBL process. This can help learners positively accept, reflect on, and learn from their mistakes in order to improve future practice. Second, the incorporation of a second simulation activity after the simulation debrief may aid students to immediately rectify errors in preparation for their future clinical practice. Finally, participation in the simulation before receiving instruction may be a beneficial approach for students to better identify their knowledge and skill deficits, thus acting as a trigger for future learning. Further research would be valuable in expanding this study to different sites and with a range of cohorts.

Author contribution

All authors meet at least one of the following criteria: (i) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; (ii) manuscript writing and revisions for important intellectual content.

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Ethical statement

The study received human research ethics approval on May 29, 2019, from the university's human research ethics committee prior to commencing the study (protocol no. ETH19-3425).

Conflict of interest

None.

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Chapter 6. Discussion and Conclusion

> We all make mistakes, and it is better to make them before we begin.
>
> — Nikola Tesla

6.1 Introduction

Previous studies have demonstrated the significant role of errors in promoting meaningful learning outcomes in various educational and training settings (Kapur & Bielaczyc, 2012; Keith & Frese, 2008; Loibl & Leuders, 2018a). PF is a pedagogical approach that allows students to make mistakes, because they are engaged in novel and challenging learning tasks before receiving the correct solution (Kapur, 2016; Kapur & Bielaczyc, 2012). In SBL, students are exposed to challenging simulation scenarios and presented with opportunities to make mistakes and learn from them in a safe learning environment (Gardner et al., 2015; King et al., 2013; Ziv et al., 2005). Even though the PF approach has been demonstrated to facilitate learning, the effectiveness of PF as a learning strategy in SBL for nursing students has not been examined.

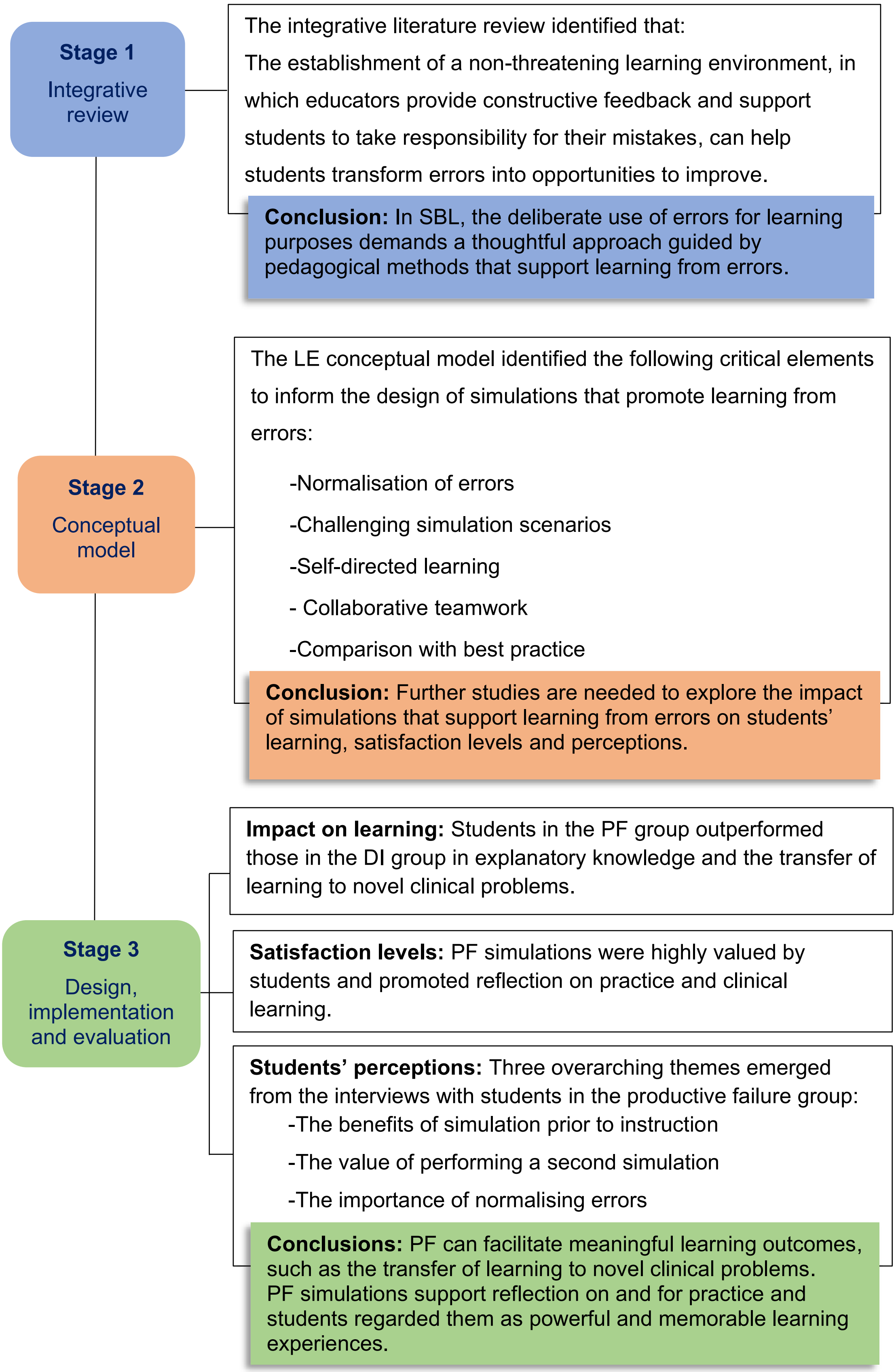
The aim of this doctoral research was to explore how PF simulations influence nursing students' learning, perceptions and satisfaction levels when compared with traditional simulations. This chapter summarises each stage of this doctoral study with its respective research question/s and key findings. The significance of the study and its contribution to knowledge is then presented. Subsequently, its implications for nursing education and future research are discussed. This chapter ends with the limitations of the study and conclusions.

6.2 Key findings

This section presents a summary of each stage of this doctoral study along with its research question/s, notable findings, and conclusions. Figure 3 illustrates the research stages of this doctoral study and their respective outcomes.

Figure 3

Research Stages and their Key Findings



Stage 1

Integrative review

The integrative literature review identified that:

The establishment of a non-threatening learning environment, in which educators provide constructive feedback and support students to take responsibility for their mistakes, can help students transform errors into opportunities to improve.

Conclusion: In SBL, the deliberate use of errors for learning purposes demands a thoughtful approach guided by pedagogical methods that support learning from errors.

Stage 2

Conceptual model

The LE conceptual model identified the following critical elements to inform the design of simulations that promote learning from errors:

-Normalisation of errors

-Challenging simulation scenarios

-Self-directed learning

- Collaborative teamwork

-Comparison with best practice

Conclusion: Further studies are needed to explore the impact of simulations that support learning from errors on students' learning, satisfaction levels and perceptions.

Stage 3

Design, implementation and evaluation

Impact on learning: Students in the PF group outperformed those in the DI group in explanatory knowledge and the transfer of learning to novel clinical problems.

Satisfaction levels: PF simulations were highly valued by students and promoted reflection on practice and clinical learning.

Students' perceptions: Three overarching themes emerged from the interviews with students in the productive failure group:

-The benefits of simulation prior to instruction

-The value of performing a second simulation

-The importance of normalising errors

Conclusions: PF can facilitate meaningful learning outcomes, such as the transfer of learning to novel clinical problems. PF simulations support reflection on and for practice and students regarded them as powerful and memorable learning experiences.

Stage 1

Research question 1: What are healthcare students' perceptions and experiences of making errors in SBL?

In SBL, learners engage in authentic clinical scenarios in settings that mimic real clinical contexts (McAllister et al., 2013). SBL offers opportunities for students to learn from things that went wrong (Bearman et al., 2018). However, students' concerns about making mistakes in simulation can trigger high levels of anxiety (Shearer, 2016; Yockey & Henry, 2019) and reduce their clinical performance and satisfaction with the learning experience (Al-Ghareeb et al., 2019; Harvey et al., 2012; Lateef, 2020).

In light of the potentially positive and negative effects of errors on students in SBL experiences, the first stage of this doctoral study was an integrative review of the literature on students' views and experiences of making errors in simulation (see Chapter 2). From the analysis of the papers included in the review, two overarching themes were identified: the impact of errors on learners and the impact of errors on learning. The impact of errors on learners included the following subthemes: the emergence of negative feelings in the face of errors; relief of knowing that mistakes made during simulation do not compromise "real" patients; and viewing mistakes as positive learning experiences as a result of the feedback received in the debriefing. The impact of errors on learning included the following subthemes: taking responsibility for the mistakes made; recognition of the potential impact of learning from mistakes on patient safety; testing abilities and developing humility; and errors as a stimulus for building confidence and developing cognitive and metacognitive skills.

The literature review demonstrated that some students experience negative feelings when making or thinking about committing errors in simulation. However, the integrative review also found that the establishment of a non-threatening learning environment, in which skilled educators provide constructive feedback and support students to take responsibility for their mistakes, was critical to moderating the negative impact of making errors and transforming them into learning opportunities.

In this doctoral thesis, the concepts of a non-threatening learning environment and a psychologically safe environment are used interchangeably (Baer & Frese, 2003). In SBL, this concept involves a set of factors that allow students to feel free to openly discuss their errors without fear of negative consequences (Fey et al., 2014; Ganley & Linnard-Palmer, 2012; Lateef, 2020). According to Turner and Harder (2018), the factors involved in the establishment of a psychologically safe learning environment are the opportunity to make mistakes without consequences for the learner or the patient; the use of foundational activities embedded within a simulation session, such as orientation and the presentation of the objectives and expectations of the simulation session; and the qualities of the educator, such as being approachable, honest and flexible and able to admit mistakes. Students' anxiety can decrease when a psychologically safe learning environment is promoted (Turner & Harder, 2018), in which they are allowed to openly discuss their errors instead of seeing them as punitive events (Rudolph et al., 2014). The sense of safety provided in simulation makes students realise that this is a place to stop being perfect (Najjar et al., 2015). It is important to note that, in addition to these important features, the integrative review identified that the educator's ability to support students to identify and take ownership of the errors made in simulation is critical to learning from errors and growing as a healthcare professional.

Mazor et al. (2005), in exploring medical students’ experiences of making errors, found that preceptors believed that students should recognise and take responsibility for their errors in order to learn from them. Similarly, Fischer et al. (2006) determined that learners should be cognisant of the importance of taking ownership of their errors, which may lead them to avoid the same errors in future situations. To accomplish this purpose, learners also need to understand what things went wrong and how and why an error occurred (Mazor et al., 2005). Consequently, to avoid the same errors in future experiences, individuals need time to recognise and reflect on their errors to understand why and how they occurred and to take responsibility for them.

The integrative literature review concluded that the negative feelings that emerge from making errors in SBL should not be entirely minimised, because the emotional component involved, associated with reflection, makes the experience powerful and highly memorable (Bearman et al., 2018; Breitkreuz et al., 2016). Further, the establishment of a psychologically safe environment that includes skilled educators providing constructive feedback and supporting students to take responsibility for their mistakes can lessen negative feelings and help learners conceptualise errors as learning opportunities. However, in simulation, the deliberate use of errors for learning purposes demands a thoughtful approach guided by pedagogical methods that support learning from errors. Stage 2 of this doctoral thesis addressed this line of inquiry.

Stage 2

Research question 2: How can SBL experiences be informed by pedagogical approaches that promote learning from errors?

Findings from the integrative literature review suggest that errors can be beneficial when they are embraced positively in a non-threatening simulation environment. However, optimising learning from errors requires crucial principles adopted by pedagogical methods that use errors as learning opportunities and ultimately inform simulation design. Therefore, the aim of stage 2 of this doctoral study was to devise an LE conceptual model that can assist educators in the design of simulations that explicitly promote learning from errors (see Chapter 3). The LE conceptual model is drawn from two pedagogical approaches, PF and EMT, and pedagogical features of high-quality healthcare simulations (Palominos et al., 2022b).

The LE model identifies the following critical elements:

- Normalisation of errors
- Challenging simulation scenarios
- Self-directed learning
- Collaborative teamwork
- Comparison with best practice.

The LE model emphasises that errors should be normalised in SBL, with educators stating explicitly that errors are opportunities to improve in simulation. This aspect is important because the normalisation of errors not only minimises negative feelings about errors in simulation but contributes to building a psychologically safe learning environment. In addition, to facilitate learning in nursing simulations that purposely promote the use of errors, it is crucial that, students work on challenging simulation scenarios and adopt the role of registered nurses who work collaboratively in the care of the patient. It is also essential that the debrief session that follows the simulation activity includes an activity in which students compare their performance with a standard or expected performance. This can help students identify their errors and subsequently rectify them with the support of skilled facilitators. Further research was needed into the impact of simulations that support learning from errors on students' learning, perceptions and satisfaction levels. Stage 3 of the doctoral thesis addressed this need.

Stage 3

Research question 3: How are nursing students' learning and satisfaction levels influenced by PF simulations compared with DI simulations?

Despite the potential benefits of making and learning from errors in SBL, identified in stage 1, and the conceptual model derived from stage 2, the effectiveness of and students' satisfaction with simulation experiences that explicitly use errors as a catalyst for learning had not been examined before this doctoral research commenced. Therefore, a novel form of simulation based on PF principles (Kapur & Bielaczyc, 2012) was designed, implemented and evaluated. This work represented stage 3 of the study and aimed to compare the impact of PF and DI simulations on nursing students' declarative knowledge, explanatory knowledge, and transfer of knowledge, and assess students' satisfaction with the simulation experience (see Chapter 4).

Impact of productive failure simulations on students' learning

This study determined that students who were exposed to a PF approach outperformed those participants exposed to a DI approach with respect to explanatory knowledge and the transfer of learning. This result is consistent with those of previous PF studies (Jacobson et al., 2017; Kapur & Bielaczyc, 2012; Loibl & Leuders, 2018a). The theory underpinning this outcome is explained below.

First, during problem-solving activities (the exploration phase of PF), students engage in a trial-and-error process, in which the feedback provided by errors leads students to identify general knowledge and skills deficits (Loibl & Rummel, 2014). In other words, students become aware of their knowledge gaps; however, they do not know which specific aspects need to be improved, leading them to pay more attention to the educator's explanations during the instruction phase (Loibl & Rummel, 2014). Consequently, students are more likely to integrate the new information acquired during this phase into their knowledge schema (Loibl & Leuders, 2018a). In contrast, students exposed to a DI approach tend to receive information passively rather than actively engaging in problem-solving activities, which reduces the likelihood that they draw on their prior knowledge (Jacobson et al., 2017).

Second, learning from errors implies that students reflect on the errors committed (Loibl et al., 2017). Errors generate the activation of controlled mental processing rather than automatic processing (Ivancic & Hesketh, 1995; Keith, 2011). Automated cognitive processing is an involuntary activation of learned elements in long-term memory (e.g., washing hands) that requires low mental effort and does not demand individuals' full attention (Devine, 1989). By contrast, controlled mental processing requires an individual's full attention and demands high cognitive effort (Kane et al., 2001). Although controlled processing may involve more mental effort, especially in challenging problem-solving activities (Sweller, 1988; Sweller et al., 1990), it generates deep cognitive processing (Keith, 2011), which facilitates the abstraction of schemas and therefore, learning (Reeves & Weisberg, 1994). In other words, errors allow individuals to recognise wrong assumptions that need further correction (Frese & Keith, 2015; Lorenzet et al., 2005). Therefore, individuals engage in effortful cognitive processes in order to improve their mental models (Ivancic & Hesketh, 1995; Lord & Levy, 1994).

Frames of reference or mental models dictate cognitive processing and drive individuals' actions (Zigmont et al., 2011). In healthcare, mental models form the basis for clinical decision-making (Mazur, 2015; Rudolph et al., 2008). For instance, a nurse's mental model of using an intravenous infusion pump may determine the time they will take to program and troubleshoot this device. The more accurate the mental model, the more precise the actions (Keith & Frese, 2008), reducing clinical errors and increasing patient safety.

Reflection on errors can be promoted by engaging students in a comparing activity in which their erroneous solutions are compared to correct solutions (Loibl & Leuders, 2019). The comparing activity, during the instruction phase of PF, can help students become aware of their specific knowledge gaps, because they focus on the components that differ (Loibl & Leuders, 2018b). In this sense, students know exactly what skills and knowledge deficits need to be improved (Loibl & Rummel, 2014), which is necessary to examine their mental models (Chi, 2000). In addition, it is theorised that students acquire a deeper understanding of the concepts of the educational session when they explore these knowledge gaps during the comparing activities and receive explanations from the educator (Sinha & Kapur, 2021).

In SBL, a comparing activity can be conducted during the debrief that follows the simulation activity and consists of students comparing their performance with a standard demonstration. The study intervention included a video demonstration of registered nurses caring for a paediatric patient who had been shaken. It allowed students to observe how experienced nurses performed in the same simulation activity and how they overcame the challenges presented.

It is important to highlight that students who participate in a PF experience will encounter desirable difficulties as they are engaged in novel and challenging learning tasks before receiving instruction on how to complete them (Kapur, 2016). Presenting students with challenging learning tasks allows them to develop a sense of agency (Sinha & Kapur, 2021), take ownership of their learning and demonstrate a willingness to persist despite struggling to solve the learning tasks (Tishman & Clapp, 2017). In this sense, providing opportunities for students to build competence and agency are essential to active engagement and learning (Gresalfi et al., 2009).

In the context of SBL, researchers have demonstrated a positive impact of the introduction of desirable difficulties on both learners and their learning. Zendejas et al. (2010) determined that students who practised simulation scenarios before receiving a lecture (desirable difficulty) scored better in knowledge acquisition tests than those who first received instruction and then performed the simulation activities. Stefaniak and Turkelson (2014) found that students who participated in the simulation first outperformed those who received the inverse pedagogical order on the knowledge test.

In the context of simulation-based medical education, Aagesen et al. (2020), working with a cohort of postgraduate physicians to learn basic surgical skills, determined that participants who engaged in practical activities first and received instruction second outperformed their counterparts in knowledge assessment and procedural skills assessment. Similarly, Willis et al. (2020) found that students who worked on the practical activities and subsequently watched the instructional video performed significantly higher on the post-test than the students who watched the video first and received detailed instructions before the practical learning activities. Consequently, these findings suggest that performing practical activities before instruction enhances procedural skills.

Regarding the impact of desirable difficulties on learners, Williamson et al. (2013) found that medical students were more satisfied when they participated in challenging clinical scenarios that involved them assuming the roles of doctors and making their own clinical decisions. Similarly, Young et al. (2016), analysing students' reflective essays about their experiences in simulation, noticed that students valued facing clinical dilemmas by themselves in a safe learning environment, which was considered a powerful learning experience.

Satisfaction levels with the simulation experience

In the current research, both the PF group and the DI group reported a high level of satisfaction with the simulation experience. However, the PF participants scored significantly higher on five satisfaction questions associated with reflection on practice and clinical learning. This could indicate that PF simulations support more meaningful reflection on practice and clinical learning than DI simulations. It is suggested that errors trigger individuals’ attention, leading them to reflect on the reasons for committing them (Ivancic & Hesketh, 2000; Keith & Frese, 2005). In SBL, errors promote the use of cognitive and metacognitive strategies in which students learn to step back and reassess their thought process (Bond et al., 2004). Simulation experiences that combine reflection and emotions are often the most meaningful and memorable (Bearman et al., 2018). Errors induce reflection on things that went wrong and provoke unpleasant emotions that cannot be avoided completely. However, because errors also facilitate meaningful learning, avoiding them represents a lost opportunity (Turton et al., 2019).

In conclusion, the key results from the quasi-experimental study suggest that PF simulations can facilitate deeper levels of explanatory knowledge and enable the transfer of learning to new clinical situations better than DI simulations. Further, participants recognised the value of PF simulations in supporting reflection on practice and clinical learning, and were generally satisfied with this novel simulation approach.

Research question 4: What are nursing students' perceptions of participating in PF simulations?

Stage 3 of this study also explored nursing students' perception of the PF simulation experience (Palominos et al., 2022a). After finalising the simulation sessions, students in the PF groups were invited to participate in a 10–15-minute group interview. Qualitative analysis of the interview data revealed three overarching themes: the benefits of simulation prior to instruction, the value of performing a second simulation, and the importance of normalising errors.

It was evident from the data that students valued the opportunity to practice first and subsequently be instructed on the topic of the simulation session, because this enabled them to identify their knowledge and skills deficits through the errors they made during the simulation. Turton et al. (2019) highlighted that simulation debriefs are often ineffective in exploring students' errors, because these sessions are often focused on what went right. Allowing students to identify their errors and take ownership of them is essential for learning (Mazor et al., 2005), and and increases the likelihood that they will not repeat them in their clinical practice (Elshami & Abuzaid, 2017; Lewis et al., 2012; Reime et al., 2016).

The qualitative data analysis identified that students highly valued the opportunity to perform a second simulation following the debrief because it allowed them to rectify their errors, consolidate what they learned in the debrief session and improve their confidence. This last finding aligns with those of previous researchers such as Song and Jeong (2015), who found that students felt more confident after participating in a second simulation activity. Boling and Hardin-Pierce (2016) noticed that the more students practise, the more confident they become in their clinical abilities. This is important because students who develop confidence in their clinical skills are likely to focus less on their own needs and more on providing safe patient care (Leigh, 2008).

With regard to the last theme, the importance of normalising errors, participants highly valued the educator normalising errors in the simulation session by stating explicitly that errors are part of the learning process. In SBL, there is often a perceived dichotomy between the importance of learning from errors and the risk of causing significant harm to the learner (Turton et al., 2019). In this sense, frank conversations about failure experiences are often avoided to reduce the likelihood of damaging “learners’ professional authority and identity” (Pelletier et al., 2019, p. 3). However, as Manalo and Kapur (2018) stated, “students need to be fully cognizant of and acculturated to such treatment of failure, and teachers need to be equipped with the necessary knowledge and skills to promote the development of such environments in their classrooms” (p. 8). Adding the normalisation of errors in simulation not only plays a crucial role in changing students’ negative beliefs about mistakes but contributes to building a psychologically safe learning environment.

6.3 Implications for nursing simulation and future research

The findings of this doctoral study can assist educators and researchers in the design, implementation and evaluation of simulation experiences that explicitly promote learning from errors. It is important to emphasise that these simulation experiences are designed to support meaningful learning outcomes, such as the transfer of learning to novel clinical tasks. Therefore, educators should consider whether PF simulations are the most suitable for the objective of the session and for students' learning needs. Further, PF simulations involve hands-on practice followed by instruction on the topic of the simulation session, so can be more appropriate for those simulations that include a component of formal instruction. In addition, PF simulations can also be used in education programs committed to improving patient safety, because it is argued that learners who identify and rectify their errors in simulations are less likely to repeat the same mistakes in clinical settings (Elshami & Abuzaid, 2017; Reime et al., 2016).

This doctoral study improved our understanding of how PF simulations influence nursing students' learning, satisfaction and perceptions. As outlined previously, it identified that PF simulations can lead to meaningful learning experiences. The study, therefore, provides a foundation for future research to continue exploring how to optimise the integration of PF principles into simulation. In order to capitalise on the benefits of learning from errors in simulation, further research into the long-term impact of PF simulations in different contexts and with different cohorts is essential. Although this study examined the impact of PF simulations on declarative knowledge, exploratory knowledge and the transfer of learning to novel clinical problems, future studies of the impact of PF simulations on students' application of learning to clinical practice are also warranted.

An additional potential avenue for research is another pedagogical approach that promotes learning from errors: EMT. In the context of healthcare education, this approach has mainly been explored in medical simulation (Dyre et al., 2017; Gardner et al., 2015; Gardner & Rich, 2014). EMT has been demonstrated to facilitate the transfer of learning to novel problems (Keith & Frese, 2008) as well as the development of strategies for coping with errors effectively (Keith, 2011; King & Beehr, 2017). Therefore, the impact of EMT on learning and learners in the context of nursing simulation represents a valuable line of future inquiry.

This research focused on how PF simulations affect students' learning, satisfaction and perceptions, and the exploration of simulation facilitators' views of the PF simulation experience was beyond the scope of this study. Therefore, an interesting area of future research is to explore the adoption of PF simulations from the educators' perspectives, which could inform future training and delivery of PF simulations.

Finally, findings from this doctoral study have profound implications for simulation pedagogy and potential to drive policy and curricula change.

6.4 Significance of the research

The general contribution of this doctoral thesis is to provide an enhanced understanding of the influence of PF simulations on nursing students' learning, satisfaction and perceptions. The specific contributions to knowledge of this doctoral research are threefold.

First, it cannot be assumed that SBL is a safe experience in which learners can make mistakes and learn from them. There is a common belief that debriefing sessions are opportunities to correct students' errors; however, this activity is too often focused on what went right (Turton et al., 2019). Therefore, from a theoretical perspective, this doctoral study contributes to a better understanding of how learning from errors in SBL can be optimised. The following recommendations are provided with the aim of improving learning from errors in SBL:

- Educators should assist students to fully identify, explore and take responsibility for their errors, which can help them understand the personal impact of errors and their role in the prevention of adverse patient outcomes (Palominos et al., 2019).
- The incorporation of a second simulation activity after the simulation debrief may aid students to immediately rectify errors in preparation for their future clinical practice (Palominos et al., 2020a).

Second, the deliberate use of errors for learning purposes demands a thoughtful approach informed by pedagogical methods that embrace errors as learning resources. Therefore, from a methodological perspective this doctoral study provides a novel LE conceptual model, an evidence-based approach, developed from literature on pedagogical approaches that promote the use of errors and have been introduced in healthcare simulation (Palominos et al., 2022b). The LE model can be used by educators and simulation facilitators to design simulations that explicitly use errors as learning tools.

Finally, from an empirical perspective the findings of this doctoral study make a substantial contribution to nursing simulation by demonstrating that PF simulations can facilitate meaningful learning outcomes, such as the transfer of learning to novel clinical problems. This outcome is particularly relevant because PF simulations could improve nursing students' future practice and ultimately, patient outcomes.

6.5 Limitations of the study

This thesis has some limitations. First, the integrative literature review performed in stage 1 only included articles written in the English language, and unpublished records and grey literature were excluded. Therefore, some relevant studies may have been overlooked. Second, the quasi-experimental study conducted in stage 3 involved nursing students at one large Australian university, potentially limiting the representativeness and generalisability of the results beyond that specific cohort. In addition, this study did not explore the opinions of nursing students who received DI simulations. Further mixed methods studies that compare PF and DI groups would enable a better understanding of the effectiveness of PF simulations. Finally, the study would have been strengthened by including assessment of the effectiveness of PF simulations in terms of long-term retention of learning and application to clinical practice.

6.6 Conclusion

Although the rhetoric about SBL being safe to learn from errors is common in the literature, closer attention to the impact of errors on learning and learners in simulation experiences was needed. This study demonstrated the feasibility and value of integrating PF principles into SBL in the context of nursing education, as well as the impact of PF simulations on nursing students' learning, perceptions and satisfaction. Learning from errors in simulation demands an integral and thoughtful approach that involves several critical elements. One element involves students being fully aware of the role of errors in their learning and simulation facilitators normalising them. The normalisation of errors in simulation not only plays a crucial role in changing students' negative beliefs about mistakes but contributes to building a psychologically safe learning environment in which students accept, reflect on and learn from their mistakes to improve future clinical practice. Promoting a self-directed approach in a collaborative group environment before instruction, and undertaking a comparing activity during the debriefing, are also components that are crucial to maximise students' learning and make the PF simulation experience meaningful and memorable.

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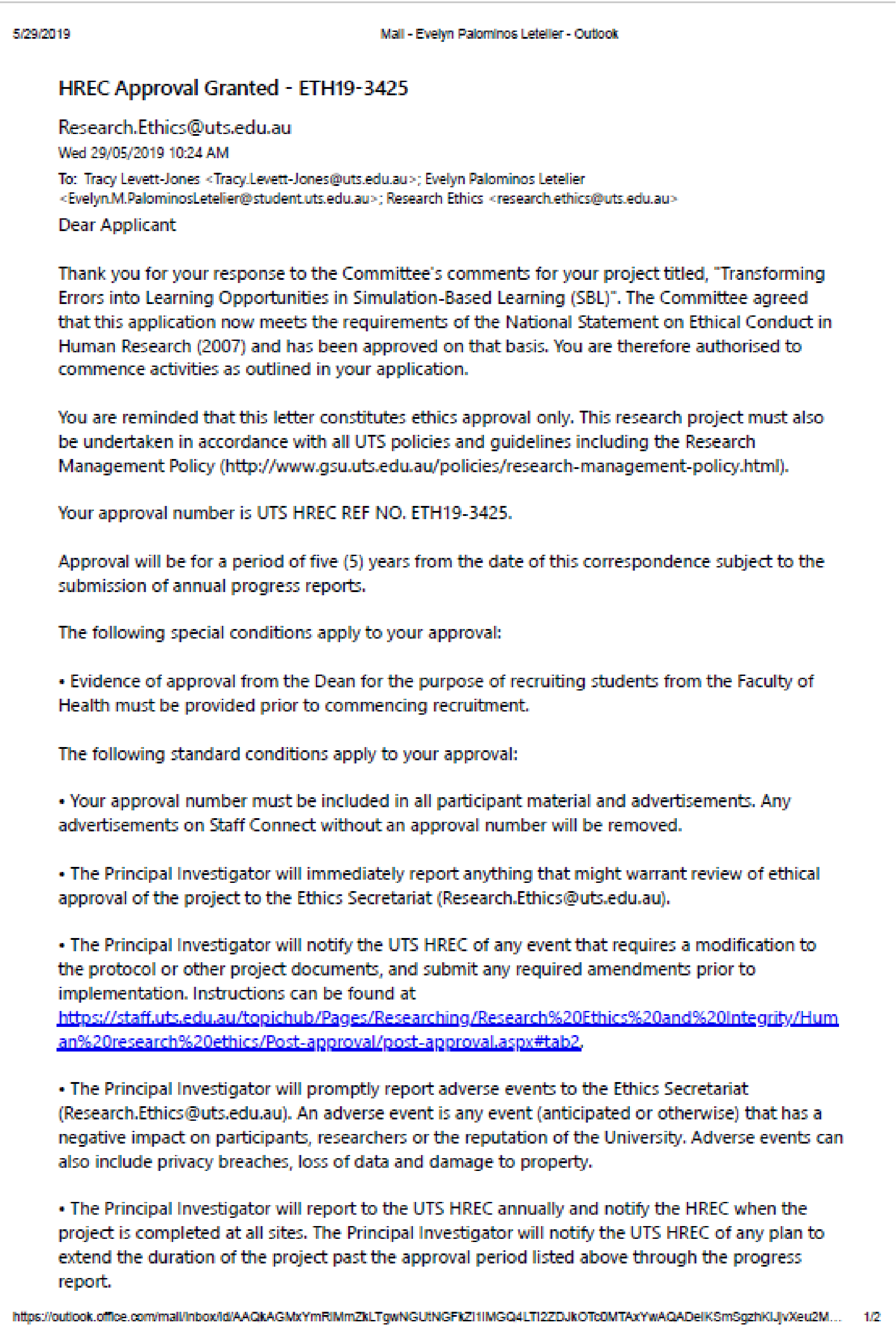
Zendejas, B., Cook, D. A., & Farley, D. R. (2010). Teaching first or teaching last: Does the timing matter in simulation-based surgical scenarios? *Journal of Surgical Education*, *67*(6), 432-438.

Zigmont, J. J., Kappus, L. J., & Sudikoff, S. N. (2011). Theoretical foundations of learning through simulation. *Seminars in Perinatology*, *35*(2), 47-51. https://doi.org/10.1053/j.semperi.2011.01.002

Ziv, A., Ben-David, S., & Ziv, M. (2005). Simulation based medical education: An opportunity to learn from errors. *Medical Teacher*, *27*(3), 193-199. https://doi.org/10.1080/01421590500126718

Appendices

Appendix 1. HREC approval letter



5/29/2019 Mail - Evelyn Palominos Letelier - Outlook

HREC Approval Granted - ETH19-3425

Research.Ethics@uts.edu.au
Wed 29/05/2019 10:24 AM
To: Tracy Levett-Jones <Tracy.Levett-Jones@uts.edu.au>; Evelyn Palominos Letelier <Evelyn.M.PalominosLetelier@student.uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Transforming Errors into Learning Opportunities in Simulation-Based Learning (SBL)". The Committee agreed that this application now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application.

You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all UTS policies and guidelines including the Research Management Policy (http://www.gsu.uts.edu.au/policies/research-management-policy.html).

Your approval number is UTS HREC REF NO. ETH19-3425.

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following special conditions apply to your approval:

- Evidence of approval from the Dean for the purpose of recruiting students from the Faculty of Health must be provided prior to commencing recruitment.

The following standard conditions apply to your approval:

- Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.

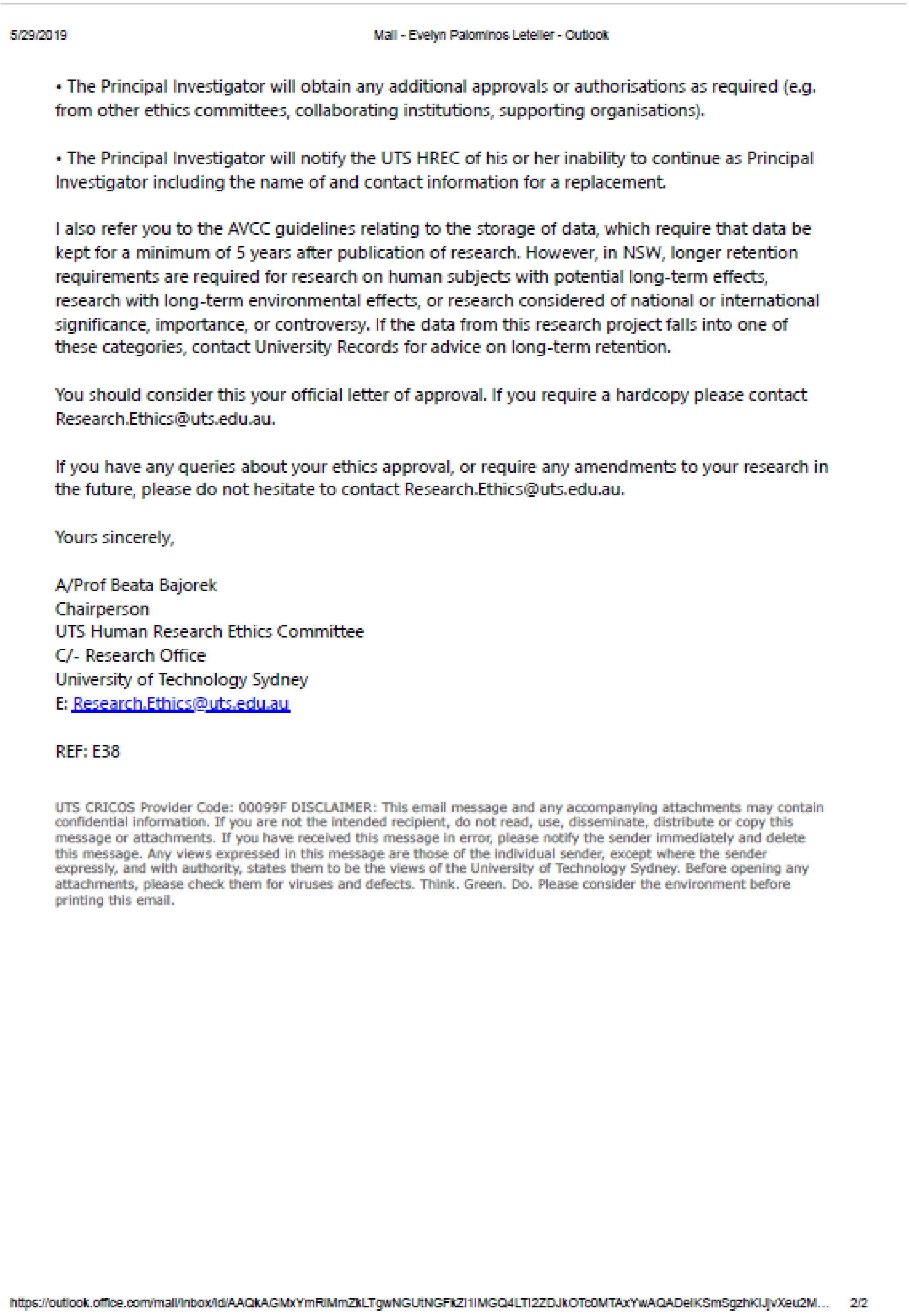
- The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the Ethics Secretariat (Research.Ethics@uts.edu.au).

- The Principal Investigator will notify the UTS HREC of any event that requires a modification to the protocol or other project documents, and submit any required amendments prior to implementation. Instructions can be found at https://staff.uts.edu.au/topichub/Pages/Researching/Research%20Ethics%20and%20Integrity/Human%20research%20ethics/Post-approval/post-approval.aspx#tab2.

- The Principal Investigator will promptly report adverse events to the Ethics Secretariat (Research.Ethics@uts.edu.au). An adverse event is any event (anticipated or otherwise) that has a negative impact on participants, researchers or the reputation of the University. Adverse events can also include privacy breaches, loss of data and damage to property.

- The Principal Investigator will report to the UTS HREC annually and notify the HREC when the project is completed at all sites. The Principal Investigator will notify the UTS HREC of any plan to extend the duration of the project past the approval period listed above through the progress report.

https://outlook.office.com/mail/inbox/id/AAQkAGMxYmRlMmZkLTgwNGUtNGFkZi1lMGQ4LTI2ZDJkOTc0MTAxYwAQADeIKSmSgzhKlJjvXeu2M... 1/2



- The Principal Investigator will obtain any additional approvals or authorisations as required (e.g. from other ethics committees, collaborating institutions, supporting organisations).

- The Principal Investigator will notify the UTS HREC of his or her inability to continue as Principal Investigator including the name of and contact information for a replacement.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

A/Prof Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research Office
University of Technology Sydney
E: Research.Ethics@uts.edu.au

REF: E38

Appendix 2. Consent form

Transforming Errors into Learning Opportunities in Simulation-Based Learning (SBL)

I ______________________ agree to participate in the research project *Transforming Errors into Learning Opportunities in Simulation-Based Learning (SBL),* UTS HREC approval number ETH19-3425 approval reference number being conducted by Evelyn Palominos (evelyn.m.palominosletelier@student.uts.edu.au; +61 [redacted]). I understand that funding for this research has been provided by *the Faculty of Health, University of Technology Sydney.* I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney.

I understand that I will be given a signed copy of this document to keep.

I agree to be audio and video recorded and other multimodal data (e.g. student location, verbal participation) be captured.

I agree that the research data gathered from this project may be published in a form that does not identify me in any way.

I am aware that I can contact Evelyn Palominos by email (evelyn.m.palominosletelier@student.uts.edu.au; or by phone +61 [redacted]) if I have any concerns about the research.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher or delegate] Date

____ ____/____/____

Name and Signature [witness*] Date

*** Witness to the consent process**

If the participant, or if their legally acceptable representative, is not able to read this document, this form must be witnessed by an independent person over the age of 18. In the event that an interpreter is used, the interpreter may not act as a witness to the consent process. By signing the consent form, the witness attests that the information in the consent form and any other written information was accurately explained to, and apparently understood by, the participant (or representative) and that informed consent was freely given by the participant (or representative).

Appendix 3. Participant information sheet

Transforming Errors into Learning Opportunities in Simulation-Based Learning (SBL)

WHO IS DOING THE RESEARCH?

My name is Evelyn Palominos and I am a PhD (doctoral) candidate. My supervisors are Professor Tracy Levett-Jones, Dr Tamara Power and Dr Roberto Martinez-Maldonado.

WHAT IS THIS RESEARCH ABOUT?

The provision of safe environment in clinical simulation where students are free to make and learn from errors is frequently espoused in simulation literature. However, there is limited understanding of the impact of these particular learning experiences on learning and on learners.

FUNDING

No funding has been obtained for this study.

WHY HAVE I BEEN ASKED?

You have been invited to participate in this study because you are a second-year nursing student, suitable to practice in the Faculty of Health simulation laboratories.

IF I SAY YES, WHAT WILL IT INVOLVE?

If you decide to participate, during your usual simulation class we will ask you to:

- complete a demographic survey and a pre-simulation knowledge test that takes approximately 10 minutes;
- perform a simulation scenario plus a debriefing activity that takes approximately 30 minutes to complete;
- answer a 15-minutes post-simulation knowledge test;
- complete a 5-minutes satisfaction survey; and participate in a 15 minutes face-to-face interview.

*Please note even if you do not want to participate in the research activities, the pre-brief, simulation and debrief are still a part of your normal class activities.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some inconveniences. You might experience emotional distress as you will perform a challenging simulation scenario and therefore make errors. However, you are familiar with the simulation process and are exposed to challenging simulation activities in an environment of trust and respect.

DO I HAVE TO SAY YES?

Participation in this study is voluntary. It is completely up to you whether or not you decide to take part.
Participation or non-participation will not adversely affect your course progression or assessments.

WHAT WILL HAPPEN IF I SAY NO?

If you decide not to participate, it will not affect your relationship with the researchers or the University of Technology Sydney.

If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason, by contacting Evelyn Palominos (evelyn.m.palominosletelier@student.uts.edu.au) or Tracy Levett-Jones (tracy.levett-jones@uts.edu.au)

If you withdraw from the study, your records will be erased and the transcripts will be destroyed. However, it may not be possible to withdraw your data from the study results if these have already had your identifying details removed.

CONFIDENTIALITY

By signing the consent form, you consent to the research team collecting and using personal information about you for the research project. All this information will be treated confidentially. Your personal information will be re-identified (removing participant's name) and replaced by an ID number. Data will be stored on personal password-protected laptops and backed up in an external hard drive.

Your information will only be used for the purpose of this research project and the re-identified information will only be disclosed with your permission. We plan to publish the results of this research in journal articles, conference presentations and doctoral dissertation. In any publication, information will be provided in such a way that you cannot be identified.

WHAT IF I HAVE CONCERNS OR A COMPLAINT?

If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact me by email (evelyn.m.palominosletelier@student.uts.edu.au) or by phone (+61 [redacted]) or my principal supervisor (tracy.levett-jones@uts.edu.au).

You will be given a copy of this form to keep.

NOTE:

This study has been approved by the University of Technology Sydney Human Research Ethics Committee [UTS HREC]. If you have any concerns or complaints about any aspect of the conduct of this research, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au] and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

Appendix 4. Literature search outcomes

Database or Search Engine	Main concepts	# of Results	#downloaded	#duplicates	#records excluded	#records accepted for screening	#records excluded	#records included
MEDLINE	Nursing students, medical students, health professionals, error*, mistake*, simulation.	274	274	0	254	20	17	3
CINHAL-PsycINFO	Nursing students, medical students, health occupations students, nursing graduate, medical graduate, nursing, baccalaureate errors, mistakes, simulation, patient simulation.	152	152	3	137	12	12	0
PROQUEST	Nursing students, medical students, health care professionals, health professionals, mistake*, error*, simulation, clinical simulation, making mistakes	1004	975	1	950	24	22	2
SCOPUS	Nursing students, medical students, health occupations students, trainees, errors, mistakes,	926	916	2	908	16	15	1

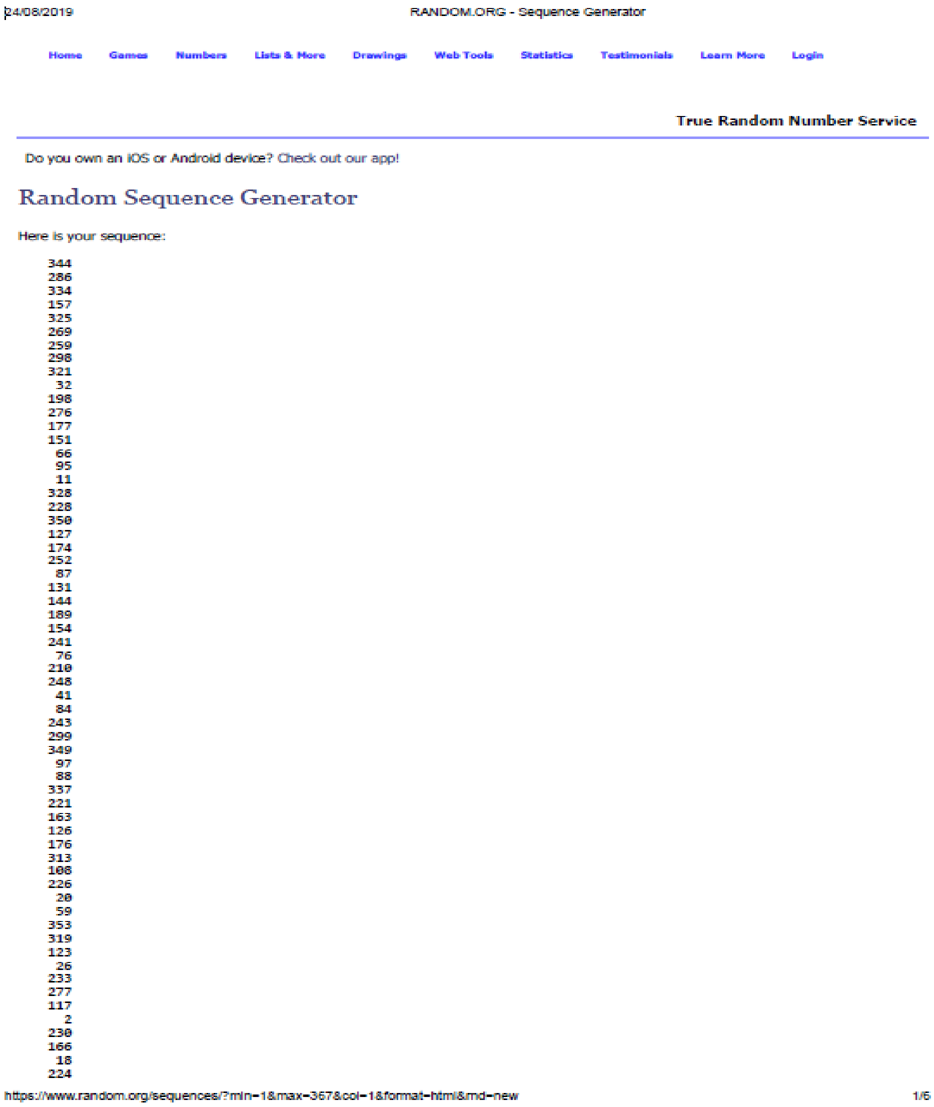
	clinical simulation, patient simulation.						
Google Scholar	Errors, simulation, healthcare.						1
Other sources (ref. list included articles)							4
Total		2317	6	2249	72	61	**11**

Appendix 5. Critical Appraisal Skills Programme checklist (Chapter 2)

Criteria	Bond et al. (2004)	Botezatu et al. (2010)	Reime et al. (2016)	Young et al. (2016)	Elshami et al. (2017)	Helyar et al. (2013)	Harder (2012)	Bussard (2015)	Song et al. (2015)	Hughes et al. (2014)	Sullivan et al. (2016)
Clear statement of the research aims	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Qualitative methodology is appropriated	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Research design is appropriated	Y	Y	CT	Y	Y	Y	Y	Y	Y	Y	Y
Recruitment strategy is appropriated	Y	Y	Y	Y	Y	Y	Y	Y	Y	CT	Y
Congruity between data collection research issues	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Relationship between researcher and participants is addressed	CT	Y	CT	Y	CT	Y	Y	Y	Y	Y	Y
Ethical issues are addressed	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N
Rigour in data analysis	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	CT
Clear statement of findings	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Value of the research	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Score	9	10	8	10	9	10	10	10	9	8	7

Y: yes; N: not; CT: cannot tell

Appendix 6. The randomisation of study participants



24/08/2019 RANDOM.ORG - Sequence Generator

Do you own an iOS or Android device? Check out our app!

Random Sequence Generator

Here is your sequence:

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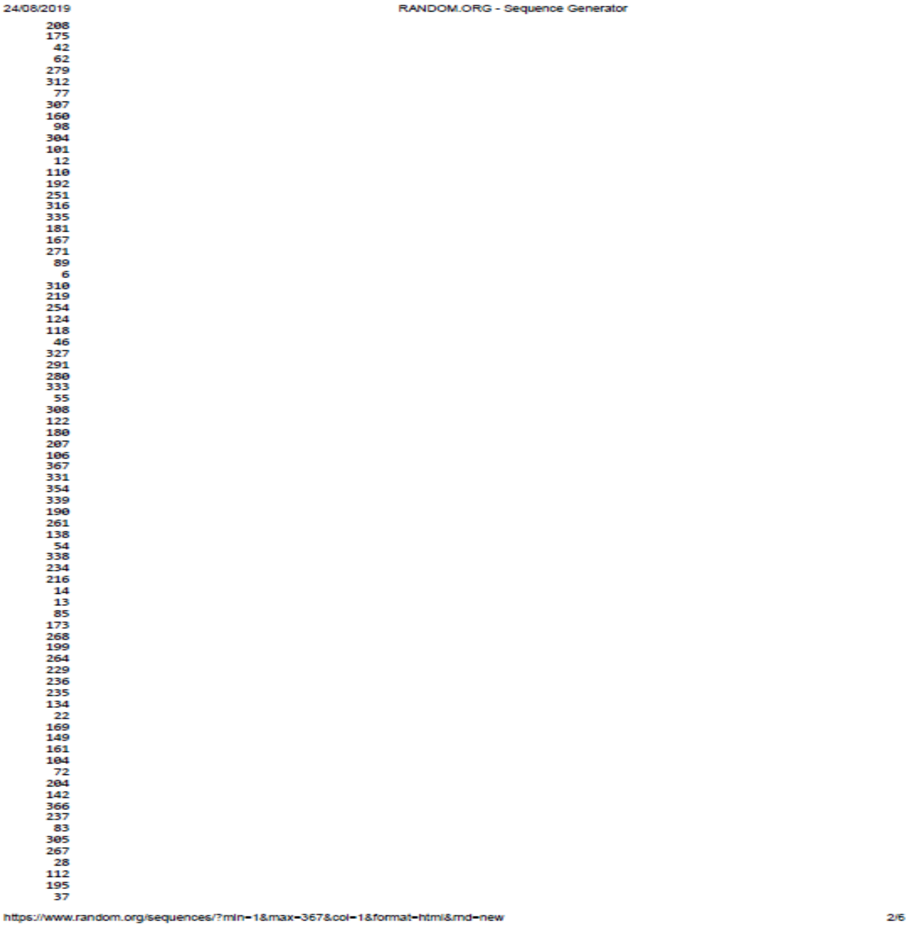

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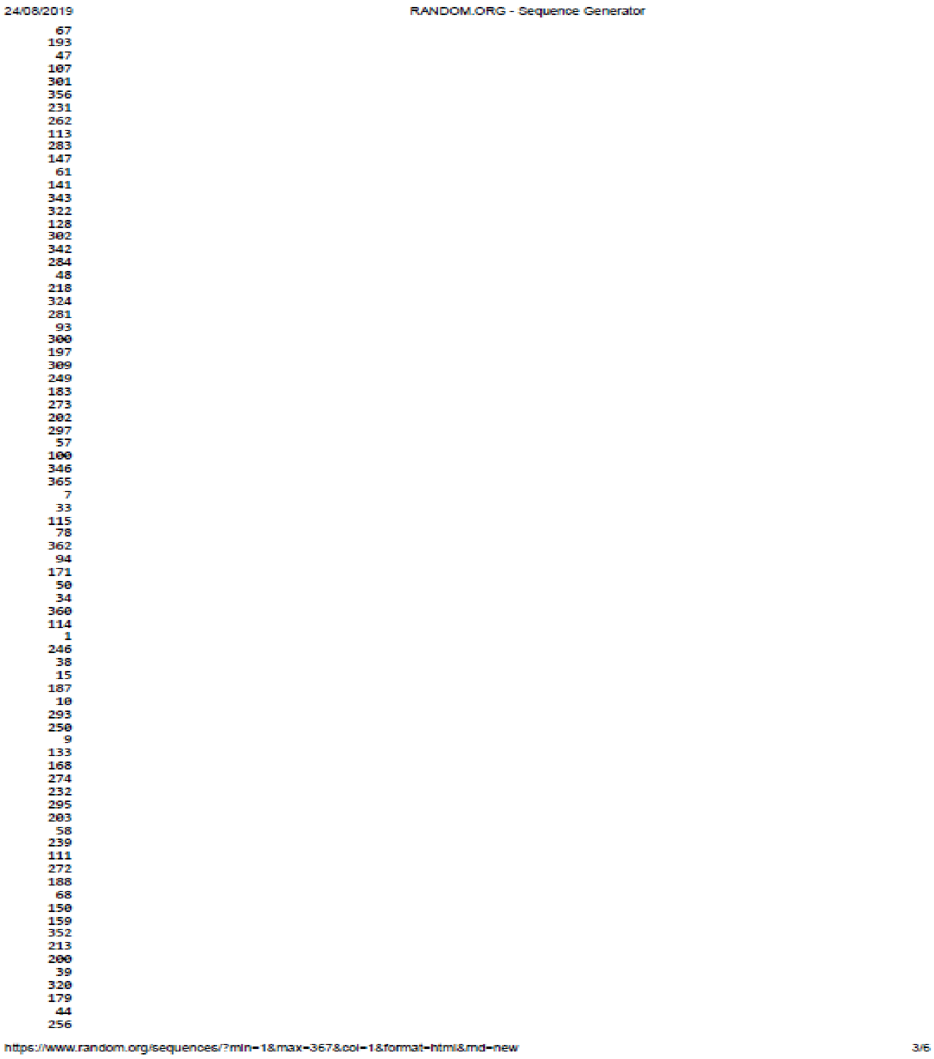

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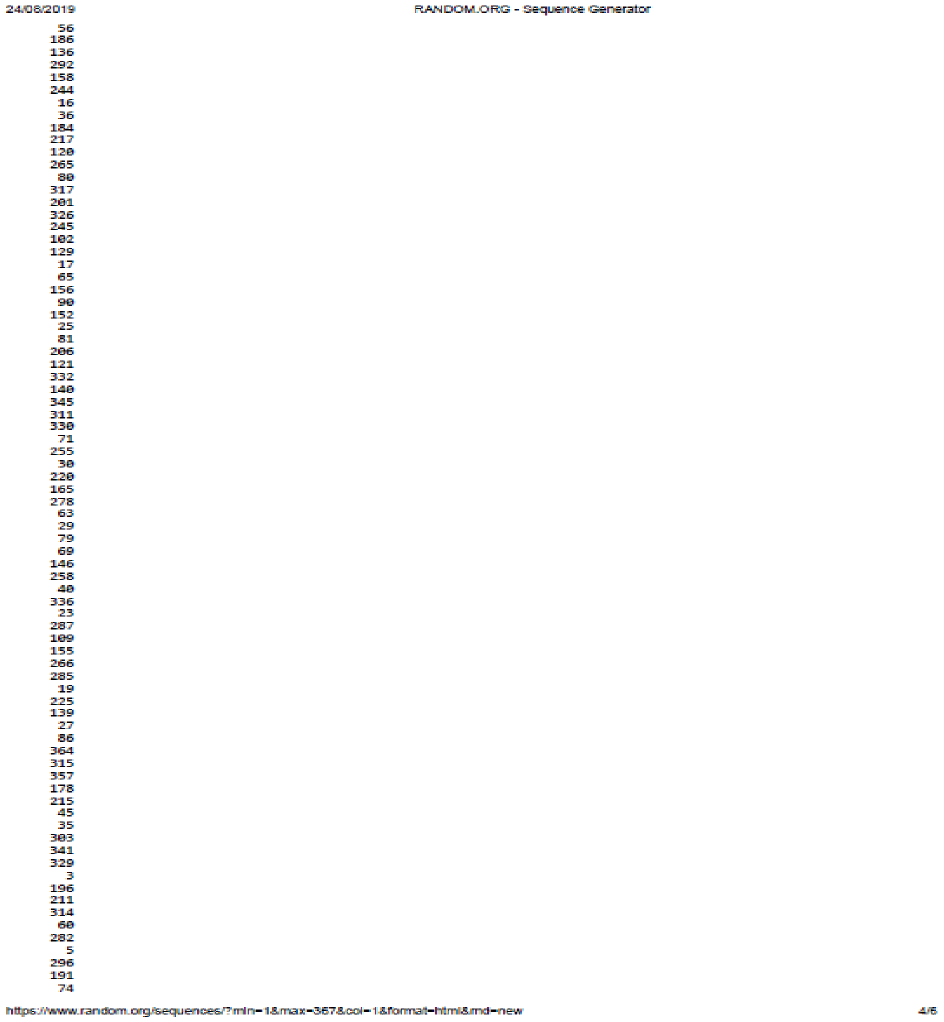

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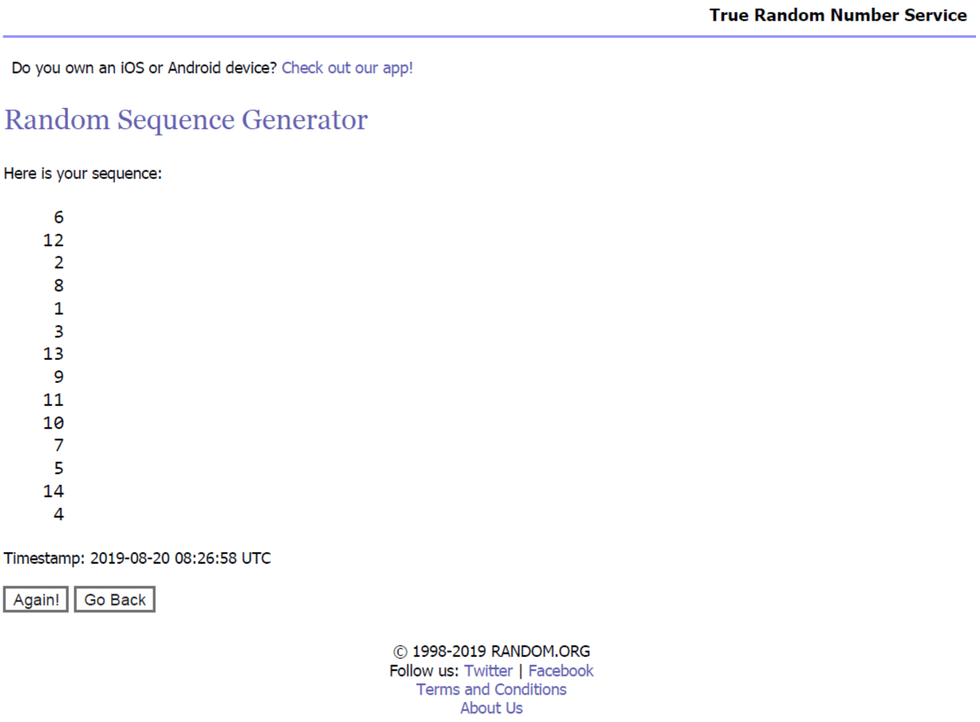
Appendix 7. The randomisation of study groups



True Random Number Service

Do you own an iOS or Android device? Check out our app!

Random Sequence Generator

Here is your sequence:

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Timestamp: 2019-08-20 08:26:58 UTC

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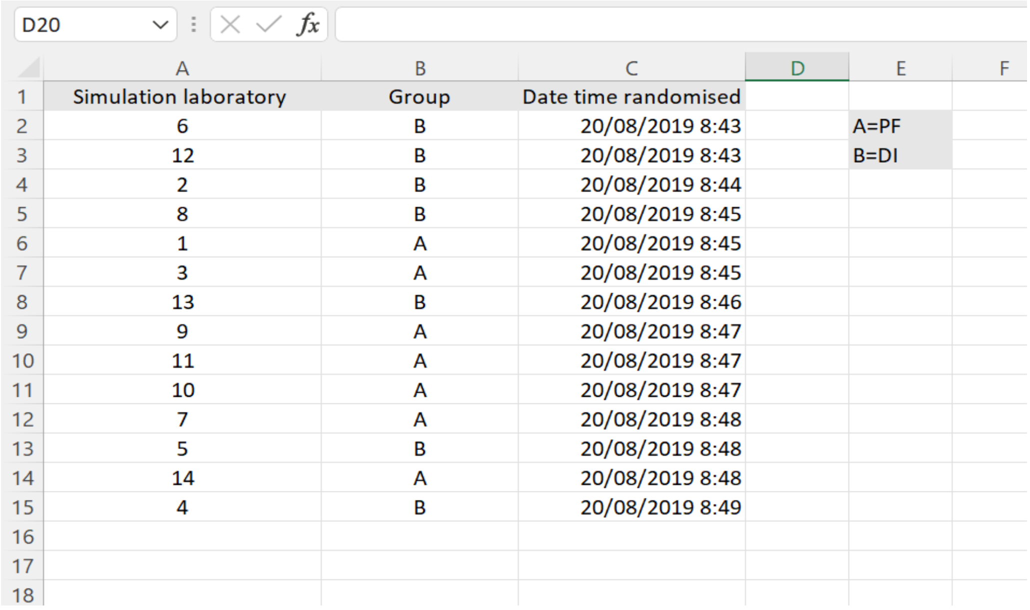


Simulation laboratory	Group	Date time randomised		
6	B	20/08/2019 8:43		A=PF
12	B	20/08/2019 8:43		B=DI
2	B	20/08/2019 8:44		
8	B	20/08/2019 8:45		
1	A	20/08/2019 8:45		
3	A	20/08/2019 8:45		
13	B	20/08/2019 8:46		
9	A	20/08/2019 8:47		
11	A	20/08/2019 8:47		
10	A	20/08/2019 8:47		
7	A	20/08/2019 8:48		
5	B	20/08/2019 8:48		
14	A	20/08/2019 8:48		
4	B	20/08/2019 8:49		

Appendix 8. Subject matter expert content and face validity of pre-and-post simulation knowledge test

The following questions will potentially be part of the pre-and-post simulation knowledge tests that nursing students have to complete as part of the study intervention.

These questions were informed with reference to the following resources:

Alcorn, N. 2019, UTS online: FCN lectures viewed 2 June 2019, <https://online.uts.edu.au/>.

Health, NSW, 2016, 'Basic Clinical Practice Guidelines for the acute treatment of infants and children with head injury', viewed 10 June 2019, <https://www1.health.nsw.gov.au/pds/ActivePDSDocuments/PD2011_024.pdf>.

Hoffman, K., Haining, N. & Wilson, A. 2017, 'Caring for a person with an acquired brain injury ', in T. Levett-Jones (ed.), Clinical reasoning: Learning to think like a nurse, Pearson Australia.

1. When classify a closed or open head injury in a child what is the main difference? (2 points)

2. The rigid cranial cavity contains **three structures**. They include:

- __________________ (80%)

- __________________ (10%)

- __________________ (10%)   (3 points)

3. **Monroe-Kellie hypothesis** states that if the volume of any of the structures described in Question 2 increases, the volume of the others must _________________ to maintain equilibrium (1 point)

4. Which **clinical manifestations** of increased intracranial pressure from the following list can be present in a **6–month-old baby**

5. List **two clinical manifestations** of increased intracranial pressure (or neurological deterioration) in a **7–year-old patient (what do you expect to see)**

6. List two altered vital signs that you may expect to find in a patient with raised intracranial pressure:

7. Alex is a six-year-old boy presented into Emergency Department. He suffered a mild head injury after a bike crash, with loss of consciousness of less than 2 minutes. Mention **two nursing interventions** to help maintain Alex's intracranial pressure within normal ranges and **explain the rationale for these interventions** (2 points).

8. Alex's current axillary temperature is 37.6°C. Alex's mother asks you the possibility to use more blankets to maintain Alex warm. How would you respond to the mother and why? (2 points)

9. **What scale** would you use to complete a neurological assessment on a 2-year-old child and **why**? (2 points)

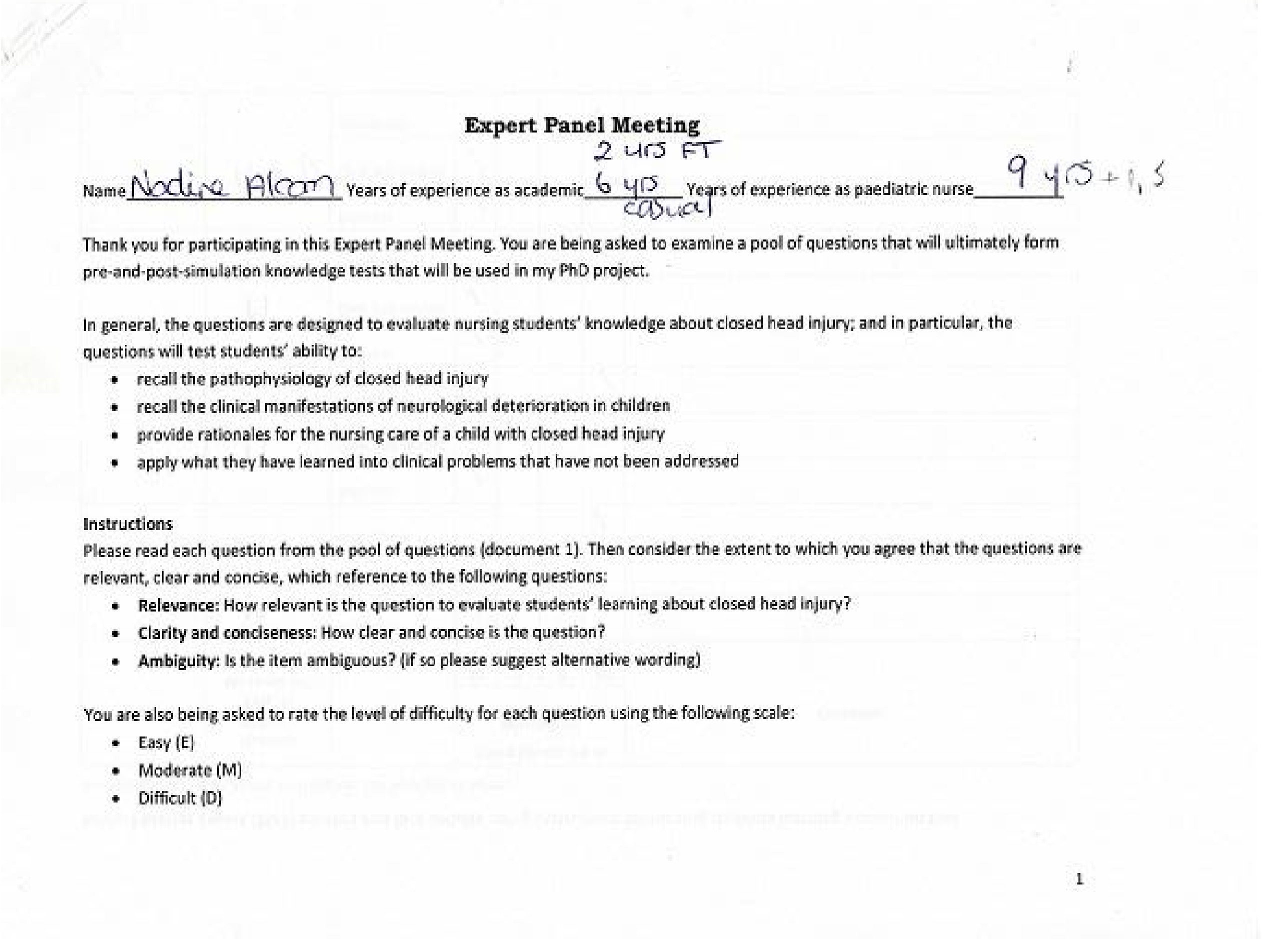
10. Amelia, an 8-year-old girl who fell off a horse and suffered a laceration in the left front head. She is presented into Emergency Department. Neurological examination reveals Glasgow Coma Scale (GCS) of 13. She refers an abnormal sensation ('pins and needles') in her toes. This is an indication for immediate cervical spine immobilisation. List **two nursing interventions** to maintain immobilisation of Amelia's c-spine and **explain the rationale for these interventions**. (3 points)

The above 10 questions will be included in the pre and post simulation quiz. The following questions (11 and 12) will be only included in the post-simulation quiz

11. Olivia is a two-year old girl who suffered a mild head injury due to a fall from the top of a bunk bed. Careful clinical examination reveals no serious intracranial injury. Before being discharged, what **nursing recommendations** would you give to parents for the care of Olivia at home? (3 points)

12. Peter, is a 16-year-old adolescent who fell on the ice while skating without using a helmet. He stayed lying on the ice for a few seconds before standing up. He is reporting a persistent headache. In the Emergency Department, Peter has had two episodes of vomiting. The registrar has ordered ondansetron 0.15 mg/kg IV and the insertion of a nasogastric tube to aspirate the stomach contents. **When inserting the nasogastric tube, what would you be most concerned about and why?** (2 points)

Answers from subject matter experts



Expert Panel Meeting

Name Nadine Alcorn Years of experience as academic 2 yrs FT 6 yrs casual Years of experience as paediatric nurse 9 yrs + 1,5

Thank you for participating in this Expert Panel Meeting. You are being asked to examine a pool of questions that will ultimately form pre-and-post-simulation knowledge tests that will be used in my PhD project.

In general, the questions are designed to evaluate nursing students' knowledge about closed head injury; and in particular, the questions will test students' ability to:

- recall the pathophysiology of closed head injury
- recall the clinical manifestations of neurological deterioration in children
- provide rationales for the nursing care of a child with closed head injury
- apply what they have learned into clinical problems that have not been addressed

Instructions

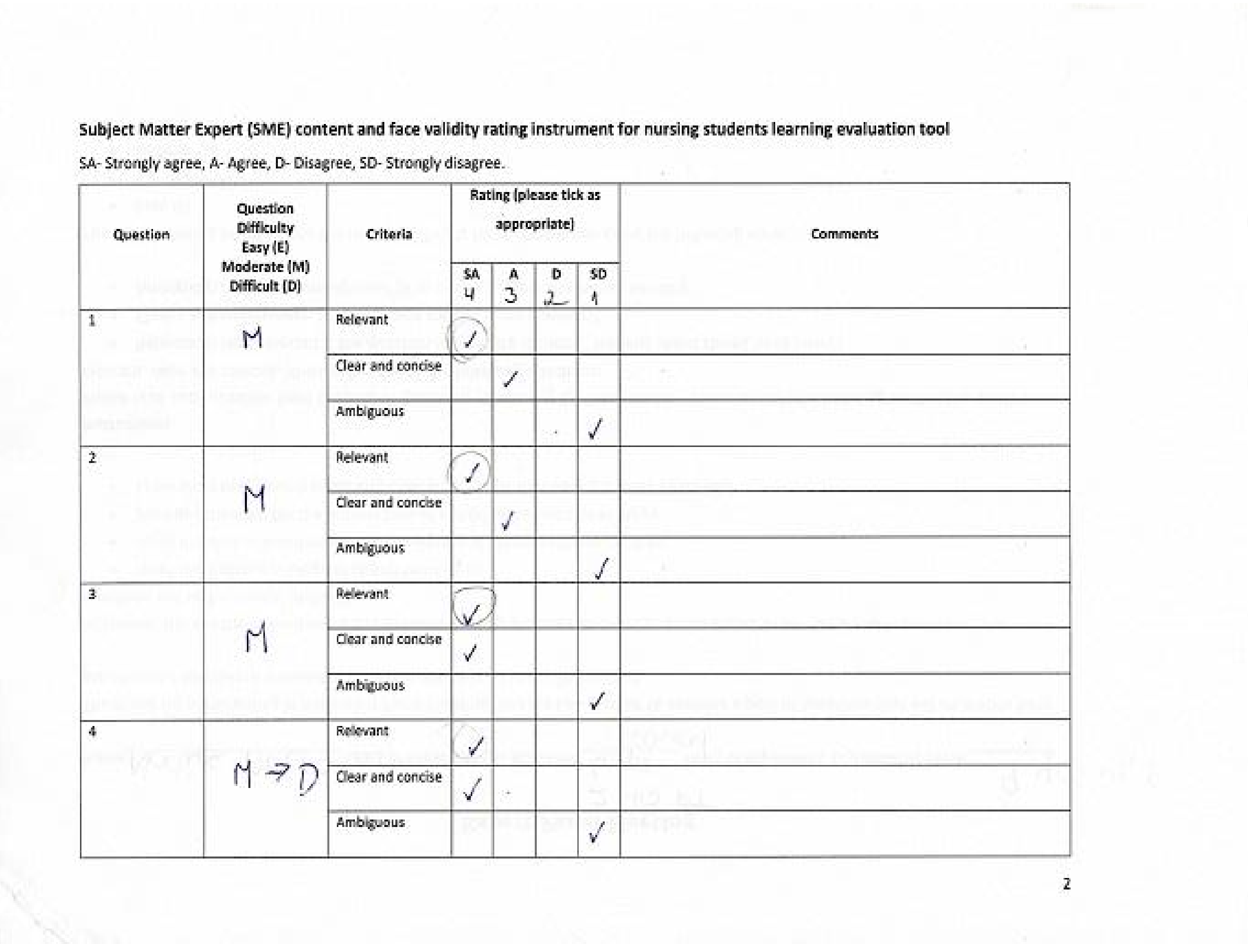
Please read each question from the pool of questions (document 1). Then consider the extent to which you agree that the questions are relevant, clear and concise, which reference to the following questions:

- **Relevance:** How relevant is the question to evaluate students' learning about closed head injury?
- **Clarity and conciseness:** How clear and concise is the question?
- **Ambiguity:** Is the item ambiguous? (if so please suggest alternative wording)

You are also being asked to rate the level of difficulty for each question using the following scale:

- Easy (E)
- Moderate (M)
- Difficult (D)

1



Subject Matter Expert (SME) content and face validity rating instrument for nursing students learning evaluation tool

SA- Strongly agree, A- Agree, D- Disagree, SD- Strongly disagree.

Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA 4	A 3	D 2	SD 1	
1	M	Relevant	✓				
		Clear and concise		✓			
		Ambiguous				✓	
2	M	Relevant	✓				
		Clear and concise		✓			
		Ambiguous				✓	
3	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
4	M → D	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	

Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
5 M→D		Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
6	E	Relevant	✓				Students may want to change answers to 4 + 5.
		Clear and concise	✓				
		Ambiguous			✓		
7	D	Relevant		✓			
		Clear and concise			✓		
		Ambiguous		✓			
8	M→D	Relevant	✓				
		Clear and concise		✓			
		Ambiguous		✓			

Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
9	M	Relevant		✓			
		Clear and concise		✓			
		Ambiguous			✓		
10	M	Relevant	✓				
		Clear and concise		✓			
		Ambiguous			✓		
11	E→M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
12	M→D	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	

a) With regards to the ability of the questions to assess nursing students' knowledge of paediatric closed head injury, do you believe that overall the instrument is (please click on one alternative):

1. Extremely suitable
[✓ 2. Suitable]
3. Adequate
4. Inadequate for evaluating nursing students' knowledge of paediatric closed head injury

b) Is there any unnecessary repetition of questions? If so which ones?

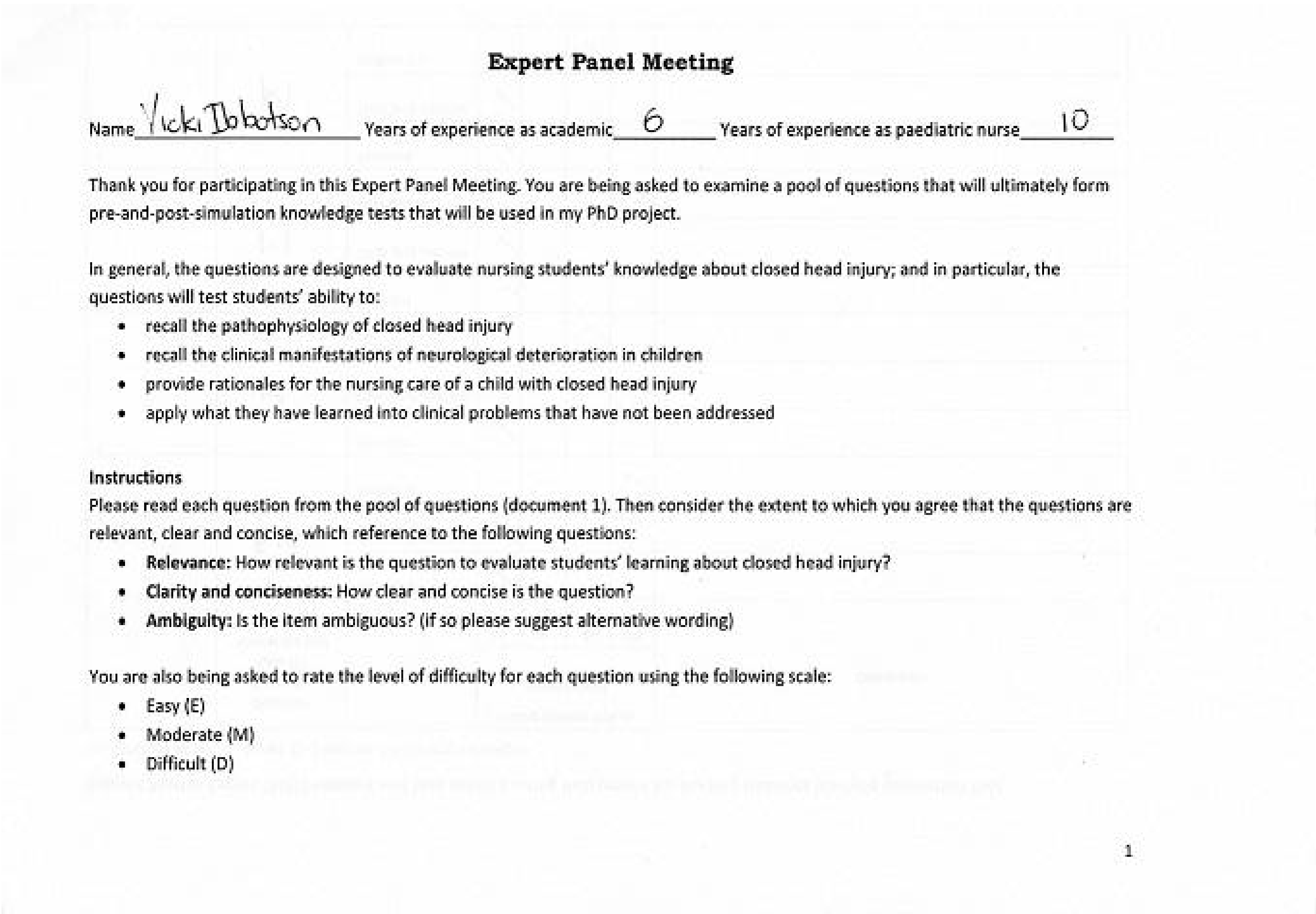
✓ Potential for Qu 6 to give students the answers to 4+5.

c) Are there any knowledge questions that should have been included but appear to have been omitted?

? Age appropriate responses
- GCS
- Pain

d) Any other comments?

✓ More context to the scenarios would help → in ED



Expert Panel Meeting

Name Vicki Ibbotson Years of experience as academic 6 Years of experience as paediatric nurse 10

Thank you for participating in this Expert Panel Meeting. You are being asked to examine a pool of questions that will ultimately form pre-and-post-simulation knowledge tests that will be used in my PhD project.

In general, the questions are designed to evaluate nursing students' knowledge about closed head injury; and in particular, the questions will test students' ability to:

- recall the pathophysiology of closed head injury
- recall the clinical manifestations of neurological deterioration in children
- provide rationales for the nursing care of a child with closed head injury
- apply what they have learned into clinical problems that have not been addressed

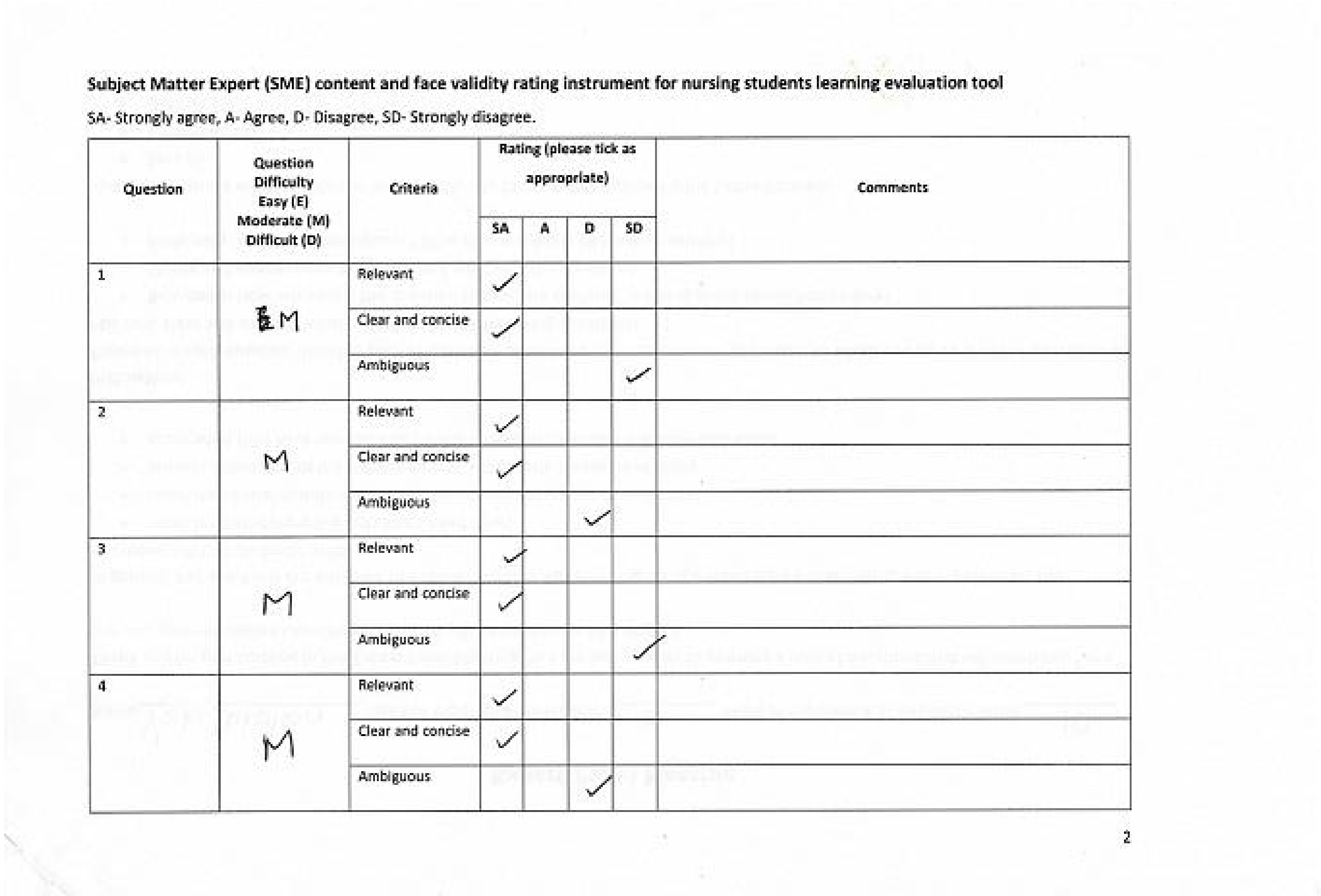
Instructions

Please read each question from the pool of questions (document 1). Then consider the extent to which you agree that the questions are relevant, clear and concise, which reference to the following questions:

- **Relevance:** How relevant is the question to evaluate students' learning about closed head injury?
- **Clarity and conciseness:** How clear and concise is the question?
- **Ambiguity:** Is the item ambiguous? (if so please suggest alternative wording)

You are also being asked to rate the level of difficulty for each question using the following scale:

- Easy (E)
- Moderate (M)
- Difficult (D)

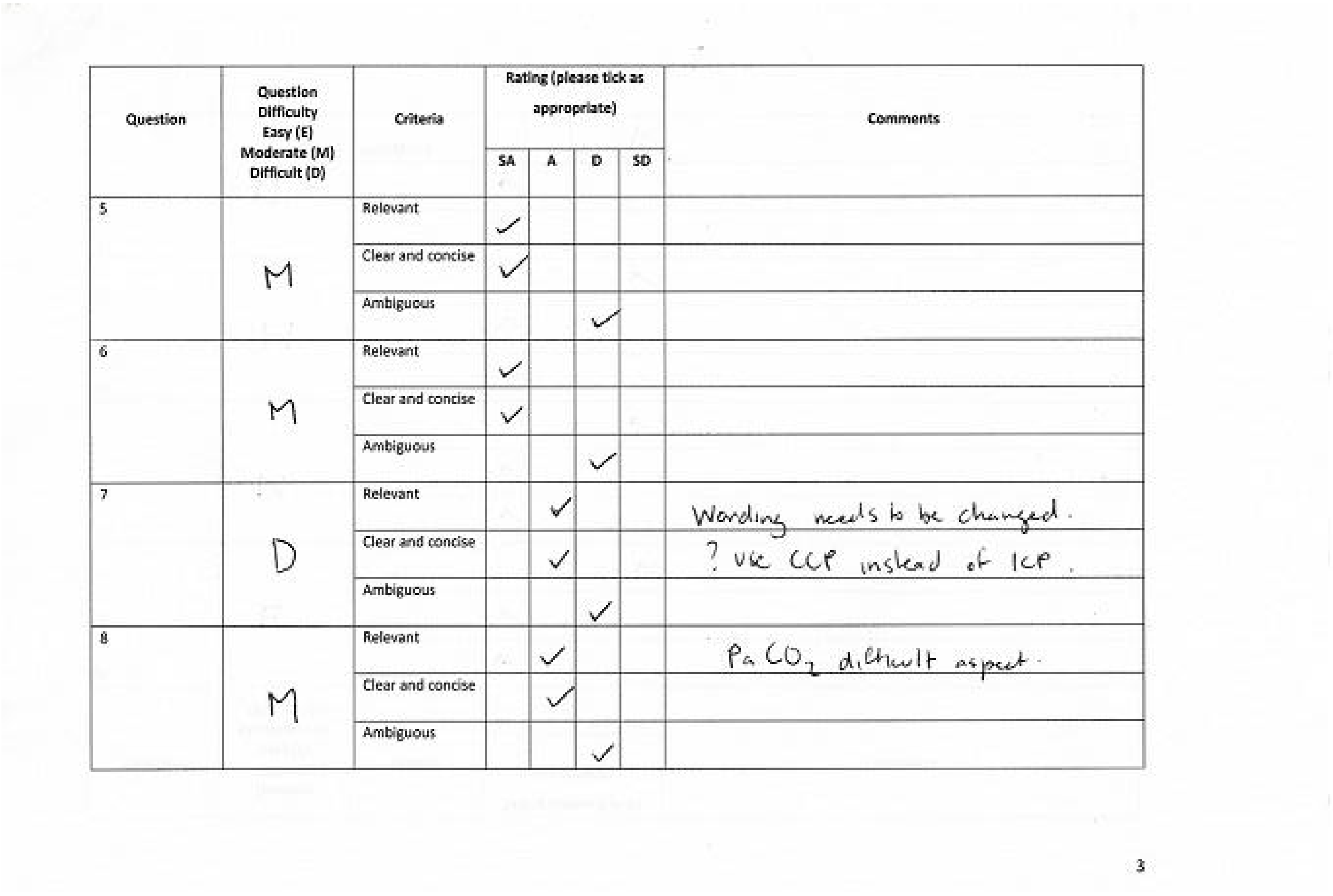


Subject Matter Expert (SME) content and face validity rating instrument for nursing students learning evaluation tool

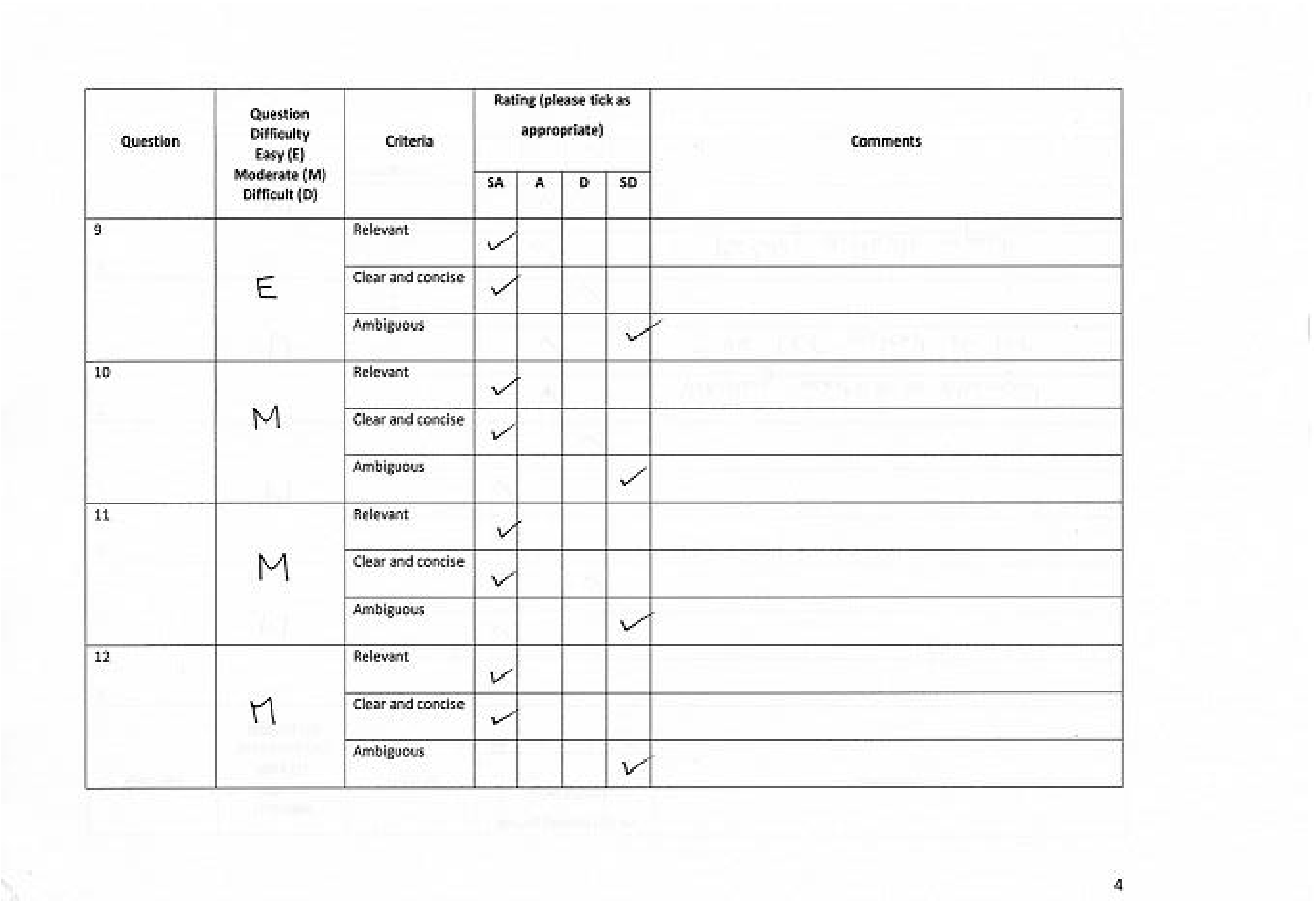
SA- Strongly agree, A- Agree, D- Disagree, SD- Strongly disagree.

Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
1	~~E~~ M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
2	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		
3	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
4	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		

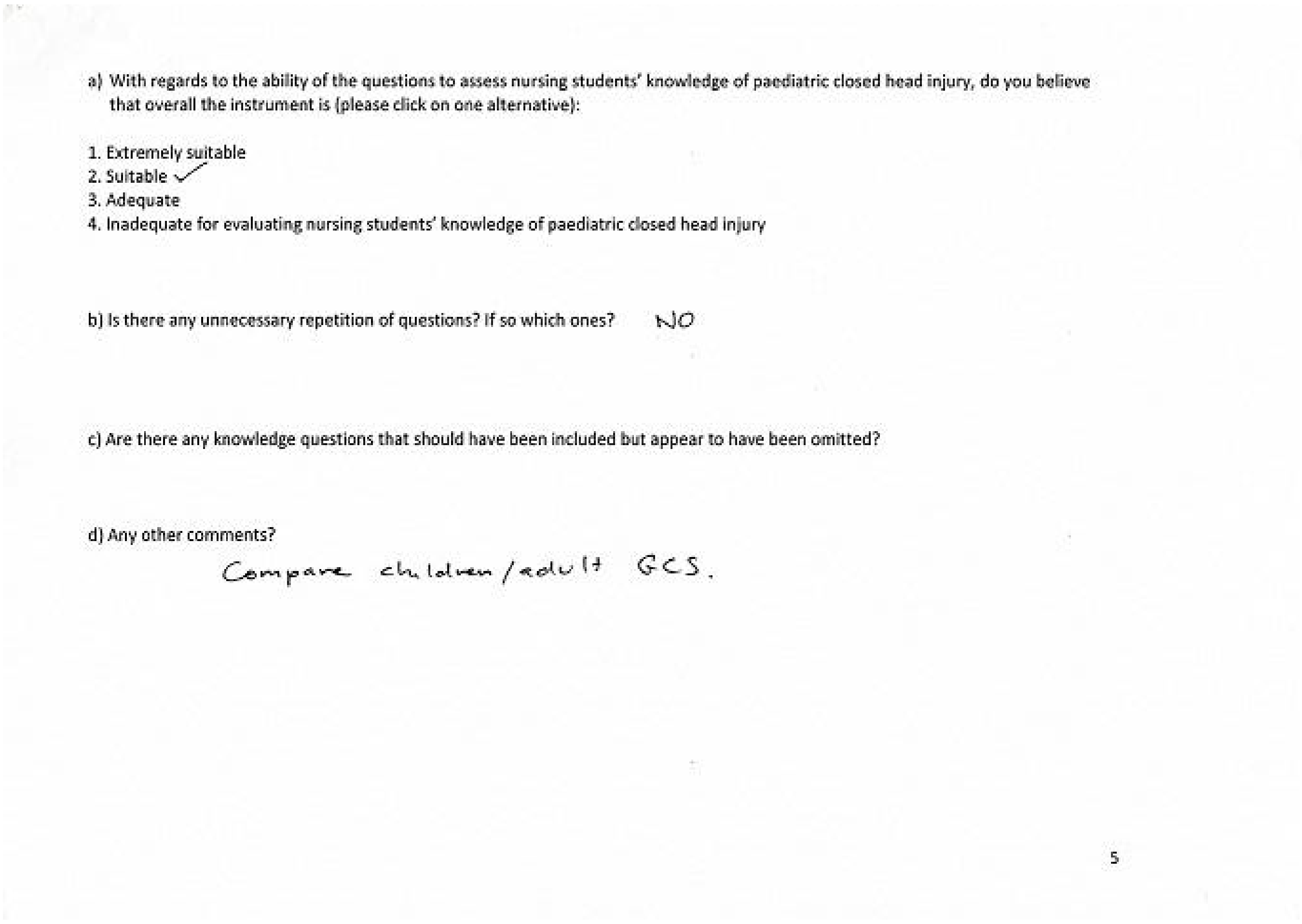
2



Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
5	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		
6	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		
7	D	Relevant		✓			Wording needs to be changed.
		Clear and concise		✓			? use CCP instead of ICP.
		Ambiguous			✓		
8	M	Relevant		✓			Pa CO_2 difficult aspect.
		Clear and concise		✓			
		Ambiguous			✓		



Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
9	E	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
10	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
11	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
12	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	



a) With regards to the ability of the questions to assess nursing students' knowledge of paediatric closed head injury, do you believe that overall the instrument is (please click on one alternative):

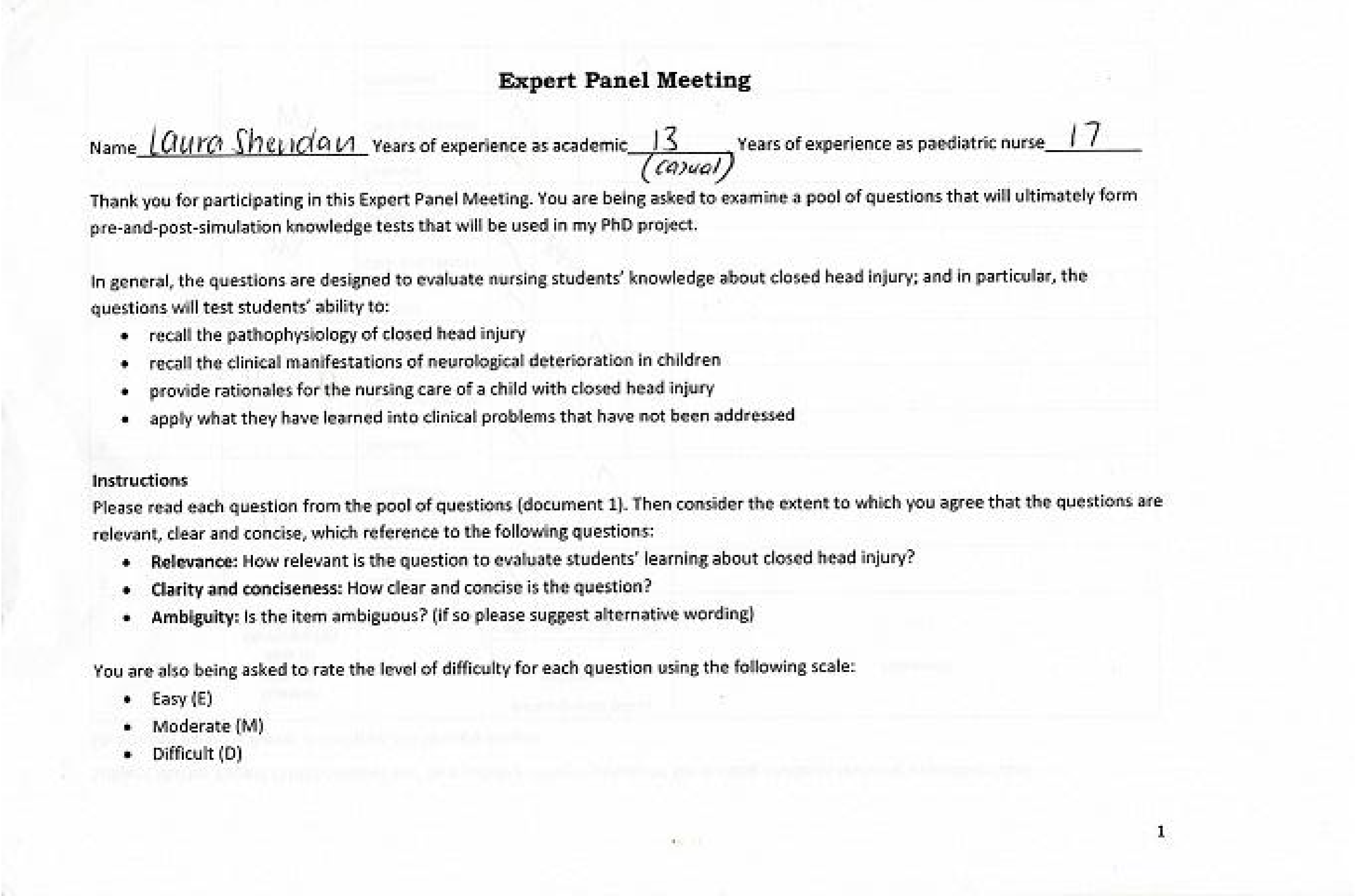
1. Extremely suitable
2. Suitable ✓
3. Adequate
4. Inadequate for evaluating nursing students' knowledge of paediatric closed head injury

b) Is there any unnecessary repetition of questions? If so which ones? NO

c) Are there any knowledge questions that should have been included but appear to have been omitted?

d) Any other comments?

Compare children/adult GCS.



Expert Panel Meeting

Name Laura Sheridan Years of experience as academic 13 (casual) Years of experience as paediatric nurse 17

Thank you for participating in this Expert Panel Meeting. You are being asked to examine a pool of questions that will ultimately form pre-and-post-simulation knowledge tests that will be used in my PhD project.

In general, the questions are designed to evaluate nursing students' knowledge about closed head injury; and in particular, the questions will test students' ability to:

- recall the pathophysiology of closed head injury
- recall the clinical manifestations of neurological deterioration in children
- provide rationales for the nursing care of a child with closed head injury
- apply what they have learned into clinical problems that have not been addressed

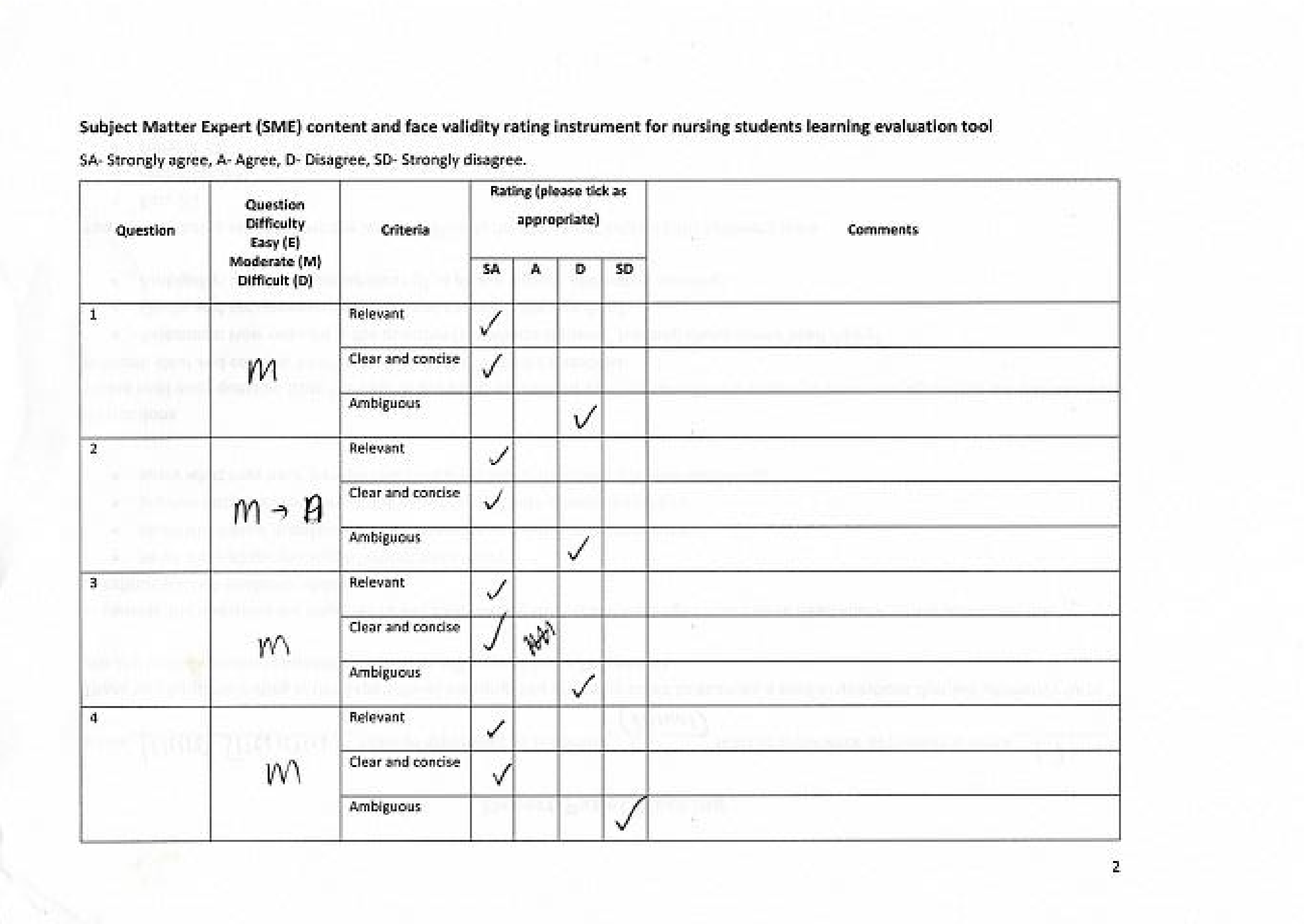
Instructions

Please read each question from the pool of questions (document 1). Then consider the extent to which you agree that the questions are relevant, clear and concise, which reference to the following questions:

- **Relevance:** How relevant is the question to evaluate students' learning about closed head injury?
- **Clarity and conciseness:** How clear and concise is the question?
- **Ambiguity:** Is the item ambiguous? (if so please suggest alternative wording)

You are also being asked to rate the level of difficulty for each question using the following scale:

- Easy (E)
- Moderate (M)
- Difficult (D)

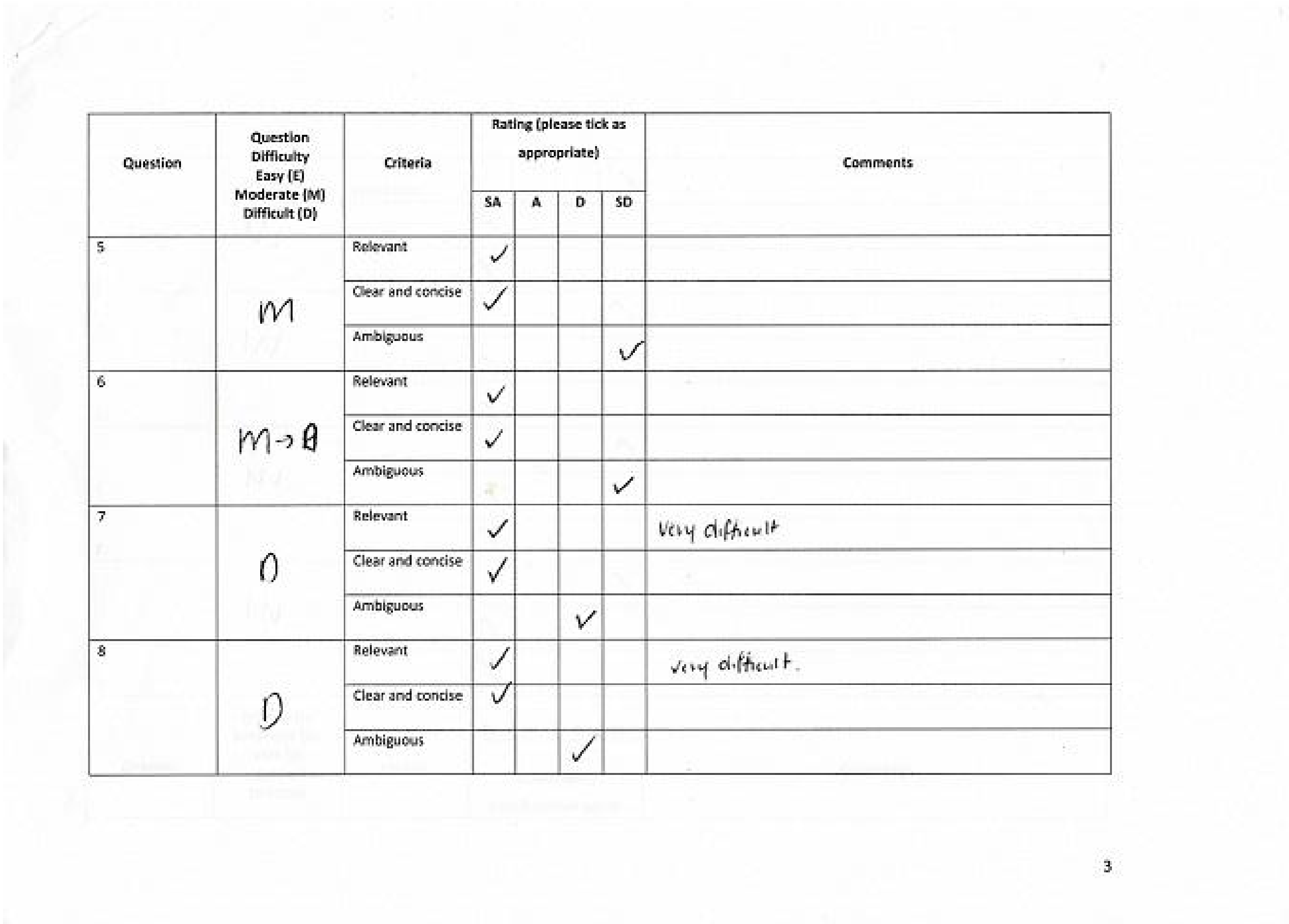


Subject Matter Expert (SME) content and face validity rating instrument for nursing students learning evaluation tool

SA- Strongly agree, A- Agree, D- Disagree, SD- Strongly disagree.

Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
1	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		
2	M → D	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		
3	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous			✓		
4	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	

2



Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
5	M	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
6	M->D	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
7	D	Relevant	✓				Very difficult
		Clear and concise	✓				
		Ambiguous			✓		
8	D	Relevant	✓				very difficult.
		Clear and concise	✓				
		Ambiguous			✓		

Question	Question Difficulty Easy (E) Moderate (M) Difficult (D)	Criteria	Rating (please tick as appropriate)				Comments
			SA	A	D	SD	
9	m	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
10	m	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
11	m	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	
12	m.	Relevant	✓				
		Clear and concise	✓				
		Ambiguous				✓	

a) With regards to the ability of the questions to assess nursing students' knowledge of paediatric closed head injury, do you believe that overall the instrument is (please click on one alternative):

[✓ 1. Extremely suitable]
2. Suitable
3. Adequate
4. Inadequate for evaluating nursing students' knowledge of paediatric closed head injury

I think the questions are challenging overall, but should get the students thinking and drawing on their knowledge from their adult nursing subjects.

b) Is there any unnecessary repetition of questions? If so which ones?

No.

c) Are there any knowledge questions that should have been included but appear to have been omitted?

Modified GCS for paed patients. Getting students to identify strategies/techniques on how they would complete a neurological assessment on a young patient.

d) Any other comments?

Appendix. 9 Demographic survey

1. Please type in your participant number and colour e.g., Pink 001 *

2. What is your gender identity? (Please select): *

- ○ Female
- ○ Male
- ○ Trans male/Trans man
- ○ Trans female/trans woman
- ○ Indigenous Brotherboy
- ○ Indigenous Sistergirl
- ○ Non-binary/gender fluid
- ○ Different gender identity

3. My age is (Please select): *

- ○ 18-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ 55-64
- ○ 65+

4. My country of birth is: *

- ○ Australia
- ○ China
- ○ Nepal
- ○ New Zealand
- ○ Korea
- ○ Other - Write in (Required) _______________

5. Where did you complete your high school studies? *

- Australia
- China
- Nepal
- New Zealand
- Korea
- Other - Write in (Required) ________________________

6. What is the primary language that you speak at home? *

- English
- Spanish
- Mandarin
- Nepali
- Korean
- Indigenous Australian language
- Other - Write in (Required) ________________________

*

7. What types of simulation have you previously practised? (Select all that apply) *

- A simulation scenario using a manikin
- Role-play with other students
- Task training (for example, a plastic leg you have done a dressing on)

8. Approximately, how many times you have practised in-class simulation? *

- 1-3
- 4-6
- 7-9
- >10

9. Which of the following FCN lectures have you attended or listened to on UTSOnline? (Select all that apply) *

- FCN lecture: Growth and Development & Nursing Care Considerations
- FCN lecture: Physiological Differences when Caring for Children
- FCN lecture: Keeping Kids Safe - Child Health Priorities
- FCN lecture: Ethical and Legal considerations when caring for Children

Appendix 10. Pre-and post-simulation tests and related rubrics

1. What is the main difference in the classification of a closed and open head injury? (3 points)

Answer:

In open head injury, an object strikes a person's head breaking the skull and penetrating the person's brain. In closed head injury, there is also an impact between a person's head and an object, but the skull is not broken by the object.

Criteria	3	2	1	0
Use of clinical terms and explanation of how they are related	Use of more than two relevant clinical terms with an accurate and complete explanation of how these terms are related .	Use of more than two relevant clinical terms but the explanation of how these terms are related is inaccurate or incomplete	Use of one or two relevant clinical terms without explanation OR Use of one or two relevant clinical terms but the explanation of how these terms are related is incorrect	Incorrect idea or answer left blank, or full stop.
	Examples:	Examples:	Examples:	
	In open head injury, an object strikes a person's head breaking the skull and penetrating into the person's brain AND In closed head injury, there is also an impact between a person's	In open head injury, an object strikes a person's head breaking the skull and penetrating into the person's brain OR In closed head injury, there is also an impact	In open head injury, an object strikes a person's head OR In closed head injury, there is an impact between a person's head and an object.	

head and an object but the skull is not broken by the object.	between a person's head and an object but the skull is not broken by the object.

2. **The rigid cranial cavity contains three elements. What are these three elements? (3 points)**

Answer:

- Brain (80%)
- Blood (10%)
- Cerebrospinal fluid (CSF) (10%)

3	2	1	0
Brain 80% CSF (10%) Blood (10%) OR Brain (80%) Blood (10%) CSF (10%)	Brain (80%), CSF (10%) OR Brain (80%), blood (10%) OR Blood (10%), CSF (10%)	Brain (80%) OR CFS (10%) OR Blood (10%)	Answer left blank, or question mark, or full stop or I do not know, unsure.

1. **The Monroe-Kellie hypothesis states that if the volume of any of the elements described in Question 11 increases, the volume of the others must __________________ to maintain equilibrium (1 point)**

Answer: decrease, fall

2. **Which clinical manifestations of increased intracranial pressure from the following list can be present in a 6-month-old baby (what you expect to see). Select all that apply (2 points)**

Answer:

○ **Bulging fontanelle**

- ○ Headache
- ○ **Raising head circumference**
- ○ Blurred vision

2	1	0
Bulging fontanelle AND Raising head circumference.	Bulging fontanelle OR Raising head circumference.	Answer left blank, or question mark or full stop or I do not know or unsure, or Headache, or blurred vision or three answers or all four answers.

3. **Which clinical manifestations of increased intracranial pressure from the following list can be present in a 7-year-old patient. Select all that apply (2 points)**

Answer:

- ○ High-pitched cry
- ○ **Blurred vision**
- ○ Bulging fontanelle
- ○ **Nausea**

2	1	0
Blurred vision AND Nausea.	Blurred vision OR Nausea.	Answer left blank or question mark or full stop, or I do not know, or unsure or bulging fontanelle or High-pitched cry or three answers or all four answers.

6. List two altered vital signs that you may expect to find in a patient with raised intracranial pressure: (2 points)

Answer:

Low HR (low pulse, bradycardia), Hypertension (high BP), irregular breathing

2	1	0
Hypertension, High blood pressure AND Low pulse, bradycardia, low HR OR Hypertension, High blood pressure AND Irregular breathing OR Low pulse, bradycardia, low HR AND irregular breathing.	Hypertension, High blood pressure OR Low pulse, bradycardia, low HR OR Irregular breathing.	I do not know, or unsure, or GCS.

7. Alex is a six-year-old boy who presented to the Emergency Department. He suffered a mild head injury after a pushbike accident, with loss of consciousness of less than 2 minutes. Write down two nursing interventions to help maintain Alex's intracranial pressure within the normal range. (2 points)

Answer:

- First nursing intervention Keep patient's head mid-line and supine semi fowler (30) or keep patient's head mid-line and supine with bed flat if the patient is at risk of cervical #
- Second nursing intervention: Keeping a calm/quiet environment, no flexion of neck or hips
- Other possible interventions: Analgesia for pain relief to avoid raised ICP
- Other possible interventions: Strict fluid balance chart to prevent exposing the patient to fluid overload and risk of raised ICP
- Other possible interventions: oxygen therapy (in patients with sign of shock-non-intubated children)

2	1	0
Keep a calm/quiet environment AND No flexion of neck or hips OR Keep a calm/quiet environment AND Keep patient's head mid-line OR Analgesia AND Strict fluid balance.	Keep patient's head mid-line and supine semi fowler (30) OR keep patient's head mid-line and supine with bed flat if the patient is at risk of cervical # OR No flexion of neck or hips OR Analgesia OR Strict fluid balance OR Oxygen therapy OR	I do not know, or unsure.

	OBS (HR, RR, Temperature, BP, oxygen saturations) OR GCS.

8. Explain the rationale for each of the nursing interventions you named in Question 7 (3 points)

Answer:

- Keep patient's head in-line to avoid occlusion of blood venous drainage and therefore raised intracranial pressure and cerebral blood volume
- Keep a calm/quiet environment/ analgesia as any stimuli may increase ICP
- No flexion of neck or hips to avoid raised ICP due to raised cerebral blood volume

Criteria	3	2	1	0
Use of clinical terms and explanation of how they are related	Use of more than two relevant clinical terms with an accurate and complete explanation of how these terms are related	Use of more than two relevant clinical terms but the explanation of how these terms are related is inaccurate or incomplete	Use of one or two relevant clinical terms without explanation OR Use of one or two relevant clinical terms but the explanation of how these terms are related is incorrect	Incorrect idea or answer left blank, or full stop
	Examples: Keep patient's head in-line to avoid occlusion of blood venous drainage and therefore raised intracranial	Examples: Keep patient's head in-line to avoid occlusion of blood OR	Examples: Keep patient's head in-line OR Keep a calm/quiet environment	Example: To keep the patient comfortable

pressure and cerebral blood volume AND Keep a calm/quiet environment as any stimuli may increase ICP.	Keep a calm/quiet environment to avoid stimuli.

9. Alex’s axillary temperature is 37.6°C. Alex’s mother asks you if you can put a blanket on Alex to keep him warm. How would you respond to Alex's mother? (3 points)

Answer:

Alex’s axillary temperature is 37.6°C, which is within normal ranges. However, if Alex is warmed up by adding more blankets it may provoke that Alex’s brain increases its working capacity, which could cause more brain damage, so we need to keep him within normal temperature values and avoid fevers.

Criteria	3	2	1	0
Use of terms and explanation of how they are related	Use of more than two relevant terms with an accurate and complete explanation of how these terms are related	Use of more than two relevant terms but the explanation of how these terms are related is inaccurate or incomplete	Use of one or two relevant terms without explanation OR Use of one or two relevant terms but the explanation of how these terms are related is incorrect	Incorrect idea or answer left blank, or full stop
	Example: Alex’s axillary temperature is 37.6°C, which is within normal ranges.	Example: if Alex is warmed up by adding more blankets it may provoke that Alex’s brain increases its	Example: Alex’s axillary temperature is 37.6°C, which is within normal ranges.	

	However, if Alex is warmed up by adding more blankets it may provoke that Alex's brain increases its working capacity, which could cause more brain damage, so we need to keep him within normal temperature values and avoid fevers.	working capacity.

10. What is the significance of body temperature when a child has a head injury? (3 points)

Answer:

It is necessary to maintain normothermia because fever may trigger cerebral metabolic needs which leading to ischemic brain injury.

Criteria	3	2	1	0
Use of clinical terms and explanation of how they are related	Use of more than two relevant clinical terms with an accurate and complete explanation of how these terms are related	Use of more than two relevant clinical terms but the explanation of how these terms are related is inaccurate	Use of one or two relevant clinical terms without explanation OR Use of one or two relevant clinical terms but the explanation of how these	Incorrect idea or answer left blank, or full stop

		or incomplete	terms are related is incorrect	
	Example:	Example:	Example:	Example:
	It is necessary to monitor temperature and maintain normothermia because fever may trigger cerebral metabolic needs which leading to ischemic brain injury (low blood flow to the brain).	To maintain normothermia to prevent increased cerebral metabolic needs.	to maintain normothermia.	To keep the patient comfortable.

11. Which scale would you use to complete a neurological assessment on a 2-year-old child? (1 point)

Answer:

Modified Paediatric Glasgow Comma Scale (PGCS) or Modified GCS or Paediatric Glasgow Comma Scale

12. What is your rationale for choosing the scale you chose, in Question 11? (3 points)

Answer:

Modified Paediatric Glasgow Comma Scale (PGCS) assess the mental state of paediatric patient. This scale is the equivalent of the Glasgow Coma Scale (GCS) used in adults. As many of the assessments for an adult patient would not be appropriate for infants, the Glasgow Coma Scale was modified slightly to form the PGCS. Modified GCS scale is used according to their aged related cognitive abilities and appropriate responses.

Criteria	3	2	1	0
Use of clinical terms and explanation of how they are related	Use of more than two relevant clinical terms with an accurate and complete explanation of how these terms are related Example: Modified PGCS assess the mental state of paediatric patient. It is used according to their aged related cognitive abilities and appropriate responses.	Use of more than two relevant clinical terms but the explanation of how these terms are related is inaccurate OR incomplete Example: Modified PGCS is used to measure cognitive abilities.	Use of one or two relevant clinical terms without explanation OR Use of one or two relevant clinical terms but the explanation of how these terms are related is incorrect Example: Modified PGCS is used.	Incorrect idea or answer left blank, or full stop.

13. Amelia, is an 8-year-old girl who fell off a horse and suffered a laceration to the left side of her forehead. She has presented to the Emergency Department. Neurological examination reveals a Glasgow Coma Scale (GCS) of 13. She is complaining of an abnormal sensation ('pins and needles') in her toes. This is an indication for immediate cervical spine immobilisation. List two nursing interventions to maintain immobilisation of Amelia's c-spine (2 points)

Answer:

First nursing intervention: Use jaw thrust technique for airway assessment

Second nursing intervention: Use logrolling technique to assess her back

Other nursing interventions:

- Keep patient’s head mid-line, keep patient’s head mid-line and supine with bed flat
- Education on cervical collar precautions
- Place neck collar, fully body spinal board, education on cervical collar precautions.
- Sedation and reassurance

2	1	0
Use jaw thrust technique for airway assessment AND use logrolling technique to assess her back OR Keep patient’s head mid-line OR keep patient’s head mid-line and supine with bed flat OR Place neck collar OR Place fully body spinal board OR Education on cervical collar precautions.	Use jaw thrust technique for airway assessment OR use logrolling technique to assess her back OR keep patient’s head mid-line OR Place neck collar OR Place fully body spinal board OR Education on cervical collar precautions.	I do not know, or unsure.

14. Explain the rationale for each of the nursing interventions you named in Question 13 (3 points)

Answer:

- Jaw thrust technique: In patients with trauma and risk of cervical injury stabilise neck using jaw thrust technique to open airway, not chin lift, to open the airway without extending the neck.
- Logrolling technique to keep cervical spine in-line: The purpose of logrolling is to maintain alignment of the spine while turning a patient

without twisting the spine. This technique is used when a person's spinal column is unstable, or there is suspicion of c-spine injury

- Keep patient's head mid-line and supine with bed flat to avoid extending or moving the c-spine
- Place neck collar to stabilise neck and avoid further damage
- Fully body spinal board to maintain alignment of the spine
- Sedation and reassurance may be necessary to limit movement and calm a child who may be very afraid and upset, this may help with maintain immobilisation

Criteria	3	2	1	0
Use of clinical terms and explanation of how they are related	Use of more than two relevant clinical terms with an accurate and complete explanation of how these terms are related	Use of more than two relevant clinical terms but the explanation of how these terms are related is inaccurate or incomplete	Use of one or two relevant clinical terms without explanation OR Use of one or two relevant clinical terms but the explanation of how these terms are related is incorrect	Incorrect idea or answer left blank, or full stop.
	Examples: In patients with trauma and risk of cervical injury stabilise neck using jaw thrust technique to open airway, not chin lift to open the airway without extending the neck. AND Logrolling allows clinicians to maintain alignment of the spine while turning a patient without twisting the spine.	Examples: In patients with trauma and risk of cervical injury stabilise neck using jaw thrust technique to open airway, not chin lift to open the airway without extending the neck. OR	Examples: Use jaw thrust technique OR use logrolling technique OR keep patient's head mid-line.	

	OR Keep patient’s head mid-line and supine with bed flat to avoid extending the c-spine.	Logrolling allows clinicians to maintain alignment of the spine while turning a patient without twisting the spine.

Post test

15. Olivia is a two-year old girl who suffered a mild head injury due to a fall from the top of a bunk bed. Careful clinical examination reveals no serious intracranial injury. Before being discharged, what nursing recommendations would you give to parents for the care of Olivia at home? (2 points):

Answer:

Provide parents both written and verbal instructions of warrant concern and the need for re-evaluation. A paediatric patient who suffered a head injury have to be re-evaluated if he/she presents changes in behaviour or mental status, blurred vision, vomiting, persistent headache, unsteady gait, seizures.

2	1	0
Provide parents both written and verbal instructions of warrant concern and the need for re-evaluation. A paediatric patient who suffered a head injury have to be re-evaluated if he/she presents changes in behaviour or mental status, blurred vision, vomiting, persistent headache, unsteady gait, seizures.	Provide parents both written and verbal instructions of warrant concern OR A paediatric patient who suffered a head injury have to be re-evaluated if he/she presents changes in behaviour or mental status, blurred vision, vomiting, persistent headache, unsteady gait, seizures.	Incorrect idea or answer left blank, or full stop.

16. Peter, is a 16-year-old adolescent who fell on the ice while skating without using a helmet. He remained laying on the ice for a few seconds

before standing up. He is reporting a persistent headache. In the Emergency Department, Peter has had two episodes of vomiting. The registrar has ordered ondansetron 0.15 mg/kg IV and the insertion of a nasogastric tube to aspirate the stomach contents. When inserting the nasogastric tube, what would you be most concerned about and why? (3 points)

Answer:

The insertion of a nasogastric tube in this patient is contraindicated because of the risk of intracranial penetration through the base of skull fracture.

Criteria	3	2	1	0
Use of clinical terms and explanation of how they are related	Use of more than two relevant clinical terms with an accurate and complete explanation of how these terms are related	Use of more than two relevant clinical terms but the explanation of how these terms are related is inaccurate or incomplete	Use of one or two relevant clinical terms without explanation OR Use of one or two relevant clinical terms but the explanation of how these terms are related is incorrect	Incorrect idea or answer left blank, or full stop.
	Example: The insertion of a nasogastric tube in this patient is contraindicated because of the risk of intracranial penetration through the base of skull fracture.	Example: The insertion of a nasogastric tube in this patient is contraindicated because of the risk of intracranial penetration.	Example: the insertion of orogastric tube as nasogastric tube insertion is contraindicated.	Example: It is more comfortable for the patient.

Appendix 11. Instructional guideline for the simulations

Nursing care in Paediatric Closed Head Injury Simulation

The instructional guidelines for the study intervention will be broken down as follows:

Activities to be performed prior to the study intervention

1. In Family and Children Nursing (FCN) week 6, simulation laboratories (14 in total) will be allocated into one of two study condition: **Productive failure (PF) or Direct instruction (DI).**
2. **De-identification of participants**: In order to protect participants' anonymity, every participant will be randomised. The randomisation will be conducted by an external researcher not involved in the study. At the beginning of the study intervention, every student will receive ID badge that contains a random number.

Activities to be performed during the study intervention – PF group

Activity	Time
1. Presentation of the study: a person not involved in teaching or the current research project introduces the study to the students. 2. The main researcher asks students to read and sign up the participant information sheet 3. Confidentiality agreement: The facilitator highlights that whatever happens in the simulation must remain confidential and asks students to agree verbally. 4. Consenting participants complete a demographic survey and answer a pre-simulation knowledge quiz using GIZMO online platform. Every participant has access to an iPad, facilitated by the Faculty of Health, simulation laboratories.	20 minutes
5. Briefing Using a PowerPoint presentation, the facilitator: • displays the learning outcomes of the simulation session • makes an introduction to the simulation lab, clinical equipment and manikin • highlights that mistakes are part of the learning process. An example of what is explained to the students about mistakes: *During the simulation activity, you may make mistakes. Errors are part of the learning process. If you make errors, you can learn from them.*	20 minutes
6. Simulation 1: Shaken baby syndrome In this activity, students work in groups of 5-7. During this activity, the educator does not provide content-related support Phase 1: hand over from triage nurse to ED team (5 minutes) Phase 2: patient deterioration (10 minutes)	20 minutes 2 groups of 5–7 students each perform the simulation activity

	simultaneously (10 minutes). The rest of students work on printed UTS online activities. Then students swap activities
7. Debriefing The model of debriefing proposed by Rudolph et al. (2008), 'Debriefing as formative assessment' will be used in this phase as well as PF principles (Kapur & Bielaczyc, 2012). Reaction phase: How did you feel doing the sim activity? Analysis phase: The facilitator will summarise the learning outcomes of the simulation session and asks the following questions: • What happened during the simulation activity? • Why this happened? The facilitator provides a mini lecture on the topic of paediatric closed head injury and displays a video demonstration of paediatric registered nurses caring for a child who has been shaken. Subsequently, the facilitator asks the following questions: • What are the similarities between your performance and the video demonstration? • What are the differences between your performance and the video demonstration? • What aspects of your performance could you improve? Summary phase: • How can you use the information we just discussed in your clinical practice? • Can you think of other situations where this information could be applied?	40 minutes
Break	10 minutes
8. Simulation scenario 2: Closed head injury	20 minutes 2 groups of 5-7 students each perform the simulation activity simultaneously (10 minutes) whereas the rest of students work

	on printed UTS online activities. Then students swap activities
9. Post-simulation knowledge quiz	20 minutes
10. Student satisfaction survey	5 minutes
11. Interviews	10-15 minutes
Total	170 minutes

Activities to be performed during the study intervention - DI group

Activity	Time
1. Presentation of the study: a person not involved in teaching or the current research project introduces the study to the students. 2. The main researcher asks students to read and sign up the participant information sheet 3. Confidentiality agreement: The facilitator highlights that whatever happens in the simulation must remain confidential and asks students to agree verbally. 4. Consenting participants complete a demographic survey and answer a pre-simulation knowledge quiz using GIZMO online platform. Every participant has access to an iPad, facilitated by the Faculty of Health, simulation laboratories.	20 minutes
5. Briefing Using a PowerPoint presentation, the facilitator: • displays the learning outcomes of the simulation session • makes an introduction to the simulation lab, clinical equipment and manikin	20 minutes
6. Mini lecture and video demonstration The facilitator provides a mini lecture on the topic of paediatric closed head injury and displays a video demonstration of paediatric registered nurses caring for a child who has been shaken	30 minutes
7.Simulation 1: Shaken baby syndrome In this activity, students work in groups of seven. During this activity, the educator does not provide content-related support Phase 1: hand over from triage nurse to ED team (5 minutes) Phase 2: patient deterioration (10 minutes)	20 minutes 2 groups of 5-7 students each perform the sim activity simultaneously (15 minutes), whereas the rest of students (14) complete the student workbook.

	Then students swap activities.
8. Debriefing The model of debriefing proposed by Rudolph et al. (2008), ‘Debriefing as formative assessment’ will be used in this phase. a. Reaction phase: How did you feel doing the sim activity? b. Analysis phase: The facilitator summarises the learning outcomes of the simulation and asks the following questions: • What happened during the simulation activity? • Why this happened c. Summary phase: • How can you use the information we just discussed in your clinical practice? • Can you think of other situations where this information could be applied?	30-40 minutes
Break	10 minutes
9. Simulation scenario 2: Closed head injury	20 minutes
10. Post-simulation knowledge quiz	20 minutes
11. Student satisfaction survey	5 minutes
Total	175 minutes

Appendix 12. Simulation facilitator guide

Simulation facilitator guide – PF group

Dear team,

Thank you very much for your support in conducting this simulation research. This study is embedded in week 6 simulation lab activities. Students will participate in two closed head injury simulation scenarios (Mason, CHI secondary to shaken baby syndrome, and Jaxon, CHI secondary to fall from 3rd story window). Both Mason and Jaxon will present signs and symptoms of neurological deterioration. At the end of the simulation experience, students will be able to:

- Conduct a systematic assessment of a child presenting with closed head injury
- Recognise and manage a child with closed head injury
- Identify potential risk factors for child maltreatment

The following table displays the distribution of the **primary facilitator and second facilitator** that will participate in the simulation research:

Lab Times	Primary Facilitator	Second Facilitator
Monday 1230-1530	Evelyn Palominos	Tamara Power/Nadine Alcorn
Monday 1600-1900	Evelyn Palominos	Tamara Power/Nadine Alcorn
Tuesday 0900-1200	Peta Lloyd	Pauline Murray-Parahi
Tuesday 1230-1530	Peta Lloyd	Pauline Murray-Parahi
Tuesday 1600-1900	Peta Lloyd	Poonam Garg
Wednesday 0900-1200	Laura Sheridan	Nadine Alcorn
Wednesday 1230-1530	Vicki Ibbotson	Laura Sheridan
Wednesday 1600-1900	Vicki Ibbotson	Laura Sheridan
Thursday 0900-1200	Laura Sheridan	Peta Lloyd
Thursday 1230-1530	Emily Chapman	Peta Lloyd
Thursday 1600-1900	Emily Chapman	Peta Lloyd
Friday 0900-1200	Poonam Garg	Tamara Power
Friday 1230-1530	Poonam Garg	Tamara Power
Friday 1600-1900	Poonam Garg	Tamara Power

The following table displays the simulation design plan with the recommended duties and roles for the researcher, the primary facilitator and the second facilitator:

Time	Activity	Duties	Materials
5 minutes	Set up the simulation lab	The second facilitator assists the primary facilitator to tidy up the tables. Each table should contain: x4 Participant information sheet (PIS) (x2-3 folders) Simulation quiet time activities. The second facilitator makes sure that students kept the set of documents provided in the folder because they will be re-used. In each Mason's sim bed should be: Alcohol wipe, stethoscope, saturometer, thermometer, glucometer, pen torch, (x1) SPOC 3-12 months, modified GCS, FLACC pain scale, assessment sheet, dummy, 2 wrapped towels, bonnet. Manikin lying flat: Please check that Mason presents circumferential bruising in chest, bruises in thigh, left foot and back of head Please check monitor parameters: RR: 32 -irregular SpO2: 96% Lung sounds normal Self-ventilating Sinus rhythm (normal) HR: 85 - irregular BP: 115/68 mmHg Temp: 37.2 (peripheral) In each Jaxon's sim bed should be: Alcohol wipe, stethoscope, saturometer, thermometer, glucometer, pen torch, (x1) SPOC 5-11 years, modified GCS, Faces pain scale,	-Participant information sheet -Simulation quiet time activities (in yellow folders- 7 folders in total) -Paediatric vital sign devices -Pen torch -SPOC -GCS -FLACC -Assessment sheet -Dummy -2 wrapped towels -Bonnet For Mason's Mom: -1 handbag -1 bottle with milk -Pram with Ellie -Paediatric vital sign devices -Pen torch -SPOC -GCS

		assessment sheet (in blank), Hudson mask. Manikin lying flat Please check that Jaxon presents abrasions to left forehead, elbow and left side of his back Attached to manikin: paediatric cervical spine collar, PIVC right arm with 0.9% Sodium Chloride 1000 ml bag Please check monitor parameters: RR: 28 irregular SpO2 92% Lung sounds: left side – crackles and low volume, right-normal Sinus Rhythm (normal) HR: 70 - irregular BP: 130/90 mmHg Temp: 36.9 (peripheral)	-FACES scale -Assessment sheet -2 wrapped towels
	Check-in	Before students get into the lab, the second facilitator: 1. Provides each student a badge with a random number to de-identify them 2. Provides each student the consent form *Please make sure that students remove their name badge so they are not identified* Students cannot enter to the simulation lab after 15 min of commencing the simulation session	-Table outside lab 430 -Student role -ID badges (random number) -Consent form
20 minutes	Presentation of the study	A person not involved in the study introduces the simulation research and reads the first slide of the ppt provided	PPT
	Students sign up the consent from	Once students have signed up the consent form, the second facilitator collects them and placed in the box 'titled consent forms signed'	Consent form (26-28) depending on the number of students
	Confidential agreement	The primary facilitator reads the second and third slide of the ppt. Then, she invites the researcher to continue with the rest of the sim activities.	PPT

	Demographic survey and pre-simulation knowledge quiz	Evelyn invites participants to complete a demographic survey and answer a pre-simulation knowledge quiz.	online
20 minutes	Briefing .	Evelyn: • Introduces the learning outcomes of the simulation session • Makes an introduction to the simulation lab, clinical equipment and manikin • Highlights that mistakes are part of the learning process.	PPT
20 minutes	Sim activity 1 (Mason)	Evelyn splits the class in 2 groups of 14 students each. The first 14 students are divided in groups of 5-7 to perform the sim activity simultaneously, whereas the rest of students work in pairs on the tables solving quiet time activities. Evelyn informs students they have to choose one of the following roles: 1 Handover nurse 1 Nurse 1 (A, B, C) 1 Nurse 2 (D) 1 Nurse 3 (E) 1 Nurse 4 (F, G and S) 1 Faculty nurse 1 Scriber After finalising the simulation activity, students swap activities *The second facilitator adds to every folder a new sheet with questions for the quiet activity when students swap activities (copies are in the folder labelled 'Quiet time activities'). The primary and second facilitator play the role of Mason's mother (script provided) The primary and second facilitator makes set up the bed spaces for the second group of students (added a new SPOC, patient' blank sheet assessment) Evelyn makes sure that the iPads and B-line are recording the simulation activities	

40 minutes	Debriefing	Once all students have finished to participate in the simulation scenario 1 (Mason), Evelyn will run the debriefing activity.	-PPT with mini-lecture (closed head injury) -Video demonstration -Set of questions
10 minutes	Break		
20 minutes	Post-simulation knowledge quiz	Evelyn leads this activity	Online
5 minutes	Student satisfaction survey	Evelyn leads this activity	Online
20 minutes	Sim activity 2 (Jaxon)	Evelyn splits the class in 2 groups of 14 students each. The first 14 students are divided in groups of 5-7 to perform the simulation activity simultaneously, whereas the rest of students work on the tables solving quiet time activities. Evelyn informs students they have to choose one of the following roles: 1 Handover nurse 1 Nurse 1 (A, B, C) 1 Nurse 2 (D) 1 Nurse 3 (E) 1 Nurse 4 (F, G and S) 1 Faculty nurse 1 Scriber Then students swap activities *This time it is not needed to add a new sheet with questions in every folder of the 'Quite time activities' as students can continue working with their previous one. The primary and second facilitator set up the bed spaces for the second group of students (added a new SPOC and patient' blank sheet assessment)	
20 minutes	Interviews	Evelyn leads this activity	
Total: 180 minutes			

Simulation facilitator guide – DI group

Dear team,

Thank you very much for your support in conducting this simulation research. This study is embedded in week 6 simulation lab activities. Students will participate in two closed head injury simulation scenarios (Mason, CHI secondary to shaken baby syndrome, and Jaxon, CHI secondary to fall from 3rd story window). Both Mason and Jaxon will present signs and symptoms of neurological deterioration. At the end of the simulation experience, students will be able to:

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		Please check that Jaxon presents abrasions to left forehead, elbow and left side of his back Attached to manikin: paediatric cervical spine collar, PIVC right arm with 0.9% Sodium Chloride 1000 ml bag Please check monitor parameters: RR: 28 irregular SpO2 92% Lung sounds: left side – crackles and low volume, right-normal Sinus Rhythm (normal) HR: 70 - irregular BP: 130/90 mmHg Temp: 36.9 (peripheral)	-Assessment sheet -2 wrapped towels
	Check-in	Before students get into the lab, the second facilitator: 3. Provides each student a badge with a random number to de-identify them 4. Provides each student the consent form *Please make sure that students remove their name badge so they are not identified* Students cannot enter to the simulation lab after 15 min of commencing the simulation session	-Table outside lab 430 -Student role -ID badges (random number) -Consent form
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	Students sign up the consent from	Once students have signed up the consent form, the second facilitator collects them and placed in the box ‘titled consent forms signed’	Consent form (26-28) depending on the number of students
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	Demographic survey and pre-simulation knowledge quiz	Evelyn invites participants to complete a demographic survey and answer a pre-simulation knowledge quiz.	online
20 minutes	Briefing .	Evelyn: - Introduces the learning outcomes of the simulation session - Makes an introduction to the simulation lab, clinical equipment and manikin	PPT
30 minutes	Mini-lecture and video demonstration	Evelyn leads this activity	-PPT with mini-lecture (closed head injury) -Video demonstration
20 minutes	Sim activity 1 (Mason)	Evelyn splits the class in 2 groups of 14 students each. The first 14 students are divided in groups of 5-7 to perform the sim activity simultaneously, whereas the rest of students work in pairs on the tables solving quiet time activities. Evelyn informs students they have to choose one of the following roles: 1 Handover nurse 1 Nurse 1 (A, B, C) 1 Nurse 2 (D) 1 Nurse 3 (E) 1 Nurse 4 (F, G and S) 1 Faculty nurse 1 Scriber After finalising the simulation activity, students swap activities *The second facilitator adds to every folder a new sheet with questions for the quiet activity when students swap activities (copies are in the folder labelled ‘Quiet time activities’). The primary and second facilitator play the role of Mason’s mother (script provided) The primary and second facilitator makes set up the bed spaces for the second group of students (added a new SPOC, patient’ blank sheet assessment)	

		Evelyn makes sure that the iPads and B-line are recording the simulation activities	
30 minutes	Debriefing	Students participate in a debriefing activity after. Evelyn runs this activity.	-Mini-lecture (closed head injury) -Video demonstration -Set of questions.
10 minutes	Break		
20 minutes	Post-simulation knowledge quiz	Evelyn leads this activity	Online
5 minutes	Student satisfaction survey	Evelyn leads this activity	Online
20 minutes	Sim activity 2 (Jaxon)	Evelyn splits the class in 2 groups of 14 students each. The first 14 students are divided in groups of 5-7 to perform the simulation activity simultaneously, whereas the rest of students work on the tables solving quiet time activities. Evelyn informs students they have to choose one of the following roles: 1 Handover nurse 1 Nurse 1 (A, B, C) 1 Nurse 2 (D) 1 Nurse 3 (E) 1 Nurse 4 (F, G and S) 1 Faculty nurse 1 Scriber Then students swap activities *This time it is not needed to add a new sheet with questions in every folder of the 'Quite time activities' as students can continue working with their previous one.	
	Set up the simulation lab	The primary and second facilitator set up the bed spaces for the second group of students (added a new SPOC and patient' blank sheet assessment).	
Total: 180 minutes			

Appendix 13. PowerPoint presentation slides used in the study intervention

Prebriefing

Note: Productive failure groups and direct instruction groups saw the same PowerPoint presentation. The only difference was that the direct instruction groups did not receive the statement about errors (Slide 6).

UTS

Nursing care in a child with closed head injury

UTS CRICOS 00099F

(Slide 1)

Simulation research

- This FCN week lab will be part of a Simulation Research conducted by the PhD candidate Evelyn Palominos and the FCN staff.
- We have emailed you a Participant Information Sheet explaining what this is study is about. There are copies on your table for you to read it if you need it.
- The participation in this study is completely anonymous it does not contribute to or affect the subject grade (except for your attendance).
- If you do not want to participate in the research activities, the pre-brief, simulation and debrief are still a part of your normal class activities. The only exception is that your data will not be analysed.
- Please review the Consent Form and if you agree to participate please sign the form and return it to one of the facilitators.

(Slide 2)

Confidential agreement

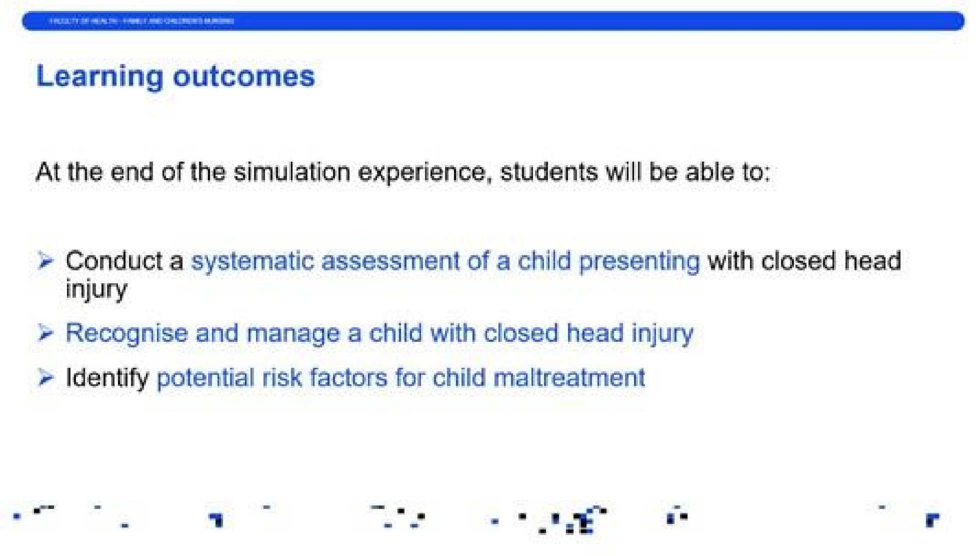
In enhancing learning and to provide a fair and consistent simulated experience for all students, today's simulation activity, including scenario information and participant performance is considered privileged and confidential in any form, whether; electronic, written, verbal, observed or overheard and we therefore ask you to respect the privacy of all participants (both staff and students) and undertake not to discuss individual or group performances outside the simulation environment.

(Slide 3)

Demographic survey and pre-quiz

https://www.surveygizmo.com/s3/5179284/demo

(Slide 4)



Learning outcomes

At the end of the simulation experience, students will be able to:

- Conduct a systematic assessment of a child presenting with closed head injury
- Recognise and manage a child with closed head injury
- Identify potential risk factors for child maltreatment

(Slide 5)

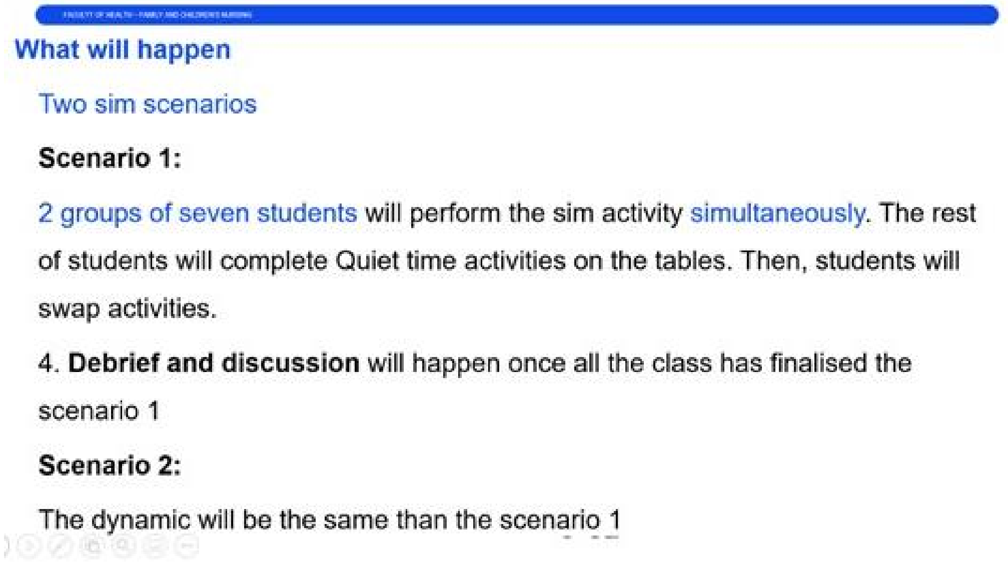
During the simulation activity, you may make mistakes. Errors are part of your learning and opportunities to improve.

(Slide 6)

Housekeeping rules

- What happens in SIM, stays in SIM
- Bathrooms
- Mobile Phones – OFF or on SILENT
- Please respect other students' right to learn without distraction

(Slide 7)



What will happen

Two sim scenarios

Scenario 1:

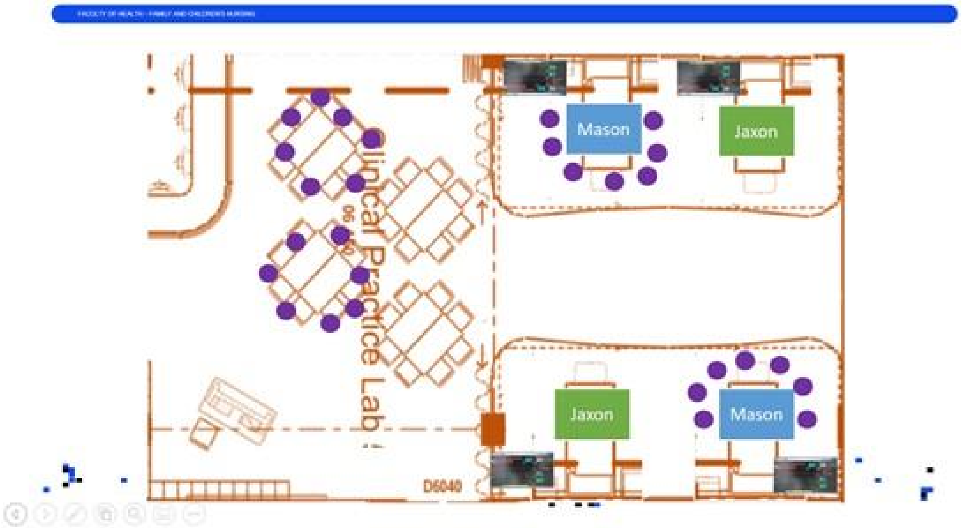
2 groups of seven students will perform the sim activity simultaneously. The rest of students will complete Quiet time activities on the tables. Then, students will swap activities.

4. **Debrief and discussion** will happen once all the class has finalised the scenario 1

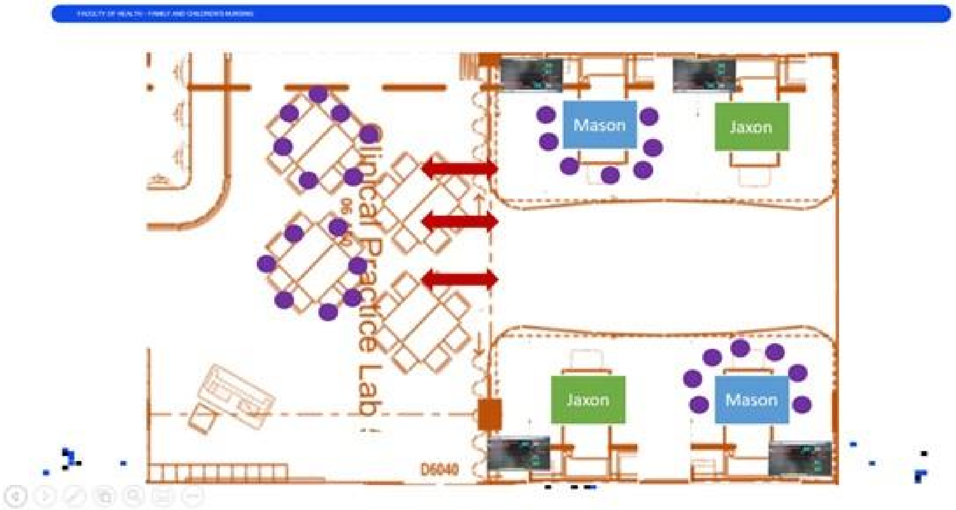
Scenario 2:

The dynamic will be the same than the scenario 1

(Slide 8)

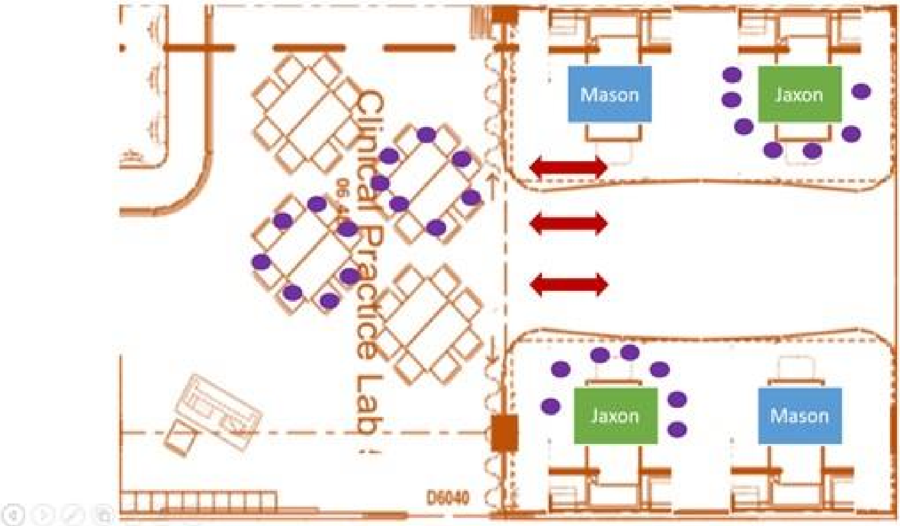


(Slide 9)

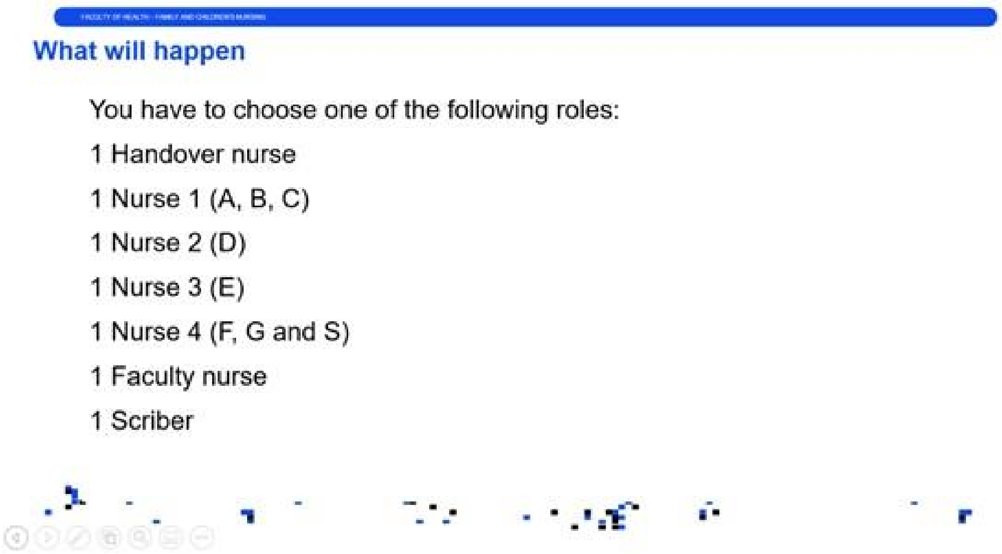


(Slide 10)

(Slide 11)



(Slide 12)



What will happen

You have to choose one of the following roles:

1 Handover nurse

1 Nurse 1 (A, B, C)

1 Nurse 2 (D)

1 Nurse 3 (E)

1 Nurse 4 (F, G and S)

1 Faculty nurse

1 Scriber

(Slide 13)

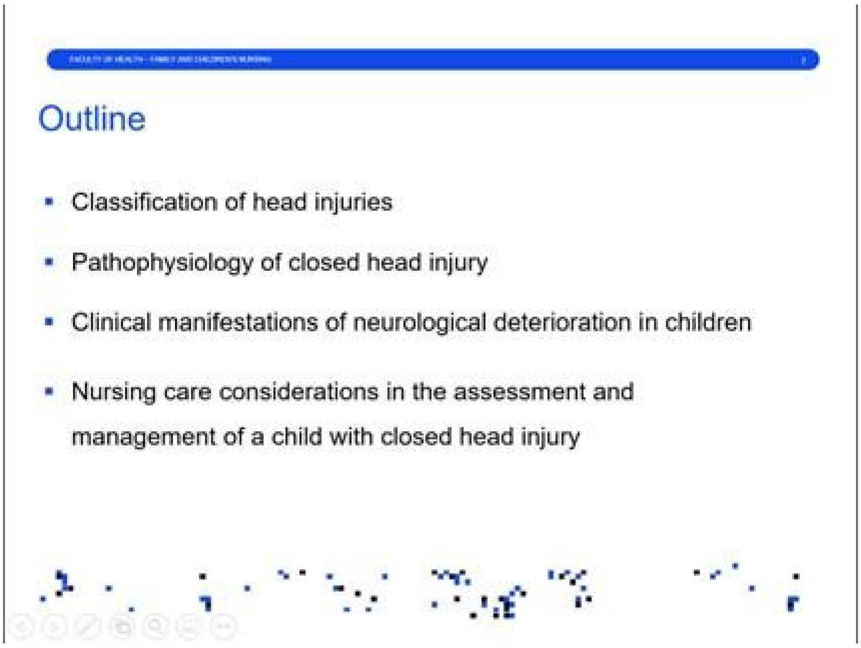
PowerPoint slides presented in the debriefing session

Closed head injury:

Considerations for Nursing Care

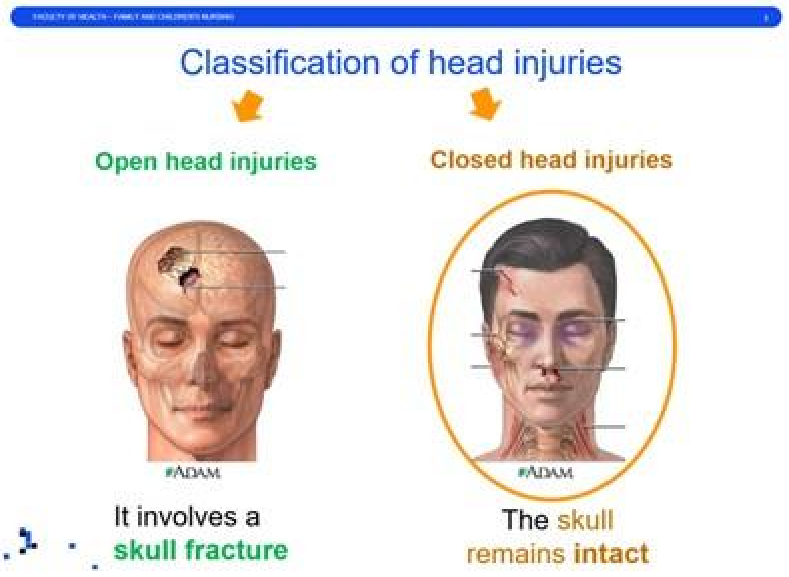
Family and Children's Nursing

Week 6



Outline

- Classification of head injuries
- Pathophysiology of closed head injury
- Clinical manifestations of neurological deterioration in children
- Nursing care considerations in the assessment and management of a child with closed head injury



Classification of head injuries

Open head injuries

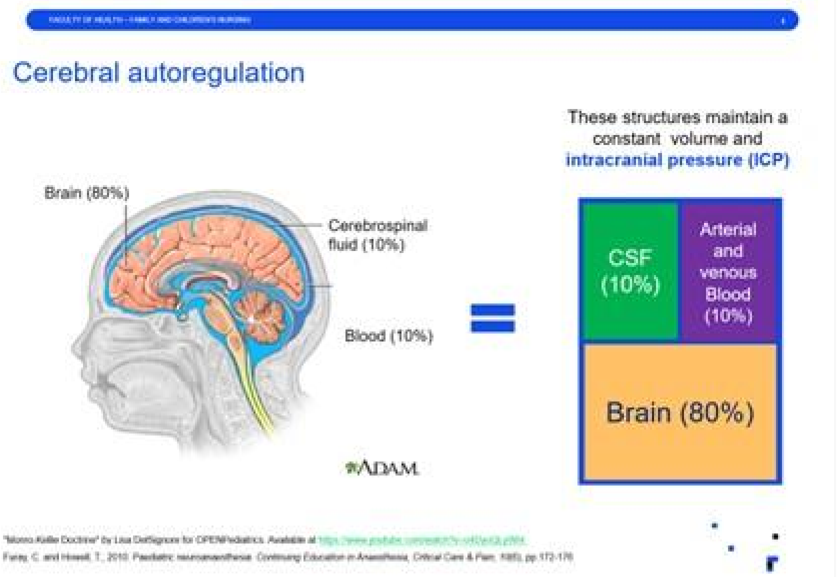
Closed head injuries

#ADAM

#ADAM

It involves a **skull fracture**

The skull remains **intact**



Cerebral autoregulation

These structures maintain a constant volume and **intracranial pressure (ICP)**

Brain (80%)

Cerebrospinal fluid (10%)

Blood (10%)

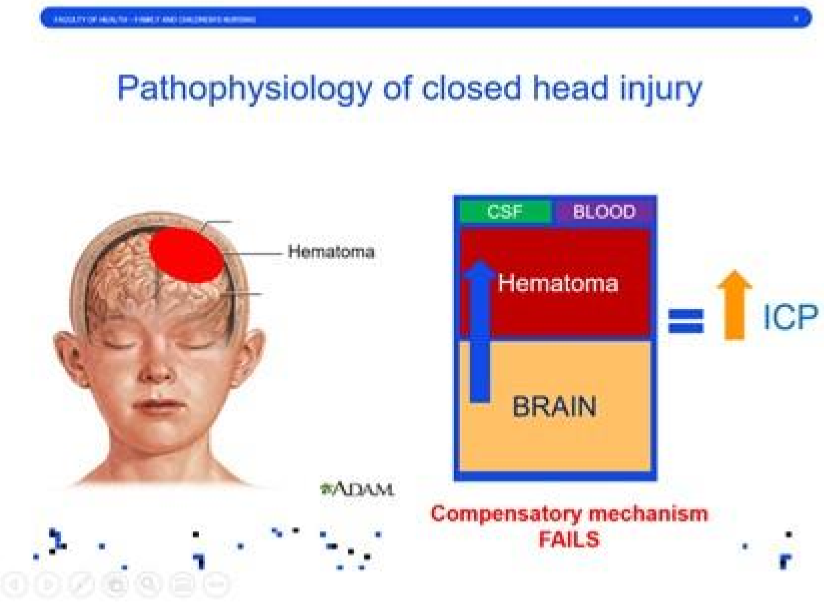
#ADAM

=

CSF (10%)	Arterial and venous Blood (10%)
Brain (80%)	

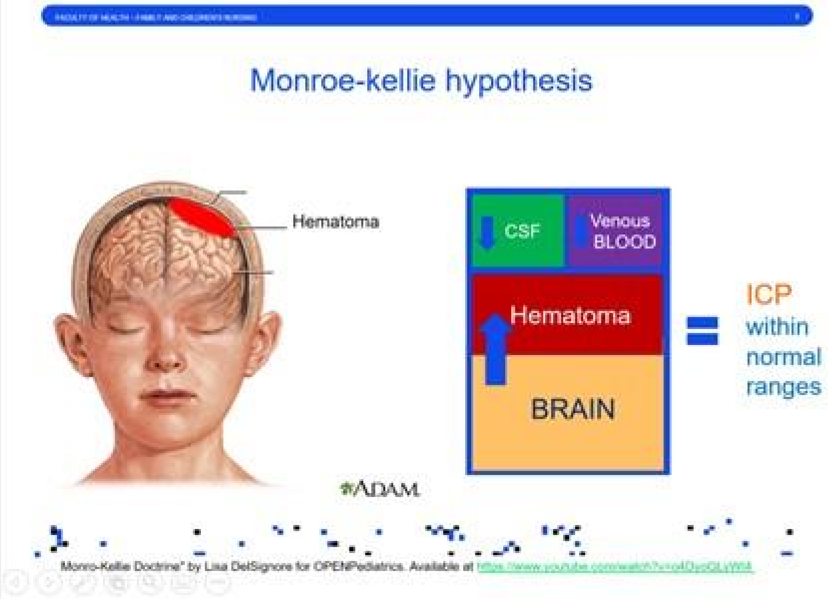
"Monro-Kellie Doctrine" by Lisa DelSignore for OPENPediatrics. Available at https://www.youtube.com/watch?v=[illegible]

Furay, C. and Howell, T., 2010. Paediatric neuroanaesthesia. Continuing Education in Anaesthesia, Critical Care & Pain, 10(6), pp.172-176



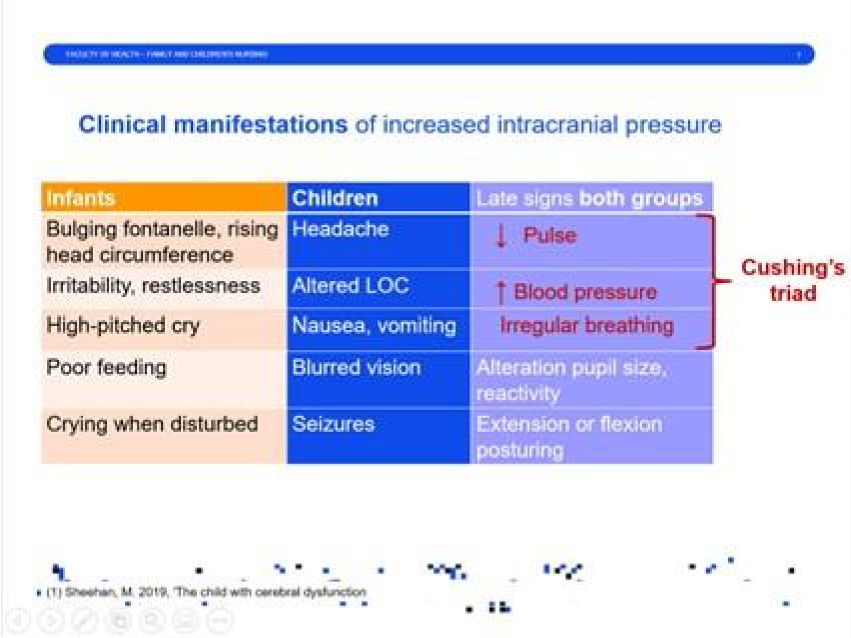
Pathophysiology of closed head injury

Compensatory mechanism FAILS



Monroe-kellie hypothesis

Monro-Kellie Doctrine" by Lisa DelSignore for OPENPediatrics. Available at https://www.youtube.com/watch?v=o4DyoQLyW4



Clinical manifestations of increased intracranial pressure

Infants	Children	Late signs **both groups**
Bulging fontanelle, rising head circumference	Headache	↓ Pulse
Irritability, restlessness	Altered LOC	↑ Blood pressure
High-pitched cry	Nausea, vomiting	Irregular breathing
Poor feeding	Blurred vision	Alteration pupil size, reactivity
Crying when disturbed	Seizures	Extension or flexion posturing

Cushing's triad

- (1) Sheehan, M. 2019, 'The child with cerebral dysfunction

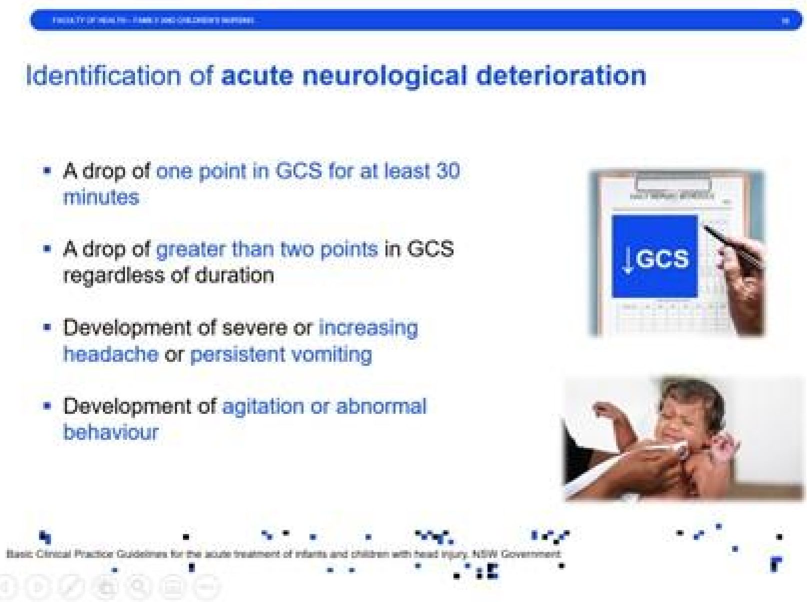
Clinical manifestations of ICP in infants

Clinical manifestations of ICP in children

Headache

Blurred vision

Altered level of consciousness



Identification of **acute neurological deterioration**

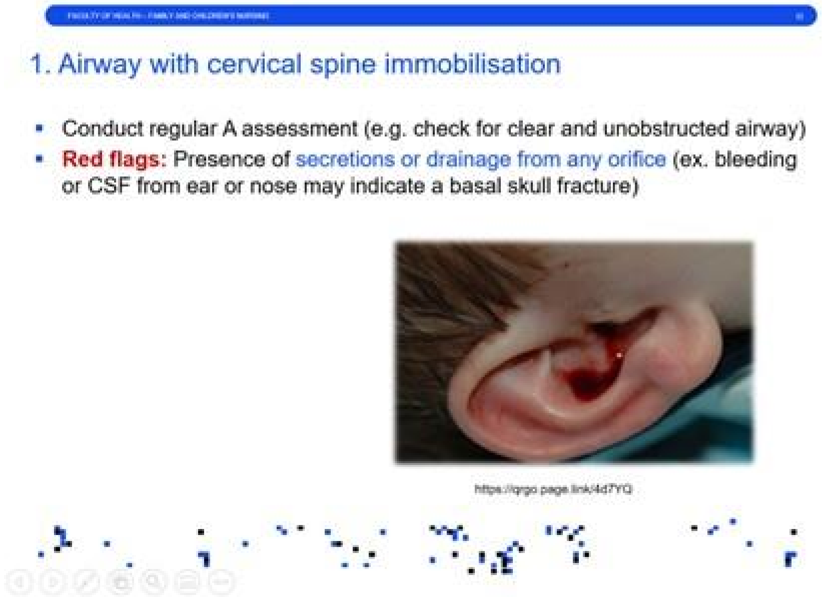
- A drop of one point in GCS for at least 30 minutes
- A drop of greater than two points in GCS regardless of duration
- Development of severe or increasing headache or persistent vomiting
- Development of agitation or abnormal behaviour

Basic Clinical Practice Guidelines for the acute treatment of infants and children with head injury. NSW Government

Assessment and management of a patient with closed head injury

1. Airway with cervical spine immobilisation
2. Breathing pattern and adequacy
3. Circulation and haemorrhage control
4. Disability
5. Exposure
6. Fluids
7. Glucose

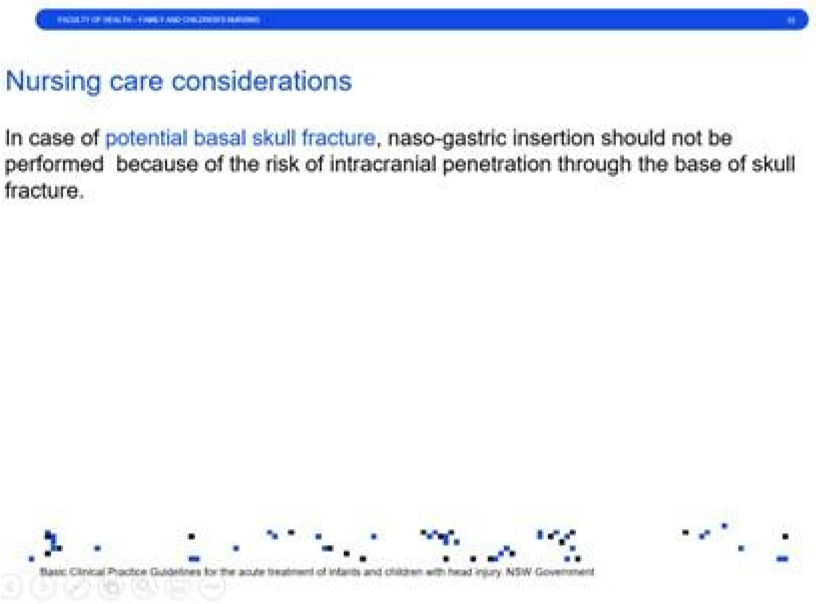
Basic Clinical Practice Guidelines for the acute treatment of infants and children with head injury. NSW Government



1. Airway with cervical spine immobilisation

- Conduct regular A assessment (e.g. check for clear and unobstructed airway)
- **Red flags:** Presence of secretions or drainage from any orifice (ex. bleeding or CSF from ear or nose may indicate a basal skull fracture)

https://qrgo.page.link/4d7YQ



Nursing care considerations

In case of potential basal skull fracture, naso-gastric insertion should not be performed because of the risk of intracranial penetration through the base of skull fracture.

Basic Clinical Practice Guidelines for the acute treatment of infants and children with head injury. NSW Government

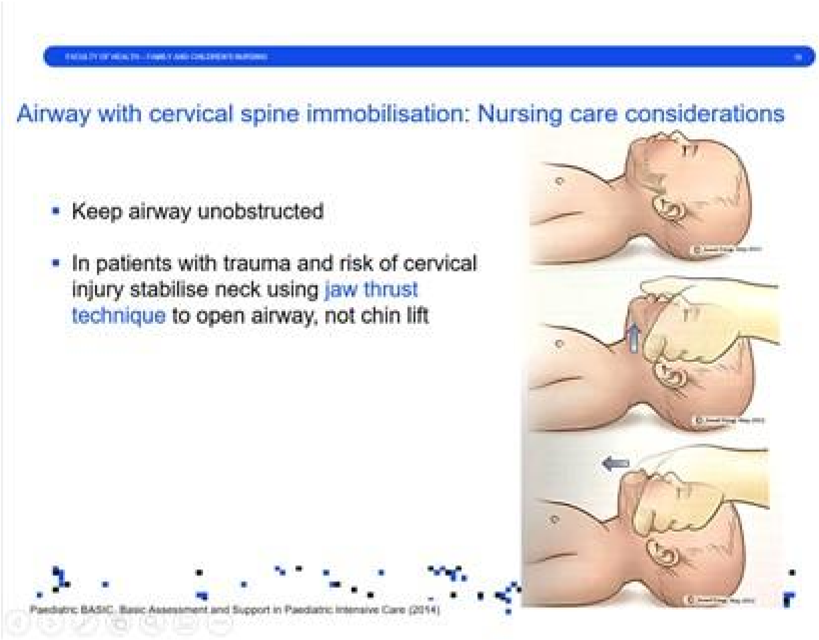
1. Airway with cervical spine immobilisation

Indications of **cervical spine immobilisation**:

- GCS <15
- Neck pain or tenderness
- Focal neurological deficit at any time since injury
- Paraesthesia in the extremities (abnormal sensation 'pins and needles')
- Any other clinical suspicion of cervical spine injury.

Sand bags

Basic Clinical Practice Guidelines for the acute treatment of infants and children with head injury. NSW Government

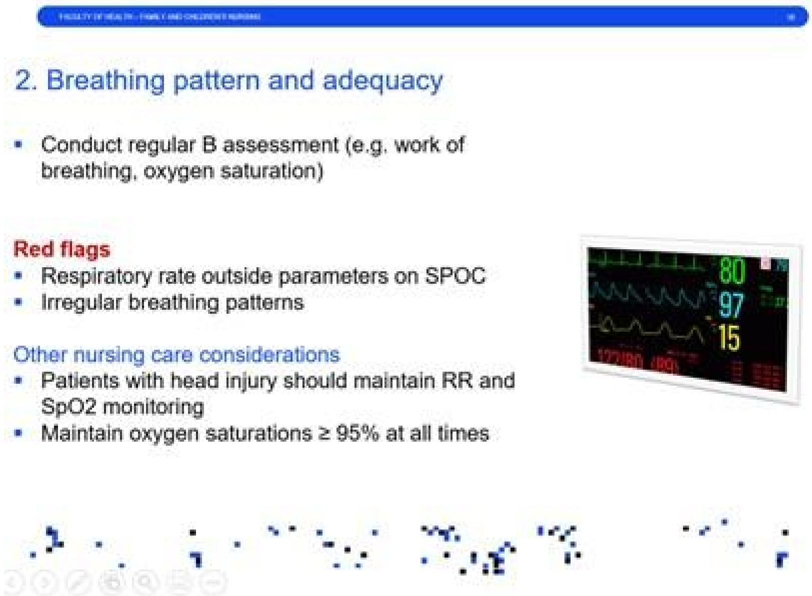


FACULTY OF HEALTH – FAMILY AND CHILDREN'S NURSING

Airway with cervical spine immobilisation: Nursing care considerations

- Keep airway unobstructed
- In patients with trauma and risk of cervical injury stabilise neck using jaw thrust technique to open airway, not chin lift

Paediatric BASIC, Basic Assessment and Support in Paediatric Intensive Care (2014)



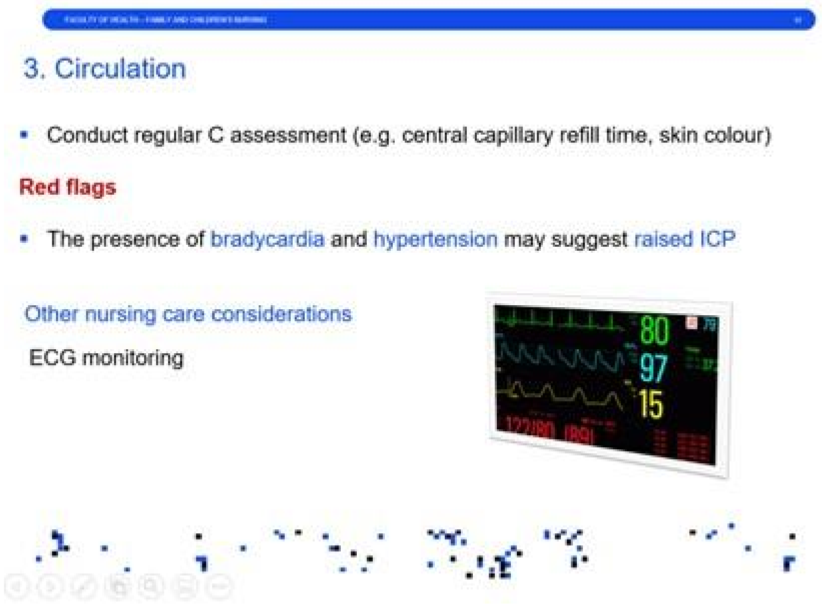
FACULTY OF HEALTH – FAMILY AND CHILDREN'S NURSING

2. Breathing pattern and adequacy

- Conduct regular B assessment (e.g. work of breathing, oxygen saturation)

Red flags
- Respiratory rate outside parameters on SPOC
- Irregular breathing patterns

Other nursing care considerations
- Patients with head injury should maintain RR and SpO2 monitoring
- Maintain oxygen saturations ≥ 95% at all times



3. Circulation

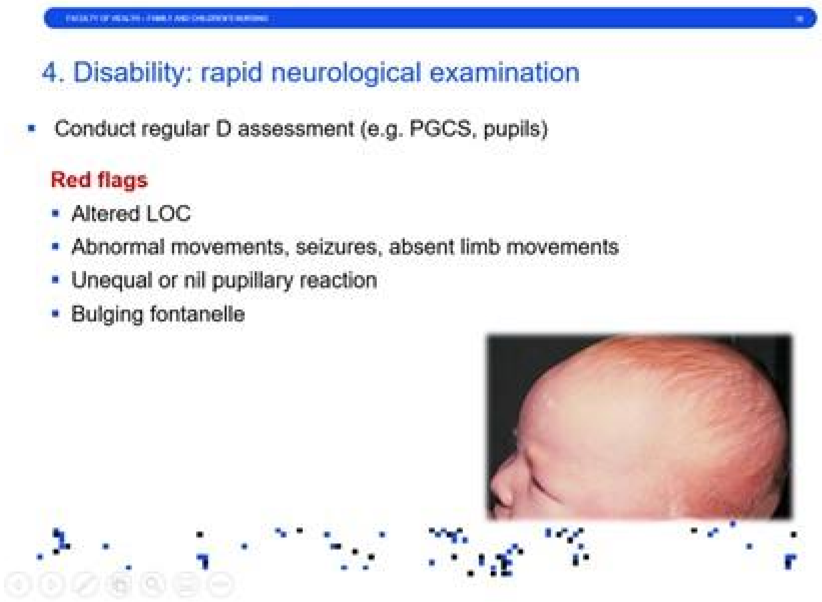
- Conduct regular C assessment (e.g. central capillary refill time, skin colour)

Red flags

- The presence of bradycardia and hypertension may suggest raised ICP

Other nursing care considerations

ECG monitoring

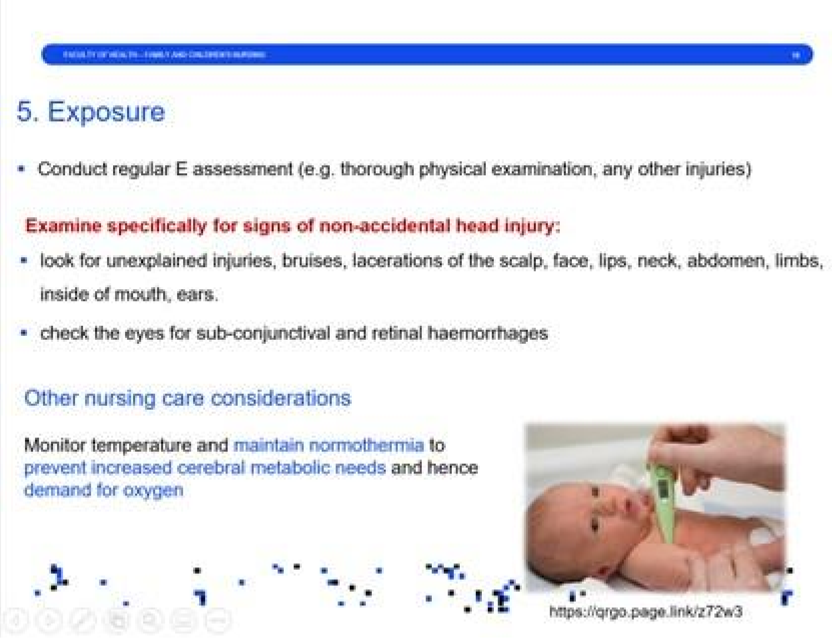


4. Disability: rapid neurological examination

- Conduct regular D assessment (e.g. PGCS, pupils)

Red flags

- Altered LOC
- Abnormal movements, seizures, absent limb movements
- Unequal or nil pupillary reaction
- Bulging fontanelle



5. Exposure

- Conduct regular E assessment (e.g. thorough physical examination, any other injuries)

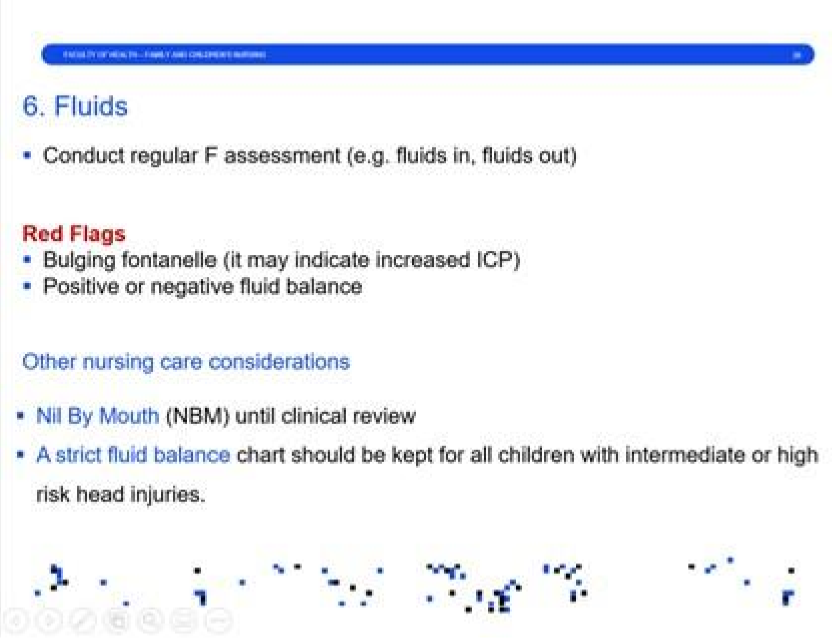
Examine specifically for signs of non-accidental head injury:

- look for unexplained injuries, bruises, lacerations of the scalp, face, lips, neck, abdomen, limbs, inside of mouth, ears.
- check the eyes for sub-conjunctival and retinal haemorrhages

Other nursing care considerations

Monitor temperature and maintain normothermia to prevent increased cerebral metabolic needs and hence demand for oxygen

https://qrgo.page.link/z72w3



6. Fluids

- Conduct regular F assessment (e.g. fluids in, fluids out)

Red Flags

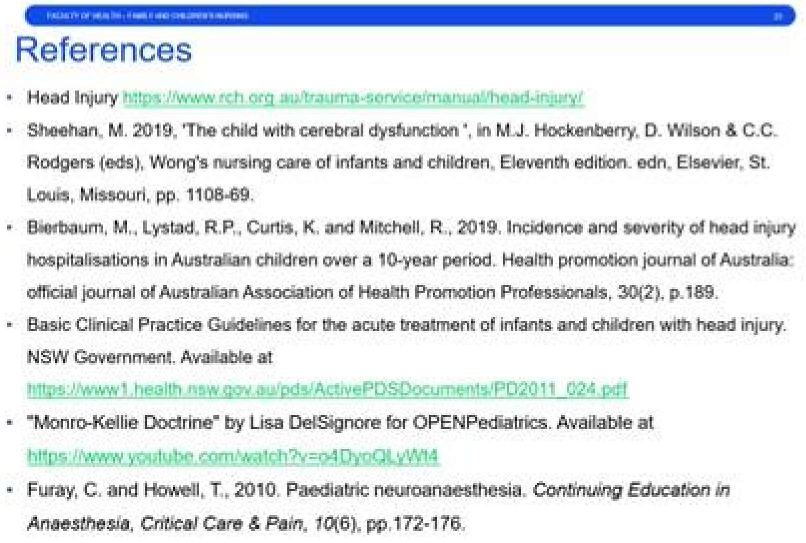
- Bulging fontanelle (it may indicate increased ICP)
- Positive or negative fluid balance

Other nursing care considerations

- Nil By Mouth (NBM) until clinical review
- A strict fluid balance chart should be kept for all children with intermediate or high risk head injuries.

7. Glucose

- Blood glucose should be checked on arrival for all children with an altered level of consciousness and monitored at least 4th hourly in infants who are nil by mouth
- Measure BGL in children with poor feeding or vomiting



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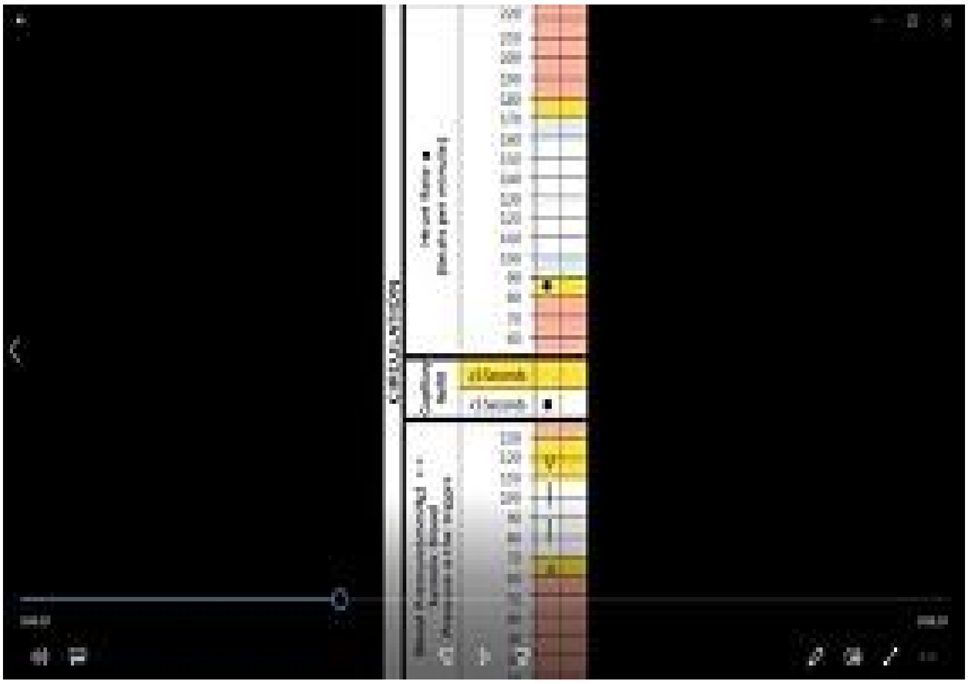
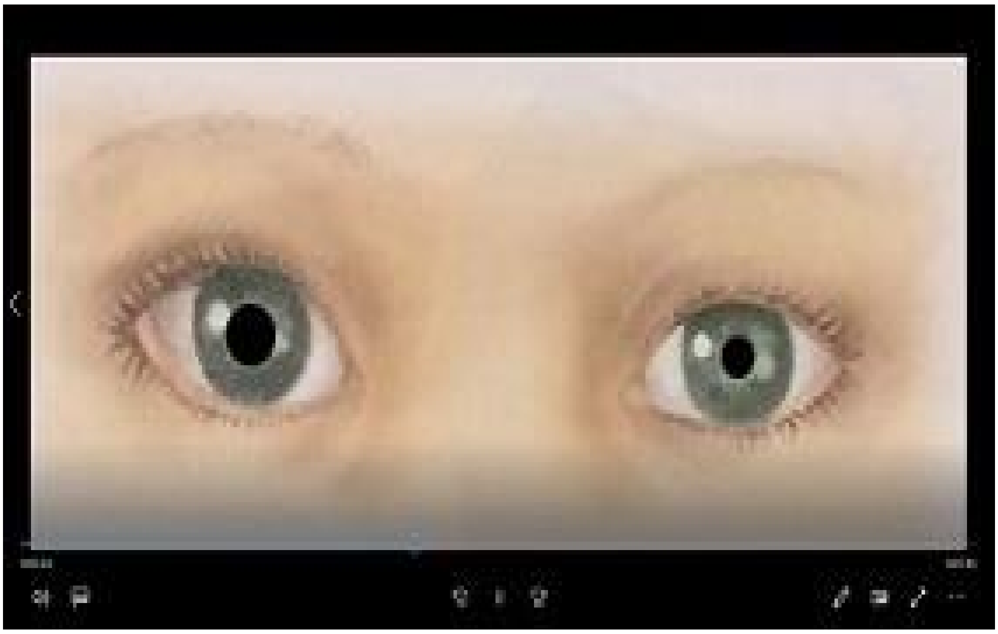
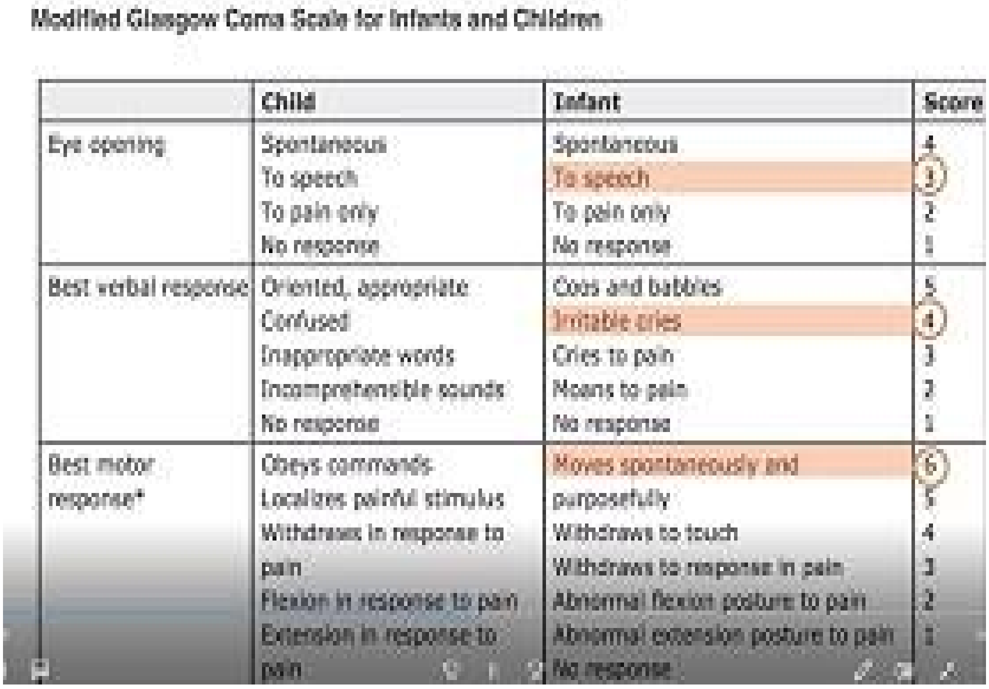
Appendix 14. Screenshots of the video demonstration


AIRWAY


HR
85
Pleth
SpO₂
96
ABP
115/68
(84)







Modified Glasgow Coma Scale for Infants and Children

	Child	Infant	Score
Eye opening	Spontaneous	Spontaneous	4
	To speech	To speech	③
	To pain only	To pain only	2
	No response	No response	1
Best verbal response	Oriented, appropriate	Coos and babbles	5
	Confused	Irritable cries	④
	Inappropriate words	Cries to pain	3
	Incomprehensible sounds	Moans to pain	2
	No response	No response	1
Best motor response*	Obeys commands	Moves spontaneously and purposefully	⑥
	Localizes painful stimulus	Withdraws to touch	5
	Withdraws in response to pain	Withdraws to response in pain	4
	Flexion in response to pain	Abnormal flexion posture to pain	3
	Extension in response to pain	Abnormal extension posture to pain	2
		No response	1

Appendix 15. 18th National Nurse Educator Conference – Abstract

Making errors matter in simulation-based learning: Effectiveness and satisfaction levels of a productive failure simulation compared to a traditional simulation

Background: Productive failure, a teaching method designed so that students solve learning tasks prior to receiving instruction, has demonstrated improved learning outcomes, including explanatory knowledge and transfer of learning. When applied to simulation-based learning, a productive failure simulation requires students to participate in the simulation prior to instruction. This contrasts with traditional simulations that typically provide instruction followed by the simulation. No previous studies have examined the effectiveness and satisfaction levels of a productive failure approach compared to a traditional approach in simulation-based learning.

Aim: To measure the impact of a productive failure simulation on nursing students' declarative knowledge, explanatory knowledge, transfer of knowledge and satisfaction levels when compared with a direct instruction approach.

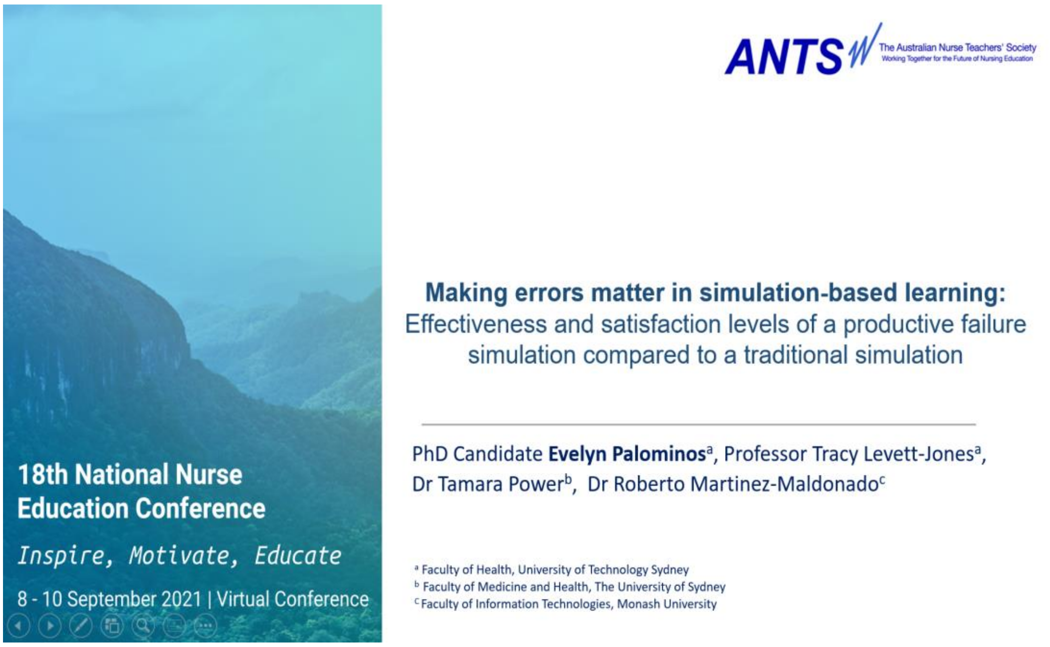
Methods: Second-year nursing students from one Australian university participated in the study. Participants (n = 344) were randomised into two groups: productive failure and direct instruction. The intervention consisted of two paediatric closed head injury simulations interspersed with a debrief. Knowledge tests were administered before and immediately after the simulation. Participants' satisfaction levels were measured using the Satisfaction with Simulation Experience Scale.

Results: The productive failure group (n = 174) significantly outperformed the direct instruction group (n = 157) in explanatory knowledge ($p < 0.001$) and the

transfer of learning to novel clinical problems ($p < 0.001$). The difference in the median scores for declarative knowledge was not significant ($p = 0.096$). Participants from both groups were highly satisfied with the simulation experience, however the productive failure group scored significantly higher in five satisfaction questions related to reflection on practice and clinical learning.

Conclusion: The productive failure simulation facilitated the acquisition of explanatory knowledge and the transfer of learning to new clinical situations; and this novel simulation approach facilitated meaningful reflection. In this presentation, potential educational strategies to implement productive failure simulations will be discussed.

Appendix 16. 18th National Nurse Educator Conference presentation



18th National Nurse Education Conference

Inspire, Motivate, Educate

8 - 10 September 2021 | Virtual Conference

ANTS The Australian Nurse Teachers' Society
Working Together for the Future of Nursing Education

Making errors matter in simulation-based learning:
Effectiveness and satisfaction levels of a productive failure simulation compared to a traditional simulation

PhD Candidate **Evelyn Palominos**[a], Professor Tracy Levett-Jones[a],
Dr Tamara Power[b], Dr Roberto Martinez-Maldonado[c]

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[b] Faculty of Medicine and Health, The University of Sydney
[c] Faculty of Information Technologies, Monash University

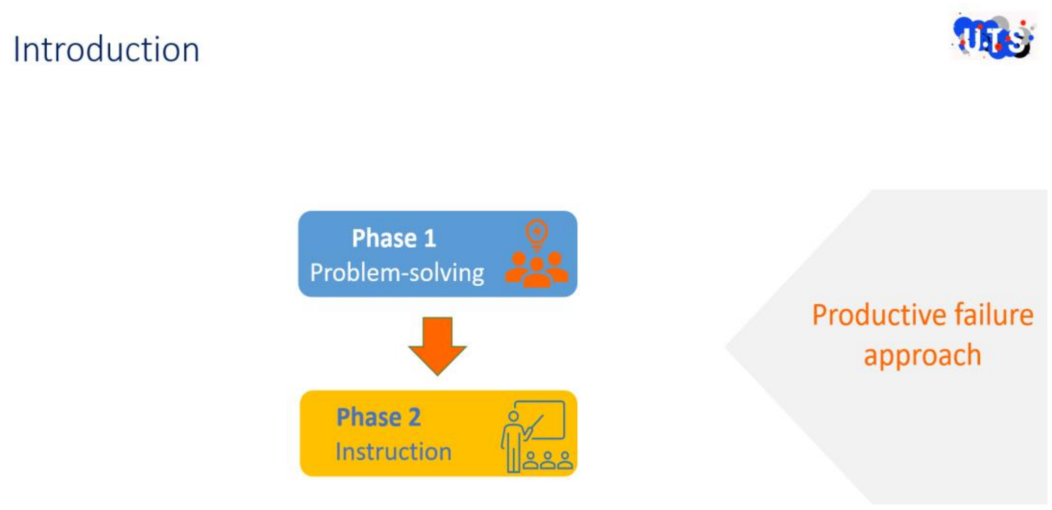
Introduction

We learn from our mistakes

Thomas Edison

Educational settings

Productive failure approach

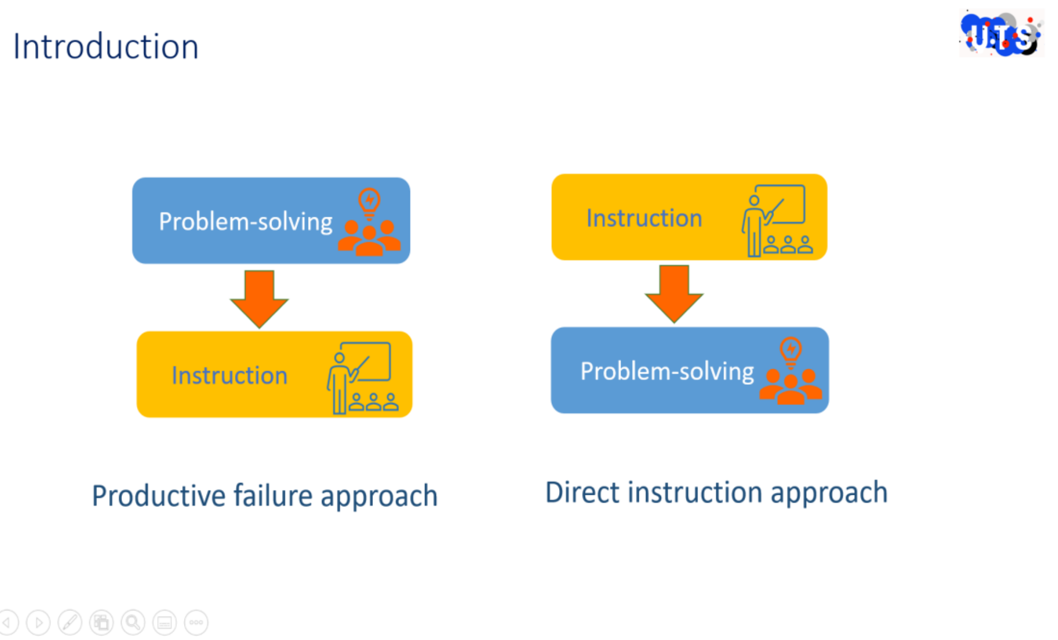


Introduction

Phase 1
Problem-solving

Phase 2
Instruction

Productive failure approach



Introduction

Problem-solving

Instruction

Productive failure approach

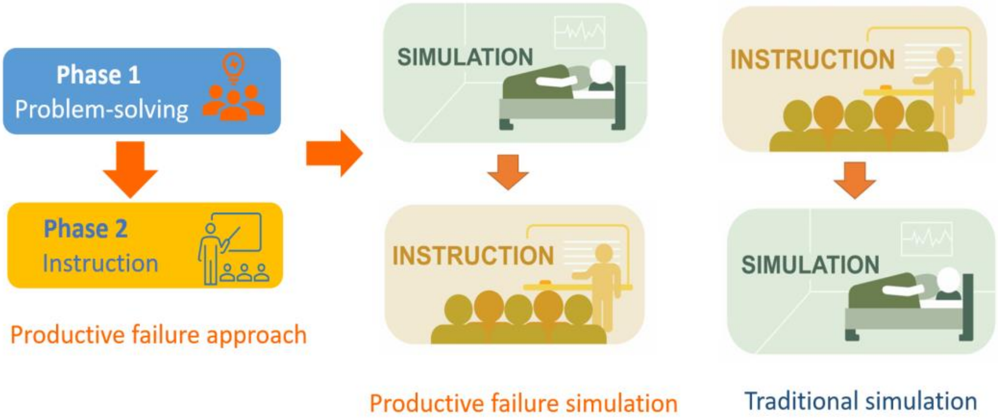
Instruction

Problem-solving

Direct instruction approach

Simulation–based learning

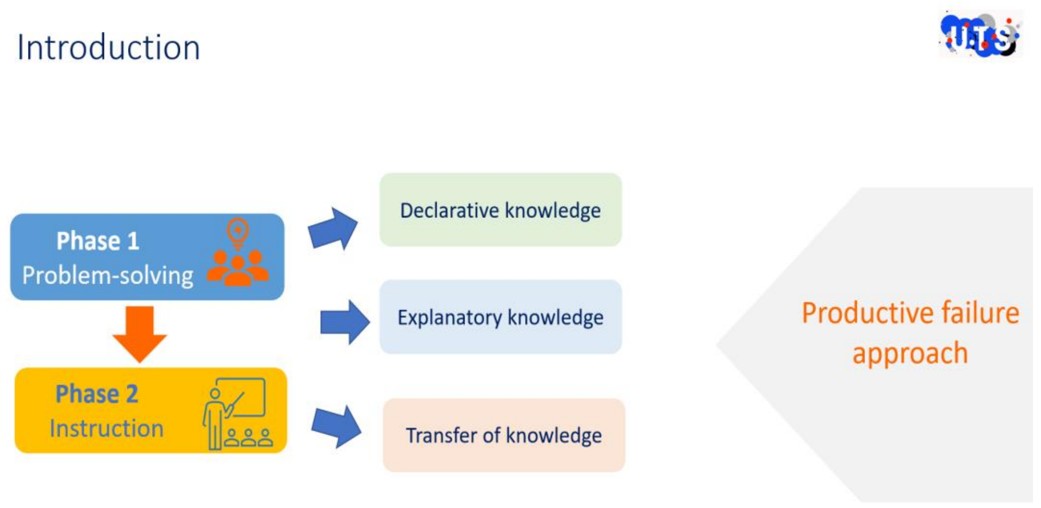
Introduction



Productive failure approach

Productive failure simulation

Traditional simulation



Introduction

Phase 1
Problem-solving

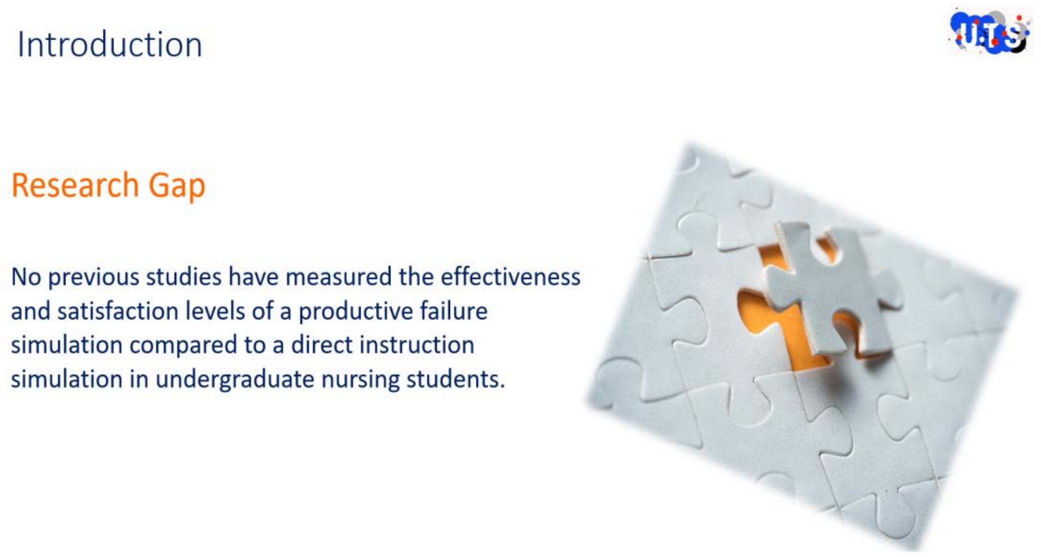
Phase 2
Instruction

Declarative knowledge

Explanatory knowledge

Transfer of knowledge

Productive failure approach



Introduction

Research Gap

No previous studies have measured the effectiveness and satisfaction levels of a productive failure simulation compared to a direct instruction simulation in undergraduate nursing students.

Study aims

To measure the impact of productive failure on nursing students' declarative knowledge, explanatory knowledge, and transfer of knowledge compared to a direct instruction approach.

To compare nursing students' satisfaction levels with a productive failure simulation and a direct instruction simulation.

Methods

Research design

A quasi-experimental, two-group, pre-test and post-test study.

Participants and setting

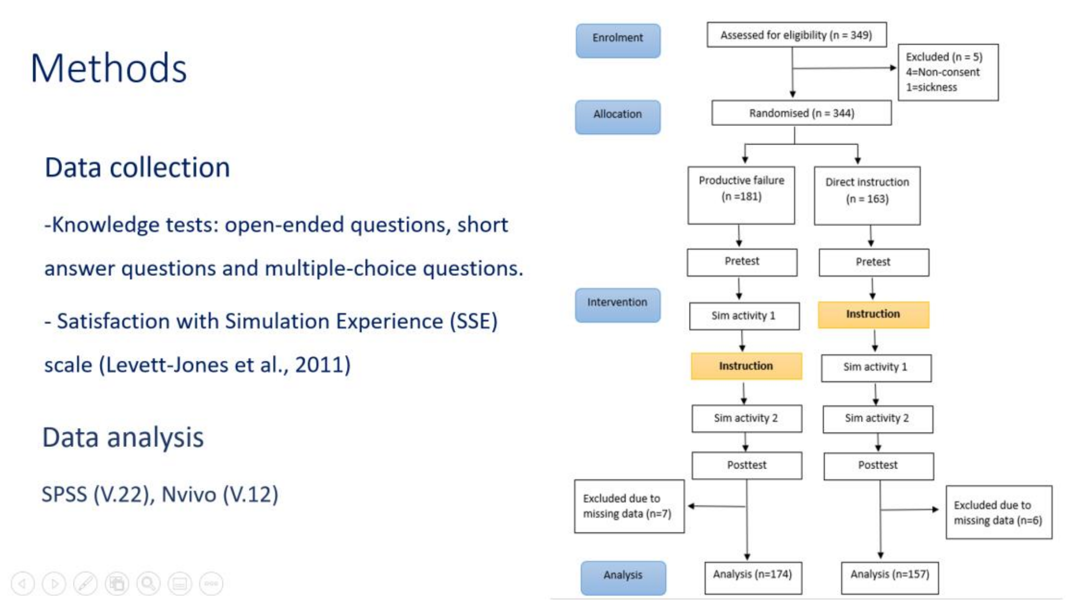
Second year nursing students (n = 349) enrolled in a paediatric clinical subject

The study was embedded in a scheduled, in-class simulation session.

Methods

Ethical considerations

- Ethical approval was granted by the university's human research ethics committee (protocol no. ETH19-3425)
- Participation was voluntary
- An identification number was used to protect the anonymity of the participants
- It was stressed that participation or non-participation will not adversely affect participants' course progression or assessments.



Methods

Data collection

-Knowledge tests: open-ended questions, short answer questions and multiple-choice questions.

- Satisfaction with Simulation Experience (SSE) scale (Levett-Jones et al., 2011)

Data analysis

SPSS (V.22), Nvivo (V.12)

Enrolment

Assessed for eligibility (n = 349)

Excluded (n = 5)
4=Non-consent
1=sickness

Allocation

Randomised (n = 344)

Productive failure (n =181)

Direct instruction (n = 163)

Intervention

Pretest

Pretest

Sim activity 1

Instruction

Instruction

Sim activity 1

Sim activity 2

Sim activity 2

Posttest

Posttest

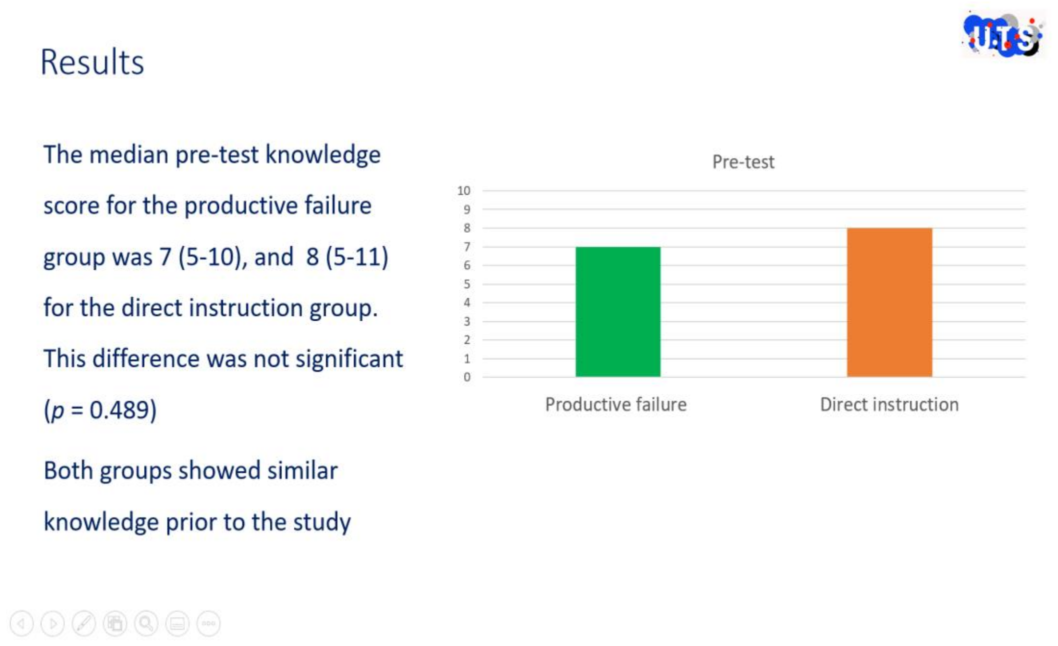
Excluded due to missing data (n=7)

Excluded due to missing data (n=6)

Analysis

Analysis (n=174)

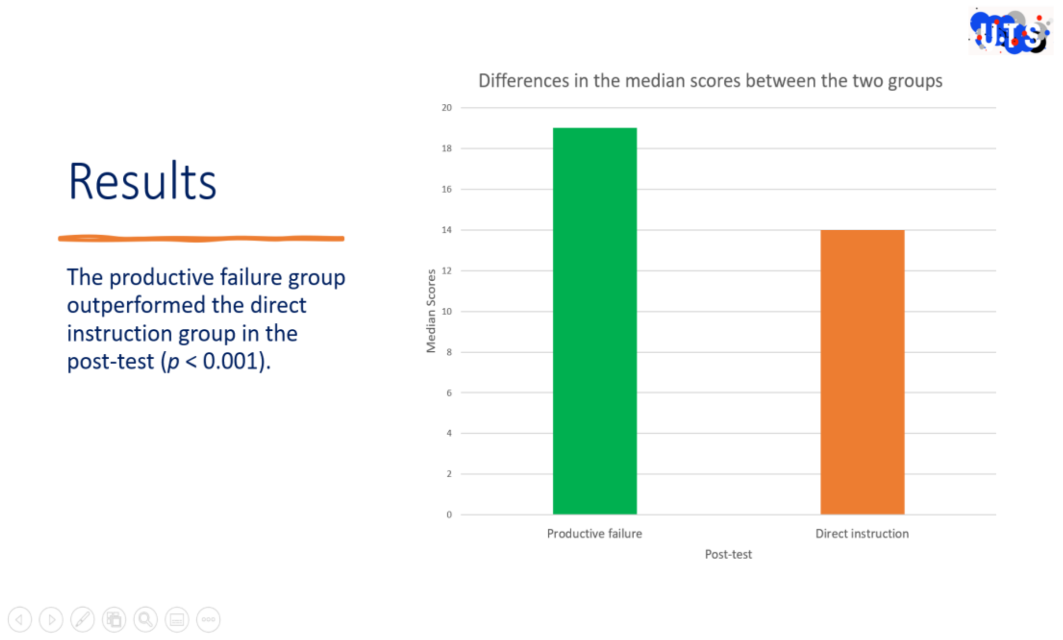
Analysis (n=157)



Results

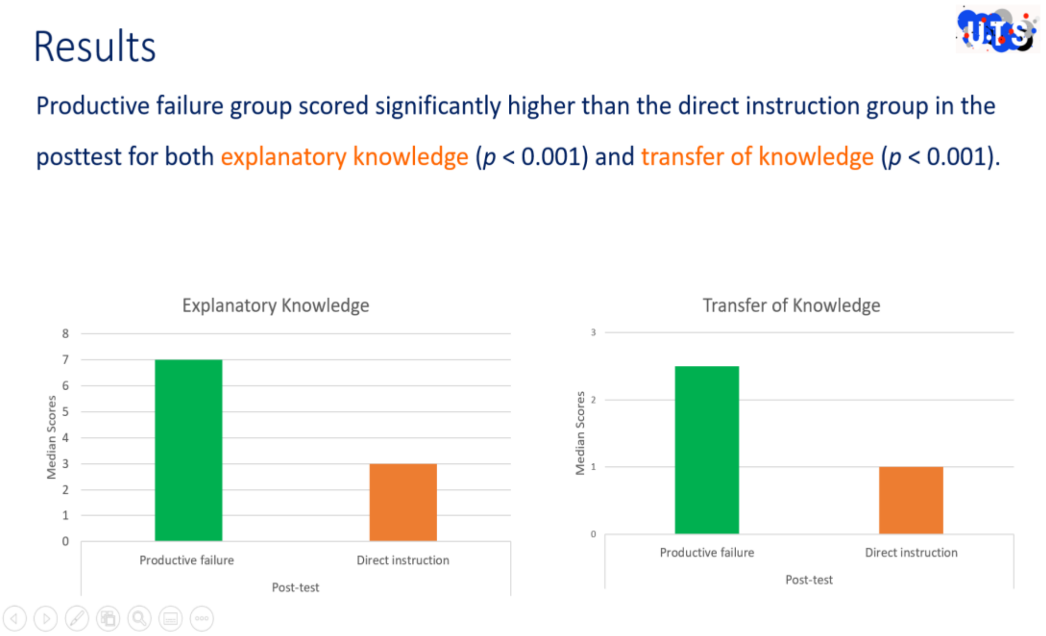
The median pre-test knowledge score for the productive failure group was 7 (5-10), and 8 (5-11) for the direct instruction group. This difference was not significant (*p* = 0.489)

Both groups showed similar knowledge prior to the study



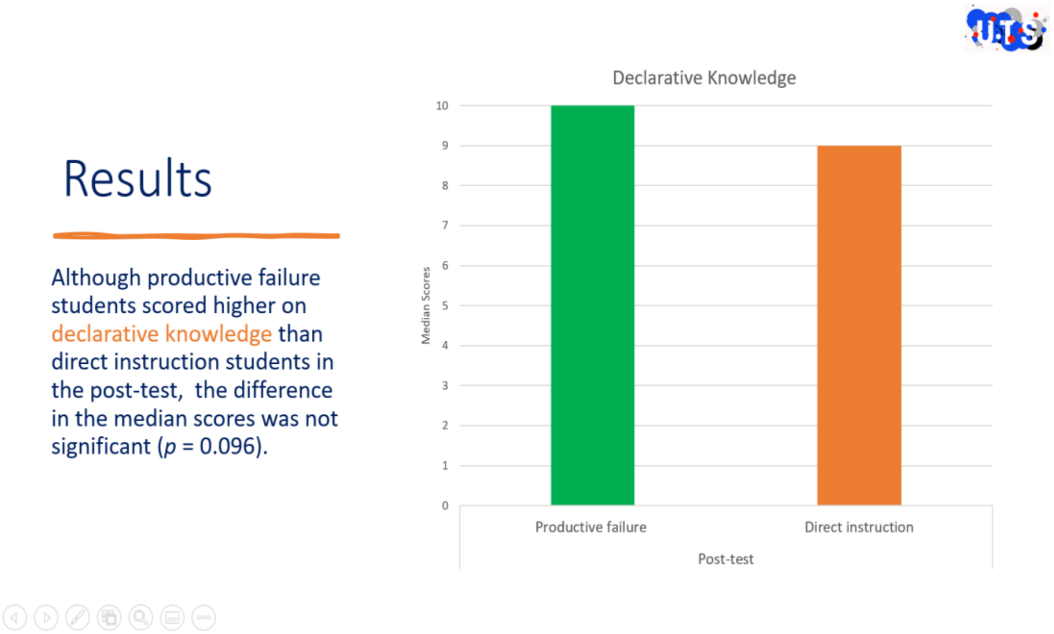
Results

The productive failure group outperformed the direct instruction group in the post-test (*p* < 0.001).



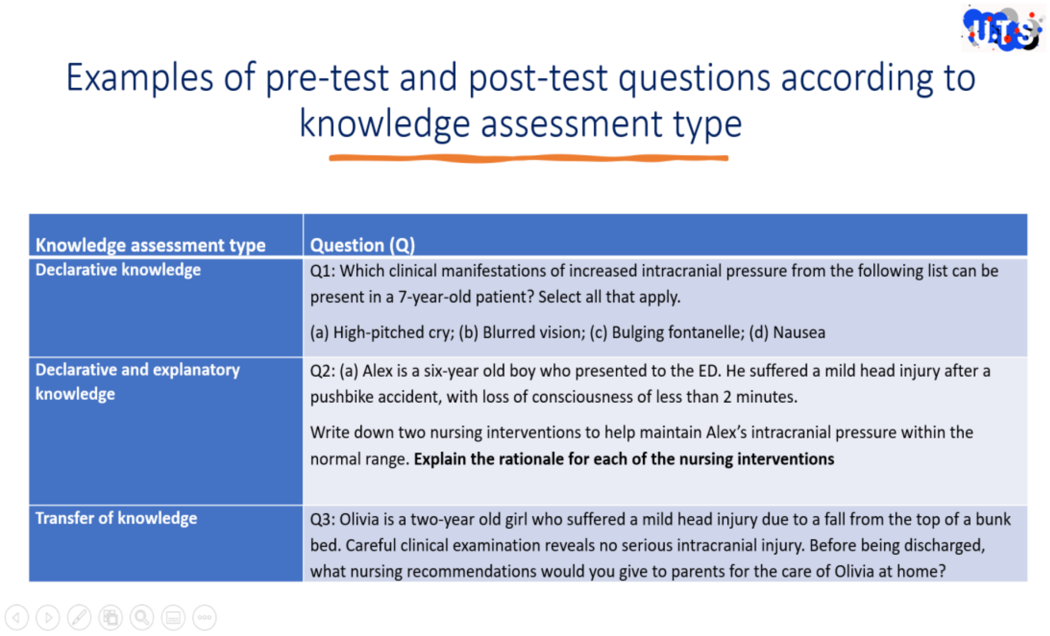
Results

Productive failure group scored significantly higher than the direct instruction group in the posttest for both explanatory knowledge ($p < 0.001$) and transfer of knowledge ($p < 0.001$).



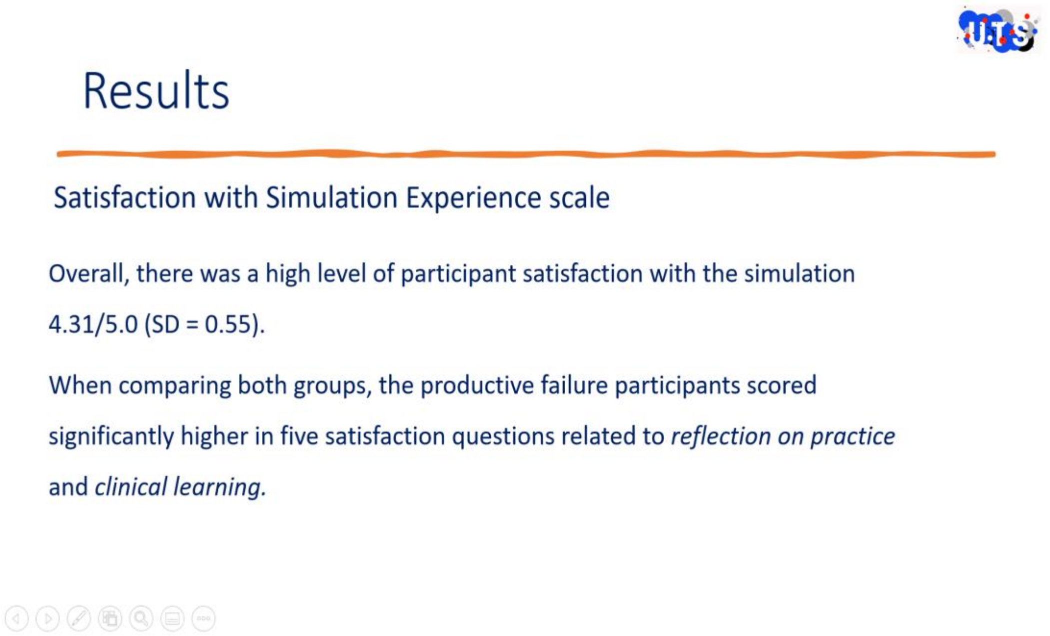
Results

Although productive failure students scored higher on declarative knowledge than direct instruction students in the post-test, the difference in the median scores was not significant ($p = 0.096$).



Examples of pre-test and post-test questions according to knowledge assessment type

Knowledge assessment type	Question (Q)
Declarative knowledge	Q1: Which clinical manifestations of increased intracranial pressure from the following list can be present in a 7-year-old patient? Select all that apply. (a) High-pitched cry; (b) Blurred vision; (c) Bulging fontanelle; (d) Nausea
Declarative and explanatory knowledge	Q2: (a) Alex is a six-year old boy who presented to the ED. He suffered a mild head injury after a pushbike accident, with loss of consciousness of less than 2 minutes. Write down two nursing interventions to help maintain Alex's intracranial pressure within the normal range. **Explain the rationale for each of the nursing interventions**
Transfer of knowledge	Q3: Olivia is a two-year old girl who suffered a mild head injury due to a fall from the top of a bunk bed. Careful clinical examination reveals no serious intracranial injury. Before being discharged, what nursing recommendations would you give to parents for the care of Olivia at home?

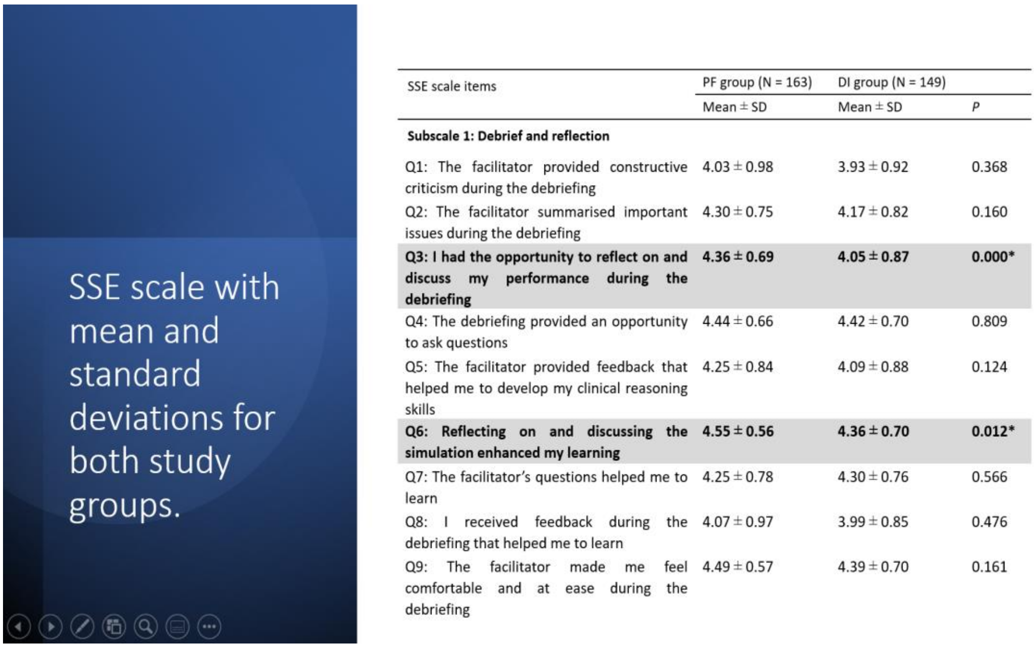


Results

Satisfaction with Simulation Experience scale

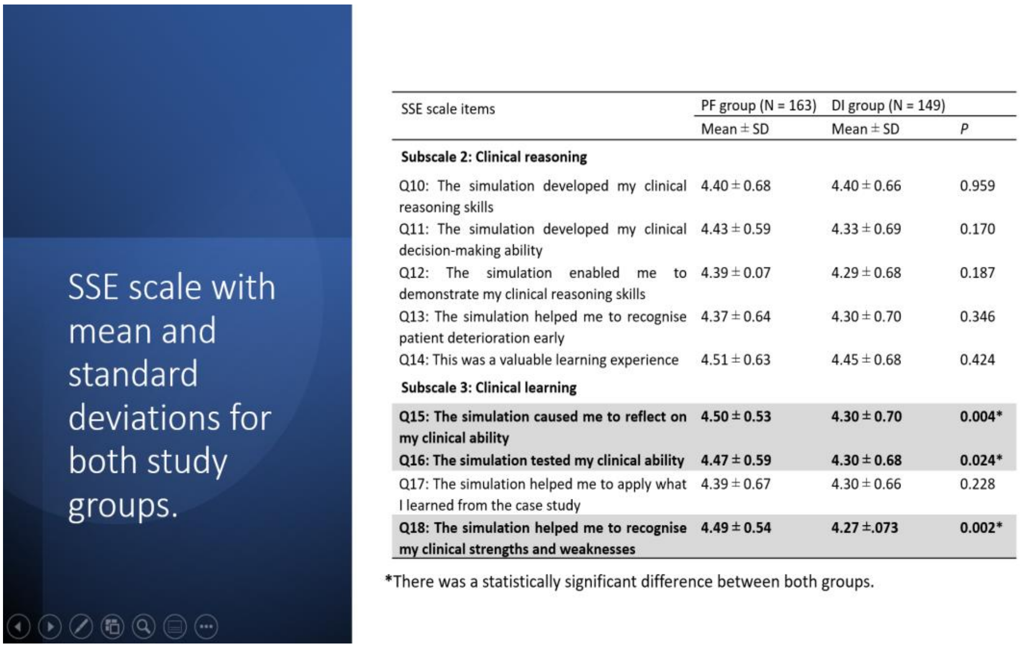
Overall, there was a high level of participant satisfaction with the simulation 4.31/5.0 (SD = 0.55).

When comparing both groups, the productive failure participants scored significantly higher in five satisfaction questions related to *reflection on practice* and *clinical learning.*



SSE scale with mean and standard deviations for both study groups.

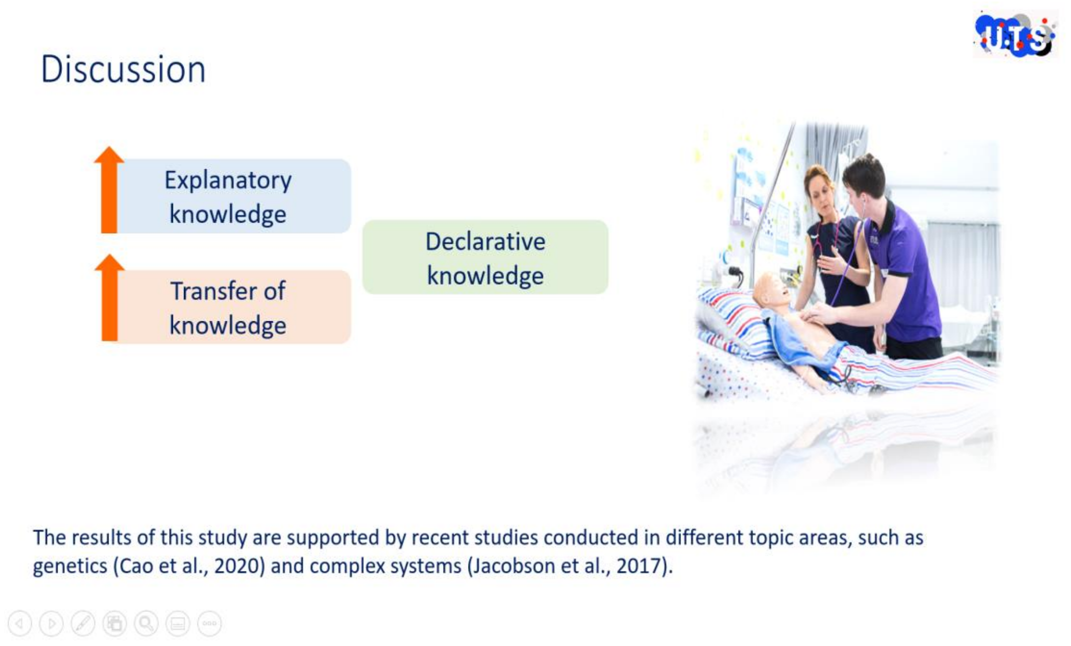
SSE scale items	PF group (N = 163)	DI group (N = 149)	
	Mean ± SD	Mean ± SD	*P*
Subscale 1: Debrief and reflection			
Q1: The facilitator provided constructive criticism during the debriefing	4.03 ± 0.98	3.93 ± 0.92	0.368
Q2: The facilitator summarised important issues during the debriefing	4.30 ± 0.75	4.17 ± 0.82	0.160
Q3: I had the opportunity to reflect on and discuss my performance during the debriefing	**4.36 ± 0.69**	**4.05 ± 0.87**	**0.000***
Q4: The debriefing provided an opportunity to ask questions	4.44 ± 0.66	4.42 ± 0.70	0.809
Q5: The facilitator provided feedback that helped me to develop my clinical reasoning skills	4.25 ± 0.84	4.09 ± 0.88	0.124
Q6: Reflecting on and discussing the simulation enhanced my learning	**4.55 ± 0.56**	**4.36 ± 0.70**	**0.012***
Q7: The facilitator's questions helped me to learn	4.25 ± 0.78	4.30 ± 0.76	0.566
Q8: I received feedback during the debriefing that helped me to learn	4.07 ± 0.97	3.99 ± 0.85	0.476
Q9: The facilitator made me feel comfortable and at ease during the debriefing	4.49 ± 0.57	4.39 ± 0.70	0.161



SSE scale with mean and standard deviations for both study groups.

SSE scale items	PF group (N = 163)	DI group (N = 149)	
	Mean ± SD	Mean ± SD	*P*
Subscale 2: Clinical reasoning			
Q10: The simulation developed my clinical reasoning skills	4.40 ± 0.68	4.40 ± 0.66	0.959
Q11: The simulation developed my clinical decision-making ability	4.43 ± 0.59	4.33 ± 0.69	0.170
Q12: The simulation enabled me to demonstrate my clinical reasoning skills	4.39 ± 0.07	4.29 ± 0.68	0.187
Q13: The simulation helped me to recognise patient deterioration early	4.37 ± 0.64	4.30 ± 0.70	0.346
Q14: This was a valuable learning experience	4.51 ± 0.63	4.45 ± 0.68	0.424
Subscale 3: Clinical learning			
Q15: The simulation caused me to reflect on my clinical ability	**4.50 ± 0.53**	**4.30 ± 0.70**	**0.004***
Q16: The simulation tested my clinical ability	**4.47 ± 0.59**	**4.30 ± 0.68**	**0.024***
Q17: The simulation helped me to apply what I learned from the case study	4.39 ± 0.67	4.30 ± 0.66	0.228
Q18: The simulation helped me to recognise my clinical strengths and weaknesses	**4.49 ± 0.54**	**4.27 ±.073**	**0.002***

*There was a statistically significant difference between both groups.



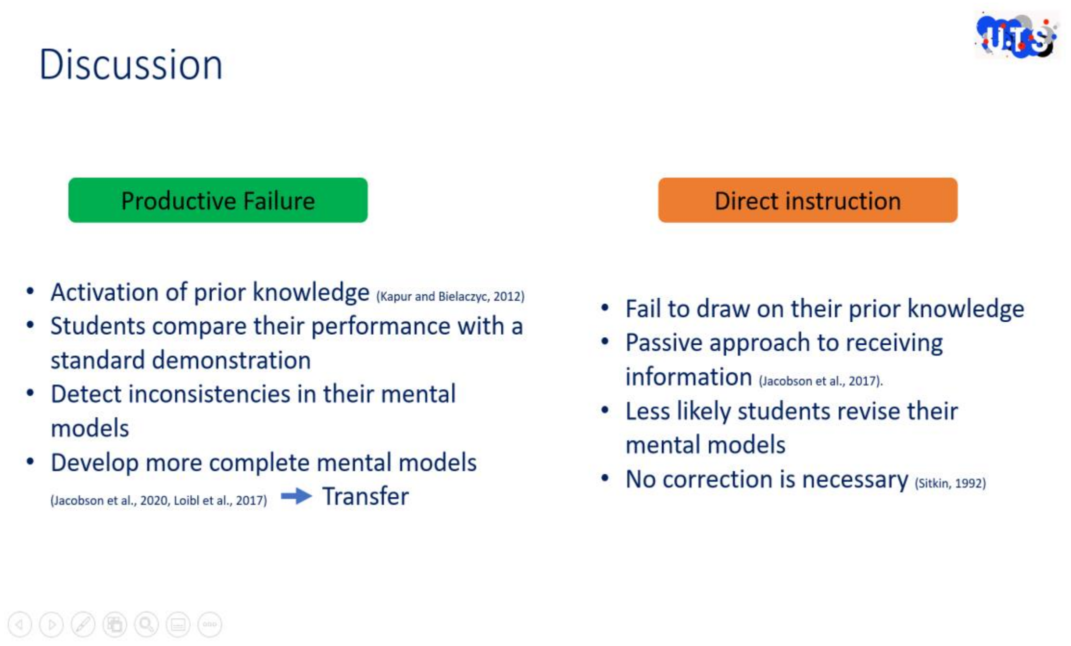
Discussion

Explanatory knowledge

Transfer of knowledge

Declarative knowledge

The results of this study are supported by recent studies conducted in different topic areas, such as genetics (Cao et al., 2020) and complex systems (Jacobson et al., 2017).



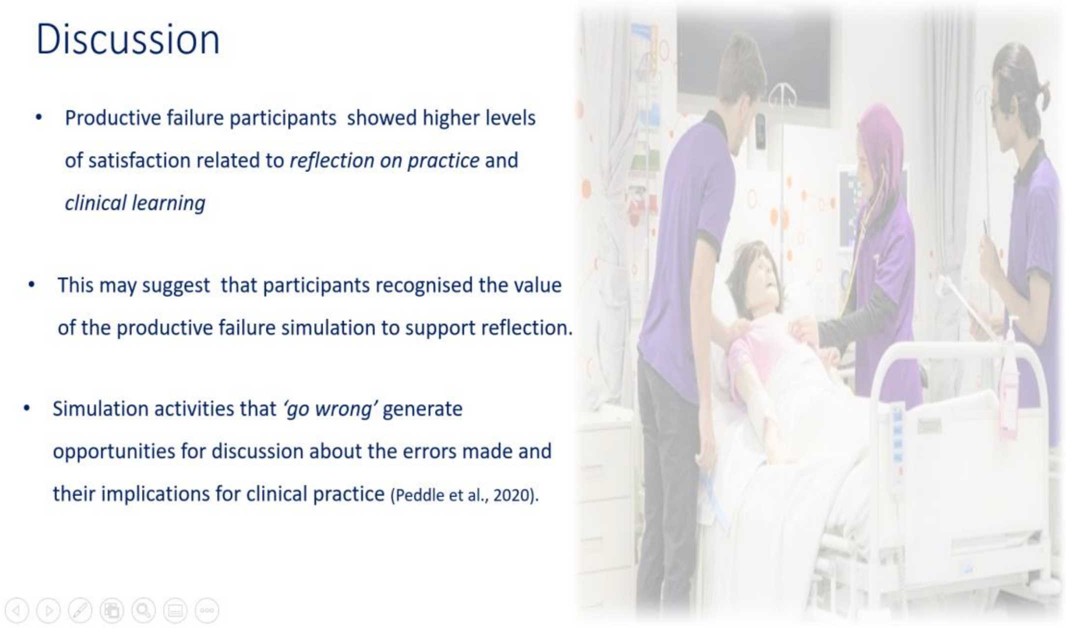
Discussion

Productive Failure

- Activation of prior knowledge (Kapur and Bielaczyc, 2012)
- Students compare their performance with a standard demonstration
- Detect inconsistencies in their mental models
- Develop more complete mental models (Jacobson et al., 2020, Loibl et al., 2017) ➔ Transfer

Direct instruction

- Fail to draw on their prior knowledge
- Passive approach to receiving information (Jacobson et al., 2017).
- Less likely students revise their mental models
- No correction is necessary (Sitkin, 1992)



Discussion

- Productive failure participants showed higher levels of satisfaction related to *reflection on practice* and *clinical learning*
- This may suggest that participants recognised the value of the productive failure simulation to support reflection.
- Simulation activities that *'go wrong'* generate opportunities for discussion about the errors made and their implications for clinical practice (Peddle et al., 2020).

Conclusion

- First study to measure the effectiveness and satisfaction levels
- Productive failure simulation may facilitate reflection of practice and clinical learning
- Productive failure approach could be integrated into the simulation curriculum to facilitate meaningful learning outcomes.

Acknowledgments

- Prof. Tracy Levett-Jones
- Dr Tamara Power
- Dr Roberto Martinez-Maldonado
- Prof. Michael Jacobson
- Dr Suzanne Sheppard-Law
- RN Nadine Alcorn
- Simulation facilitators
- Nursing students
- Mahalia Vallido
- Australian Government Research Training Program

Thank you

We all make mistakes, and it is better to make them before we begin.

— Nikola Tesla —

References available on request

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