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Critical aspects of design for educational simulations in a medical context

Ruben Hopmans
Bachelor of Multimedia

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Abstract

This thesis investigates the relationship between the design decisions of developing a medical educational simulation, the learning outcomes and student experience, in order to improve the design process for medical simulations. The research highlights the key design features of the First2Act online medical simulation that includes extensive video components and then analyses learner performance in order to identify which design decisions have the greatest impact on learning outcomes. Medical educational simulations require careful planning to achieve very specific learning outcomes. The medical industry leads the way in creating high-level simulations, and while research measures learning outcomes, it does not often include the impact of individual simulation components on those outcomes. A better understanding of the link between design elements and learning outcomes will contribute to better design guidelines in this field.

This research collected a range of data from student interactions with a simulation and mapped results to learning improvements to identify which characteristics had the greatest impact on learning. Data collected included: 1: a/b multiple-choice quiz of learner knowledge, 2: interactions with interactive video-based scenarios, and 3: a survey on student experience. The multiple-choice quiz tracked the results of 367 nursing students, giving an indication of the areas where knowledge improved. Careful analysis of interaction patterns against those test results revealed that a combination of straightforward and clear learning material, the reiteration of those concepts to the student, and explicit feedback instructing students on the ideal response to the simulated scenarios' improved the prospects of learning. The impact was greatest for poorly understood concepts.

These results concluded that the design and development process should include a definitive list of learning outcomes, careful formulation of content, composing explicit feedback and designing interactions to encourage repetition. Improving the process for development of medical educational simulations not only improves learning outcomes, but also allows designers to focus often-limited resources on the simulation features that are more effective for learning. This thesis specifically looks into the design of learning simulations for the medical industry. However, the improved methodologies gained from the research have application in other industries developing e-learning simulations.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed__________[redacted]___________________ Dated__12/02/2016_

(Ruben Hopmans)

As supervisor of Ruben Hopmans I confirm that the work submitted in this thesis/project has, to the best of my knowledge, been carried out by the student named above, and is worthy of examination.

Signed________[redacted]______________ Dated___12/02/2016__

(Dr. Matthew Butler)

Signed__________[redacted]________ Dated___12/02/2016__

(Dr. Michael Morgan)

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Table of Contents

List of Figures

List of Plates

List of Tables

Chapter 1: Introduction

1.1 Overview

Medical education institutions are leaders in using simulations for situational, or experiential learning. However, their commitment towards the accurate transfer of knowledge can make the costs of producing these simulations expensive and difficult to design and create. Moving simulations online may offer a solution. Online simulations can reduce the cost of a simulation experience through increasing the number of students who have access. Online simulations can also allow students to repeat the experience as many times as needed in order to be competent, something which is difficult with live simulation experiences. Having a better understanding of how the design of online simulation impacts learning can help to maximise their teaching potential.

This thesis investigates the design and development of the First2Act online training system targeted at nursing students (http://wwww.first2actweb.com). The First2Act online training program aims to teach nursing students how to diagnose and manage acutely deteriorating patients (all elderly males) in a simulated hospital setting using interactive video for the simulation. The First2Act team had created much of the educational material before this research began. The team includes Monash University School of Nursing and Midwifery, University of Queensland, Deakin University and Gippsland TAFE. This research occurred during the building of the online platform, the creation of interactive video scenarios, the delivery of the program and the collection of data for both this research and the First2Act Project. To clearly distinguish between what this research is investigating, the First2Act Project refers to the study undertaken by the First2Act team, and includes the online training program, as well as the face-to-face simulations that occurred before its creation.

This study investigates the design process followed for the online training program and the development of the website, quizzes and simulation. It analyses the interaction data for the simulation and utilises data collected from the online program's quizzes as a means of measuring learning outcomes. When referring to the 'artefact' or 'simulation', it will mean the three interactive video scenarios collectively, with ‘scenario’ referring to one of the three scenarios; cardiac, respiratory or shock. When referring to the ‘online program’ this will cover all aspects of the First2Act online training program’s website, which includes quizzes, questionnaires and the simulation.

The thesis analyses the development of the online training program, which includes both design of education material and the building of the online platform, and then examines the processes that create successful simulations from both a developmental and educational perspective. Taking the aggregate data collected from the simulation test results, and comparing this with pre and post multiple-choice quiz (MCQ) results, highlights the aspects that work well in educating students through this medium. Further investigation of interaction data from the simulation, student feedback, and academic results yield interesting insights into the interactions with the simulation and their impact on the educational outcomes of students. The major findings from this study suggest that the design objectives of educational material must be clear and be supported in the simulated experience. Additionally, the ability to repeat the learning experience further solidifies knowledge for the learner.

1.2 Background of the Study

The design and development of simulations for training students can have an impact on the success of educational outcomes (Aldrich, 2005; Biggs & Tang, 2011; Gibson & Baek, 2009; Herrington, Reeves, & Oliver, 2010; Moreno-Ger, Blesius, Currier, Sierra, & Fernandez-Manjón, 2008). Designing simulations requires careful attention to all steps in the process. The design process should include everything from the creation of the media assets to the instructional design. While research in areas of instructional design and user experience design is extensive, there is limited research that investigates the impact that these design processes play in achieving learning outcomes. In fact, some of the objectives from both design methodologies are often in opposition. ‘Instructional design’— the design of a learning experience — typically encourages the participant to stop and reflect, whereas ‘user experience design’ tries to minimise these types of barriers, so the user needs to think as little as possible (Peters, 2013). Furthermore, the process of designing instruction and designing the user experience often occur independently. This disconnection often results in one design process being compromised to fit the other's constraints. Some methods for a ubiquitous development exist, but further investigation could clarify these techniques and help identify elements that have positive or negative effects on learning outcomes for students.

Medical institutions are leaders in instructional design for automating the learning process, many using artefacts such as simulations in their training. Due to a need for accuracy in educating, learning outcomes for medical simulations are often extremely explicit. As a result, there is a very close correlation between the educational material and specific concepts the students need to learn. The strong link between the content and learning outcomes provides an opportunity to investigate which aspects of simulation design impacts what students learn. Through the collection of analytics of the user experience and its correlation with learning results, it is possible to highlight the aspects of simulations that have the greatest impact on learning. The analysis of this data, backed by open-commented feedback, is likely to reveal areas where the simulations excel and, more broadly, excellence in user interaction design. Development techniques that support good interaction design will help to minimise the effects of cognitive load on the user ability to learn. Herrington, Reeves and Oliver (2010) describe simulations as authentic experiences that allow situational learning to occur (p. 16). Simulations align with many education theories that support the experiential learning techniques, which will guide the analysis of the research (Prensky et al., 2007). However, the primary goal of this research will be to discover how the interaction and user experience influences learning and to adjust the design process accordingly. A better understanding of the relationship between educational material and simulations and how that influences learning will improve the development process of future projects. While this research focuses on medical simulations, the findings will also be applicable to simulation design processes in other academic fields.

Online delivery of education is a growing field and, while it has been around for several decades, only in recent years has Internet use for education started to become prolific (Mathews, 2015). Increases in Internet speed have made online simulations more accessible especially when they include video and media-rich content without the severe restrictions on file sizes (bandwidth). Online simulations and other media-rich education materials are now gaining momentum as a viable means of educating large numbers of students. Nursing is one of many medical professions that currently use live scenarios to help train students to be ready for placements in hospitals (Cant & Cooper, 2010). This technique is a very effective way to train nurses in a realistic but safe environment. However, despite its educational merit, live simulations are a very costly and logistically difficult way to teach large numbers of students (Waterhouse, 2005). Online simulations have proved an effective way of managing this problem. However, much of the research on education through simulations is limited to academic fields unrelated to medicine. When it does occur in medical related fields, the focus is often on the educational material rather than the technology and techniques used to deliver the material. It stands to reason that these two areas, education material and its delivery, are not mutually exclusive. A better understanding of the relationship would yield a better design process and better educational outcomes.

1.3 Aims of the Research

The purpose of this research is to identify the features of the First2Act online learning simulation that have the greatest impact on learning outcomes. The First2Act program is designed to assist nursing students in diagnosis and management of acute patient deterioration. Through investigating the design and development process from both an educational and technological perspective it is hoped to reveal what steps are required to develop a befitting simulation.

By collecting a mixture of data, including academic results and user interactions, there is an opportunity to cross-examine student results against how the students use the simulation. The data will help to establish relationships between students' interactions and their understanding of the learning objectives, and identify characteristics of the simulation that align with improvements in the students' perceptions of their confidence with the subject matter. Conversely, it may reveal the characteristics of the simulation that decrease students' perceptions of their confidence with the subject matter. Collecting data on the overall student experience may give further insight into the effectiveness of the simulation as an educational tool, as well as highlight features that students like or dislike. Finally, in a summary of those points, it should be clear what features need improvement in the simulation.

1.3.1 Research Questions

This section will outline each research question with the primary question being discussed first. Secondary questions broadly try to answer three areas of interest. Namely, factors for success in the early stages of development, student sentiment on their use of educational simulations, and design and technical features that impact learning. Further detail on the three outlined areas form part of the primary research question.

Primary Research Question: What are the critical aspects of designing an online learning simulation that assists nursing students in patient diagnosis and management?

A clear definition of the learning objectives of a simulation project is critical to its ultimate success (Aldrich, 2005; Herrington et al., 2010; Prensky et al., 2007; Waterhouse, 2005). Recognising how best to achieve those goals is an important factor in how successful a simulation is in delivering fundamental learning outcomes. To better understand the critical aspects of designing online simulations, the following sub-questions address specific areas of interest. The three main areas of interest are

1. an understanding of the design and development process for a simulation and which factors are important to the success of this early stage *(S1, S2)*;
2. an investigation into the student sentiment, to better understand what students consider critical to their understanding *(S3, S4, S5)*;
3. and an analysis of simulation features to understand the connections between how students use the simulation and how this impacts on their learning *(S2, S6)*

To find which aspects of designing a simulation are critical to it's success, it is necessary to have a clear idea of the impact each feature of a simulation has on the learning outcomes. When such links are made, they can be tied back to the design and development process, and the process can be adjusted to maximise learning outcome potential of future simulations. Understanding which aspects in the design process have the greatest impact on learning means that resources can be appropriately distributed to each stage in development. The sub-questions are designed to identify the steps in the design process, and identify the impact that different features of the simulation have on learning outcomes. The following sections outline the secondary research questions, necessary to answer the primary research question.

What steps are required to design an appropriate learning simulation? *(S1)*

To understand the design and development process for a simulation, this question investigates the current best practices for online simulation development, and will help to determine the key steps to follow for success. Combining this process with the First2Act learning objectives can isolate the design and development steps that are critical. However, it is important to prioritise the learning objectives against the relative difficulty involved with its technical creation; some learning objectives could be impossible to simulate. Improving the decision-making early on in the development lifecycle may highlight how to best allocate resources in order to achieve favourable outcomes.

How do students' interactions with the system relate to improvements in their performance? *(S2)*

Understanding the impact of interactions with the simulation on the students' learning is paramount to identifying which simulation features to concentrate development resources. Analysing students' pre and post quiz answers through isolating the high and low performing students, should reveal patterns within their interactions. Further segregating individual key learning objectives and measuring their performance will narrow the focus on what interaction features are most useful. With a more focused approach, it is likely that patterns will emerge around specific areas of the interface and user interactions, this can then be linked back to the design process for those areas and provide an overview for investigating which simulation features need improvement.

What characteristics of the simulation align with improvements in the students' perceptions of their confidence with the subject matter? *(S3)*

While students can learn to answer questions correctly, learning objectives can extend beyond this factual level. Improving nursing students' confidence to perform under pressure in a simulation can improve their ability to perform in equivalent real life situations (Aldrich, 2005; Bambini, Washburn, & Perkins, 2009). Student perception plays a part in the ultimate success of a simulation learning experience. Examining the interaction patterns of students who felt greater confidence after completing the simulation should identify principal characteristics that improve the students' confidence with the subject matter. The characteristics that generate the greatest improvements can be flagged as an important part of the achieving educational goals.

What characteristics of the simulation align with decreases in students' perceptions of their confidence with the subject matter? *(S4)*

Conversely, students who feel less confident with the subject matter after using the simulation may have had negative experiences. Investigating interactions of students whose confidence fell it is likely to indicate what main factors are the causes. The data of students whose confidence fell would be mapped against their quiz scores, the interaction data, and technical issues they faced, to highlight any additional causes. These potential issues can be linked to the design and development process for special attention, as possible problem areas.

What was the student reaction to the simulation experience? *(S5)*

The level of engagement that students have with a simulation can influence their ability to learn (Aldrich, 2005; Carini, Kuh, & Klein, 2006). Understanding which interactions are most engaging will help prioritise which features to develop for the simulation. Student feedback about the experience is one way to gauge their reaction to the simulation. Identifying themes in open comments helps to recognize the most engaging features of the simulation. The design and development process should encourage the use of any features that can make a simulation more engaging and find ways to link them to learning objectives.

What features of the simulation need to be improved? *(S6)*

Examining all of the sub-questions will establish a definitive list of features that have positive, neutral or negative impact on users. The list can be broken down into four main areas: impact on learning, experience/engagement, student confidence and usability. This guide will help to allocate resources appropriately for different simulation features, particularly for projects where resources are finite. Through finding areas of improvement for the First2Act program, an updated design process that recognises these flaws can be created.

Summary of research questions

The main research question aims to identify the aspects of online educational simulation design that have a critical impact on student learning outcomes. The first secondary question *(S1)* aims to identify current best practice in simulation design. The next secondary question *(S2)* will highlight the different features of the simulation and how they affect learning outcomes. The secondary questions 3-5 *(S3-S5)* investigate student experience of the simulation and identifies student expectations, then links these back to student performance and interaction with the simulation. The final secondary question *(S6)*, with findings from previous questions, hopes to identify key issues and faults in the First2Act program and isolate technical failures and potential problem areas that could then be avoided in future projects. Using data from the First2Act program, the secondary questions aim to identify critical aspects in the design and development process that have the greatest impact on learning and help to improve future versions of the First2Act program.

1.3.2 Significance

This research investigates ways to improve the process of designing and developing a simulation with educational outcomes as the focus. Design methodologies are rigorous for both instructional design and interaction design. However, there is a lack of supportive evidence for applying both methods simultaneously, in particular, the effectiveness of simulations' interactive features on the learning outcomes. A study of the impact on learning could highlight the most influential features and help to improve the design process overall.

Understanding these relationships would inform on where best to concentrate efforts to get the maximum gain from developing a simulation.

The study hopes to reveal the essential features of simulations that have the greatest impact on learning outcomes while also establishing which design methods align most with delivering the best results. Making the two typically separate design processes ubiquitous in nature, and improving the efficiency of developing e-learning simulations. Answering the primary research question should highlight critical aspects of the design and development of simulations that maximise the learning potential of medical and other educational online simulations.

1.4 Methodology

Through the documentation of the development process and the final creation of the First2Act simulation, this research will identify the key mechanisms that determine the success of the project. During design, the principal objectives are highlighted, and later reviewed to see how well they achieved their perceived goals. Once created, data of what the students have learnt from the simulation, as well as interaction data, will be collated. The data will be analysed to identify areas of improved learning and mapped against user interaction, in an effort to isolate the primary features of the simulation that had the greatest influence on learning. Second to this will be an analysis of the areas where the impact on learning was neutral or negative. The measurement of simulation features will reveal their effectiveness in the learning process, and may be applied to the design process to highlight where best to concentrate resources for the greatest benefit.

1.4.1 Conceptual Framework

Design Science is the chosen methodology for this research, as the simulation will act as the artefact for testing. Design Science aligns with the outcomes intended for this study, which is testing the effectiveness of simulation from both an educational and technological perspective. A range of quantitative and qualitative data through pre and post multiple-choice quizzes (MCQ), questionnaires and user interaction from within the simulation, will best serve the research. The ability to design a custom system that allows measurements of interaction to be mapped against educational data will yield more accurate links between how the simulation works and how it educates.

1.4.2 Design and Development of the Research Artefact

The development team of the First2Act online training program includes the Monash University School of Nursing and Midwifery, University of Queensland, Deakin University and Gippsland TAFE. The project lead, Professor Simon Cooper (Monash), began the artefact design process during face-to-face trials of the First2Act Patient Deterioration Simulation (Buykx et al., 2011). The face-to-face trials involved actors and assessors/instructors who ran the simulations with small groups of students in a simulated hospital ward. Cooper and a number of leading academics, from Monash University and the University of Queensland, devised the assessment criteria and the three online simulation themes based on the face-to-face trials. This research began after the content design and creation had almost been completed and reviews the assessment criteria set by the First2Act project team. Prior to this research commencing, a team of students under the instruction of an educational media expert created the majority of video content. The artefact design includes the creation of a website to host the program (http://www.first2actweb.com), a number of online questionnaires and a video presentation (slideshow) of the First2Act manual. Finally, the creation of the interactive video-based scenarios forms the final part of the artefact in this research. All data collection forms part of this research. The project lead directed the particular type of data collected according to terms and conditions outlined by the funding body, Office of Learning and Teaching (OLT), and data was used in other studies related to that grant.

1.5 Thesis Structure

This thesis contains six chapters, beginning with an introduction of First2Act and how this research fits into this training program. Following on from this is a discussion of current research in the fields of education and human-computer interaction, with a focus on simulation scenarios and their design. Subsequently, a description of how the research applies to the design of the interactive video-based scenarios as part of the First2act online program. The entire First2Act online program encompasses all related online activities, including the three interactive scenarios. The thesis then moves on to how the research methodology has influenced the design process relative to results and their analysis. The analysis of the results follows, discussing the particular aspects of the simulation that impact learning. Finally, a summary of the findings of the research and suggested improvements, including any limitations and further research required, is discussed.

Chapter 1 Introduction

This chapter identifies the team members and their contributions to the First2act online program while discussing how this research fits within the First2Act project. It describes the areas of research covered by this thesis and a general overview of the study and impact this research may have on designing simulations for education.

Chapter 2 Literature Review

Following on from the Introduction, this section is a review of current research in the areas covered by this thesis, consisting of learning theories, user interface and interaction design, and more pointedly; educational simulation design. A summary of the current methods of instructional design and simulation design follows. The discussion then explores the issues of combining these two design philosophies.

Chapter 3 Design of the Online Simulation

A detailed description of the design of the artefact highlights the process involved in producing the simulation. It includes a description of each aspect of the simulation design and decision process that lead to those choices. Design Science forms the basis of this design process with an explanation of that methodology in the following chapter.

Chapter 4 Methodology

Design Science as a methodology provides an ideal environment for discovery in this thesis. This chapter highlights why this methodology is used and how this affects the data collected, and its analysis. The planned analysis techniques are explained and justified, further connecting the data with each research question. Discussion of ethics and the controls and limitations follow.

Chapter 5 Experimental Results and Analysis

This chapter discusses each research question, and then presents and analyses the associated data. Each research question builds on previous findings, before summarising findings for the main research question.

Chapter 6 Conclusions and Further Research

Finally, conclusions are drawn from chapter 5, and a summary of the results described. Following the discussion of the findings is a report on limitations in the scope of the study and recommended future research.

1.6 Summary

In conclusion, this thesis hopes to improve the design and development of online simulations, with a particular focus on education for nursing students. With the intention of understanding and improving them, a thorough investigation of current methods for instructional design and online simulation design is undertaken. During experimentation, ranges of data types are collected to help gain a clear picture of the effectiveness of the features of online simulations and their impacts on learning. Improvements and efficiencies of the two design methods are then discussed, and a more cohesive design method for educational online simulations developed.

Chapter 2: Literature Review

2.1 Introduction

This chapter surveys research related to designing and developing medical simulations for training. Firstly, this chapter outlines developments in e-learning and describes the learning theory that supports it. From this a more in-depth look at simulation characteristics follows. It will then separate educational simulations from the broader genre and detail their unique features. Assessment of simulation assets will allow for a deeper understanding of each asset type and its role in the education process.

From here the literature review will take a close look at medical simulation qualities and their impacts on learning outcomes and the careful planning required to achieve favourable results. The medical industry leads the way in creating high-quality simulations, so examples are used to demonstrate important concepts. Finally, the current methods used to design simulations are discussed, highlighting key areas, such as critical design roles, defining learning objectives and feedback and evaluation. The chapter concludes by describing the limitations of simulations and the issues current design methodologies face.

2.2 E-learning and Learning Theory

Electronic educational technology or e-learning technology is a subset of education technology, which more broadly covers all technology used in learning, electronic or otherwise. Electronic educational technology is not restricted to high technology, broadly covering most media formats, including audio, videotapes, TV, CD and DVD. Luskin (2010), an education technology pioneer, describes the ‘e’ in e-learning to refer to electronic. However, Luskin (2010) also stated it could be for “exciting, energetic, enthusiastic, emotional, extended, excellent, and educational”. From the 1960s onwards there has been a steady increase in e-learning technologies across all levels of education. As Internet access has become more prevalent, e-learning has shifted from educational mediums like TV and CD software to using the Internet for delivery through websites and web applications. The use of the Internet to gain access to educational content, through a range of devices such as mobile phones and computers, is ever rapidly increasing.

E-learning as part of education technology employs a range of engagement methods utilising communication techniques and media formats. The term ‘multi-media learning’ is one of the many interchangeable terms that also define e-learning and, for clarity, the term e-learning will be all inclusive of other terms (Peters, 2013). In the context of this research, the term ‘e-learning’ refers to the use of electronic technologies to give students a learning experience. The experience would typically be delivered using mixed-format media and a range of online communication techniques. Media formats include but are not limited to: video, audio, photography and visualisations, which may or may not be interactive in nature. The communication techniques will include, but again are not limited to: email, online questionnaires and quizzes, interface and content design, human and computer generated feedback and assessment.

E-learning is not exclusive to using high-end technologies. However, as part of the contemporary setting of e-learning, the use of more cutting edge technology has become standard (Aldrich, 2005; Ertmer, Gopalakrishnan, & Ross, 2001; Holzinger, Kickmeier-Rust, Wassertheurer, & Hessinger, 2009; Peters, 2013). Many modern e-learning environments look towards the use of latest technologies to take advantage of the new and emerging opportunities that these technologies provide. As a result, e-learning environments take on many forms, including independent websites delivering content with minimal interaction or feedback. An example of this is ‘Crash Course’ a video-based lecture format that includes animations delivered via YouTube. The authors and students interact mainly through the comments section of the website. These discussions help to determine future course creation.

On the opposite side of the scale are the complex learning management systems (LMS), such as Moodle (https://moodle.com/). Many universities have adopted Moodle to help manage course material. This LMS integrates multiple subjects and courses and provides the central portal for the delivery of subject material, assignment submission and feedback. The LMS provides the ability to test students through quizzes and includes learning analytics of student behaviour. Students can also manage their individual learning. For example, a student can mark each activity as they complete it, keeping a record of where they are up to. There are many examples of dynamic and self-managed learning environments. Khan Academy is one contemporary example that is currently being used in classrooms by 500,000 teachers around the world. This e-learning website provides multiple ways for students to learn the same content. Known as an "adaptive educational system" (Ruipérez-Valiente, Muñoz-Merino, Leony, & Kloos, 2014) this complements the student's current knowledge and learning style. It has the potential to speed up the learning process by minimising cognitive load that impacts the learning process (Paas, Renkl, & Sweller, 2004).

Khan Academy is one of many education resources today that uses a broad range of technologies to reach their audience. There are countless apps, websites and stand-alone software for learning. However, with such a broad range to choose from it is increasingly important to choose the right technology to achieve the intended learning outcomes. While the primary use of the technologies mentioned above is to create a delivery platform for content, the design of the learning experience is less standardised (Herrington et al., 2010). Using technology to create a learning experience, such as a simulation, should consider interactions beyond the access of content (Peters, 2013). A holistic view of students' learning experience is important in technology selection, as technology plays an increasing role in the interaction between students and teachers educational content.

The use of media for delivery of information is an important part of the learning process, yet it is increasingly becoming secondary in the e-learning environment. Interacting with the content in a meaningful way seems both increasingly possible as technology improves, and more efficient as a learning mechanism (Aldrich, 2005; Peters, 2013; Rieber, 1996). Meaningful interaction, as described by Anderson (2003) in his Equivalency Theorem, suggests that for effective learning to happen one of three interactions need to occur at a high level: the teacher and student, student and student or student and content (p. 4). Anderson (2003) explains how technology can take these interactions out of the classroom and, provided they are designed well, can substitute the same level of learning as the classroom environment (p. 7). However, many e-learning environments are struggling to reproduce the adaptability that a teacher has as they deal with individual students.

Many education institutions that use e-learning use a blended learning approach. Blended learning combines e-learning with the traditional classroom experience. Research shows this is widely successful, but there are limitations for delivery, such as having a fixed location for the classroom (Herrington et al., 2010). Technology is providing ever-increasing options for students to remotely connect to a classroom as an alternative to physically being there with other students.

Research on the effectiveness of utilising e-learning environments in this way is varied. It is difficult to research how the rapidly changing technologies influence students. Research on e-learning that focuses on technology quickly goes out of date as the technology evolves. Limiting this research to the way students interact with the learning material (i.e. educational games), rather than the technology used for delivery (i.e. web browsers), will help the study's outcomes to be relevant for longer. Providing a better understanding of how we learn through e-learning can be continually applied even when the technological environments change.

Excluding technological advances, the development of learning environments in the e-learning industry has broadly accepted the constructionist approach to learning (Herrington et al., 2010; Papert, 1986). Constructionism encompasses experiential learning or 'problem-based' learning (Papert, 1986). The constructionist approach to education differs from instructionist, as it encourages the student to take a more reflective approach to learning through authentic experiences, rather than to passively learn standards established by others (Ertmer et al., 2001). According to Wilson (1996), the instructional strategies for developing problem-based learning include the following:

1. Learning activities should be related to a larger task, to allow students to see connections between what they are learning and how it applies externally, in the 'real world'.
2. Students need to be supported while they develop ownership of the overall problem.

3. An authentic task should be designed to match a learner's abilities to make learning more valuable.
4. Reflection on the activity should occur so the learner can consolidate what they have learned.
5. Encouraging students to test the ideas they have learned in different contexts or environments.

While problem-based learning is not exclusive to situational problem-solving, simulation style learning links strongly with strategies listed above. Simulations can provide opportunities for students to work through an authentic situation where problems faced can be directly related to real-world scenarios (Herrington et al., 2010). Simulations can support students with their learning through responsive design, such as help menus, hints and other guidance whilst also providing a safe environment to practice. Simulations generate opportunities for reflection by showing students how they performed and how they might improve. Variability of simulations can provide a myriad of situations for the student to apply their new knowledge, increasing it relevance to real world equivalents. Simulations differ from alternative forms of instruction in that they follow the methodology of 'Learning by Doing' (Aldrich, 2005). Aldrich (2005) ascribes to four genres of simulation: branching stories; interactive spreadsheets; game-based models; and virtual products and labs (p. 4).

2.3 Overview of Simulation Environments and their Advantages

Education-based simulations align well with constructionist learning when they provide students with an authentic experience (Rieber, 1996). Authentic experiences allow students to see the practicalities of what they learn translated into the real world equivalent. By including opportunities for students to reflect on their performance and learning, students can deepen their understanding (Herrington et al., 2010). Creating multiple situations for them to apply this new knowledge broadens its application and relevance, as well as entrenching the knowledge in students through repetition.

2.3.1 Simulation Types

There are many uses of simulations in education such as vocational training or theoretical study. Simulations can be live or digital. For this research, a live simulation is one in which a student experiences either the real environment or artefact or simulated physical version of the real environment or artefact, and where the student physically interacts with the environment or artefact. A digital simulation will represent any environment or artefact that is presented to a student via an interface and has no physical representation beyond that interface the student uses. This research will focus on digital simulations. Live and digital simulations can be used to teach a process, such as, how to operate a plane or, how to apply abstract ideas such as the maximum tensile strength of steel cable. Some examples of digital simulations include The Adaptive Mechanics Portal, produced using the Smart Sparrow software for teaching students about higher order physics problems. Developed at UNSW by Prusty and Russell (2011), this system posed questions to the students and asked them to simulate the problems. An example of this would be placing cars on a bridge to exert the maximum possible force on the bridge *(Plate 2.1)*.

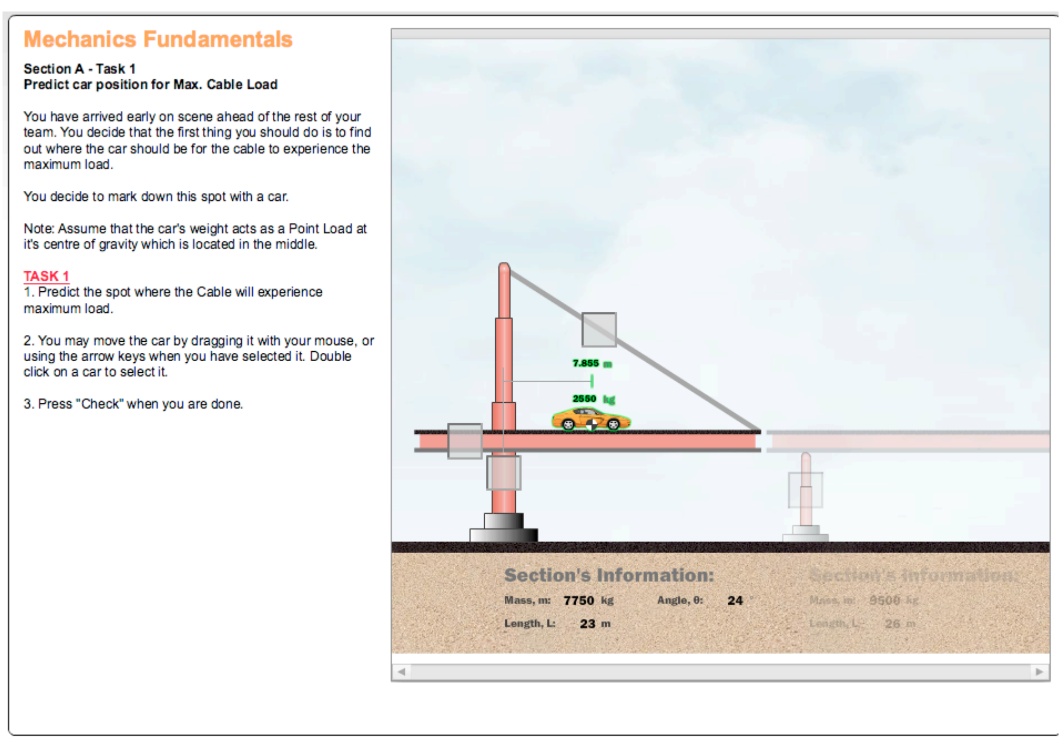


Plate 2.1: Mechanics Fundamentals, by UNSW and Smart Sparrow - https://aelp.smartsparrow.com/bronte/viewer/open/0efffd7dc4f1442b84a8759c12658b8f

This simulation helped the students to connect the mathematics with the physical forces exerted on a bridge, lending relevance and authenticity to the knowledge. Visual feedback from the system, as well as the act of placing cars on the bridge gave the user control over the experience, may help to consolidate knowledge by making it more engaging and memorable. However, the simulation did require substantial understanding of the maths involved and, therefore, proved confusing and frustrating for any students who did not have this prior knowledge (Prusty & Russell, 2011). If students began to struggle, support was offered through hints within the simulation as well as external educational material presented in class.

Like many other educational simulations, the Adaptive Mechanics simulation focused on delivering accurate information and applying it to a situation. However, it is important to note that simulations can also train students in processes where the students learn how to do something through the act of doing it. This is important for a number of industries where practicalities of live simulations can be dangerous to students, equipment or other participants. A familiar example of this would be flight simulators, where trainees use a simulator that represents a real cockpit *(Plate 2.2)*.

Plate 2.2: "AC97-0295-13 a". Licensed under Public Domain via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:AC97-0295-13_a.jpeg#/media/File:AC97-0295-13_a.jpeg

The benefits for this are obvious in that the flight crew and expensive equipment is not at risk. In many of these simulations the more authentic (realistic) the experience, the better the training experience (Herrington et al., 2010). The goal of training in a flight simulator is to become competent in flying a real plane, and therefore authenticity of the experience is crucial. However, authenticity does not necessarily mean realism, in some case a high-level of realism may not significantly impact the students ability to learn, for example presenting the landscape as graphics rather than photo-realistic (Herrington et al., 2010, p.81). Accuracy of the information given should provide students with enough detail to simulate an equivalent real world landscape. However, the learning objectives can dictate the information presented to students, and this may distort the realism of a simulation (Moreno-Ger et al., 2008). An example might be when teaching students about how air moves between mountains, the simulation might show air movement visually and this additional information may enhance the learning experience despite reducing authenticity.

While educational-based simulations like Adaptive Mechanics have been designed to deliver highly accurate information, the NASA simulator *(Plate 2.2)* requires a highly authentic experience as its primary method of teaching. The two simulations have slightly different learning objectives. The former can reduce realism in an effort to impart knowledge more efficiently, and the latter must provide a high level of realism for a more authentic experience.

Many other simulations fit somewhere in between these two simulation examples. A balance between focusing on important concepts through abstraction and simplification and the level of fidelity in representing the experience is required to impart knowledge effectively (Alessi & Trollip, 2001, p. 234). The learning objectives primarily determined this balance. In the case of the NASA simulator, the objective is to make the process of flying second nature, learning the steps for take-off, location of switches and the sensation of flying itself. Whereas for Adaptive Mechanics simulation the objective is to understand the formulas and how they can be applied to the real-world physics. The graphical representation here aids that understanding and serves to make the information more memorable through interaction (Aldrich, 2005). Simulations, where the learning objectives require experiential learning but also need to impart theoretical knowledge, have an equitable distribution of realism of a simulation and accuracy of information. Simulations provide unique environments for students to experience situations that they are likely to encounter once in the industry, and can be coupled with learning information useful to those situations.

2.3.2 Simulation Attributes

When designing the simulation, consideration needs to include all the different aspects that may impact how the student reaches the learning objectives. Alessi and Trollip (2001) outlines the particular combination of learner attributes, simulation attributes and knowledge attributes that determine the learning transfer that will occur, and therefore, the learning objectives that will be met (p. 232). The knowledge attributes include the type of information that the student needs to learn. The learner attributes refer to the type of student and how they learn. Lastly, the simulations attributes are the way the simulation is constructed. The appropriate weight needs to be given to each attribute in any given learning experience. Designing simulation attributes should consider both the realism and the imparting theoretical knowledge in order to achieve the learning objectives efficiently *(Fig 2.1)*.

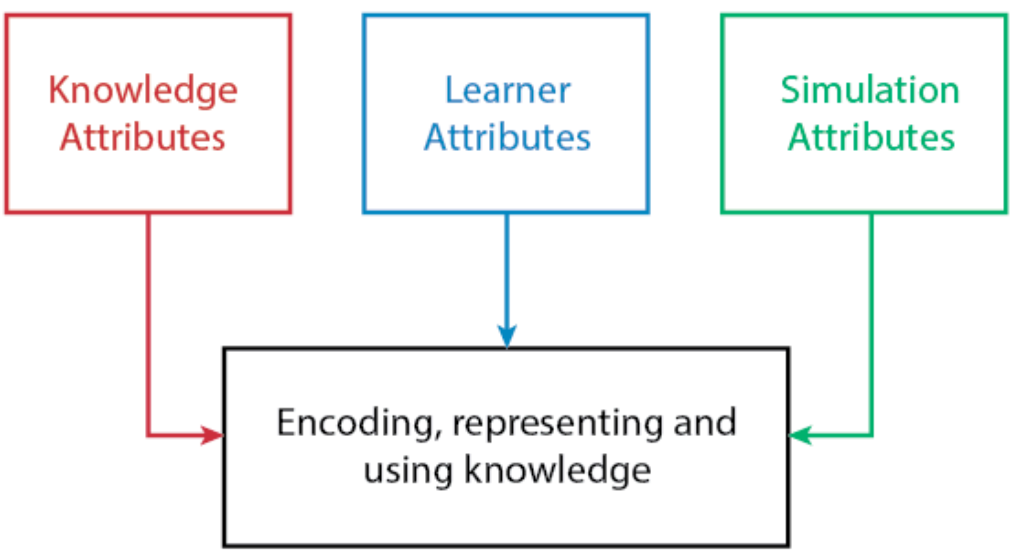


Figure 2.1: Diagram adapted from (Alessi & Trollip, 2001, p. 232) *Multimedia for Learning: Methods and development*.

Improper combination of realism and theoretical knowledge can result in limiting the learning capacity of the student. There are many technical issues that impact the simulations ability to represent realistic environments. Often truly realistic simulations would require an inordinate amount of computer processing to achieve a perfect representation of an environment. For example, a branching narrative-based simulation might become exceedingly complex, with far too many possible pathways to ever be able to produce it in a realistic timeframe. Unfortunately, the kind of artificial intelligent programming models that might be able to manage realistic narrative are far from accessible to the average developer (Shaw, 2008). Fortuitously, this level of detail is not required to achieve learning objectives for the majority of simulations (Alessi & Trollip, 2001; Herrington et al., 2010).

The difficulty in producing high-level realism can be reduced by identifying the key factors that need to be realistic in order to teach critical aspects of that experience. Such experiences might include the time pressure associated with emergency response, which could be achieved without high-level realism. However, more realistic environments can increase student engagement in the activity through 'suspension of disbelief' (Herrington et al., 2010, p.63). Engagement is an important part of the learning process, and has a direct impact on levels of learning, achieved through simulations and other interactive learning environments (Cant & Cooper et al., 2010; Hake, 1998). Highly realistic simulations will often require large file sizes, such as video and audio, or in the case of 3D worlds, often high-end computer power to generate the realistic environments quickly. Computer processing power and internet speeds are constantly improving, meaning realistic simulations no longer need to be dispensed via CD/DVD, or use specialised software. With advances in technology, more of these simulations can be delivered online.

2.3.3 Educational Simulation Definitions

While accessibility of simulations is better than ever, educational simulations still require careful planning and research if they hope to make lasting impacts on the students' education (Aldrich, 2005; Alessi & Trollip, 2001; Herrington et al., 2010). The requirements of educational simulations go beyond just representing an environment, or passing on facts through a slideshow. Educational simulations are framed around achieving specific learning objectives and, in doing so, often hold a balance somewhere between teaching through experience (realism) and presenting theory (theoretical knowledge) (Herrington et al., 2010). With a combination of realistic experience and application of learning, educational simulations fall neatly into the authentic learning experience, and encourage students to learn, apply and reflect on new knowledge (Aldrich, 2005; Peters, 2013; Alessi & Trollip, 2001).

Educational simulations vary in complexity and cover a broad number of industries. Medicine, business, education, military and transport are just a few of the major industries involved in using educational simulations to train and teach. There are many definitions that industry use to describe simulations; however, they broadly fit into two categories (Alessi & Trollip, 2001, p. 214). The first is 'to learn *about* something', divided into a physical or iterative experience. Gibson & Baek (2009) describes these two experiences as continuous and discrete (p. 7). The second category is 'to learn how *to do* something', which can use a procedural or situational experience.

A summary of Alessi and Trollip's (2001) and Gibson and Baek's (2009) definitions generate the four experiences that cover the majority of simulations:

- ***To learn about something***
    - **Physical:** Usually a continuous simulation experience with a physical representation where the student learns about an object or thing. Some examples could be the concept of gravity, or how a combustion engine works. Users may be able to interact with the simulation and explore the effects of their actions. A contemporary simulation is SimCity, a game released by Maxis and EA in 2013, where players create a city by building houses, businesses and transport, among other things. The simulation uses an underlying computer model to react to the player's actions. The objective is to learn about those models, be it a city, a farm, gravity or a car engine.
    - **Iterative:** While very similar to the physical, it differs slightly in the way it presents to the student. Iterative, as the name suggests, encourages students to trial the simulation over and over in order see how changes affect the results.

Time is often manipulated in this type of simulation, with time freezing while a student makes changes to parameters, in order to test the new situation. Time manipulation is advantageous for simulations where timeframes are not practical for experimentation, such as examining genetics over generations or very fast chemical reactions. One example would be Ined's population simulator, which teaches students about population growth over time *(Plate 2.3)*. Changing parameters in the simulator can show the effect on population numbers over decades or centuries.

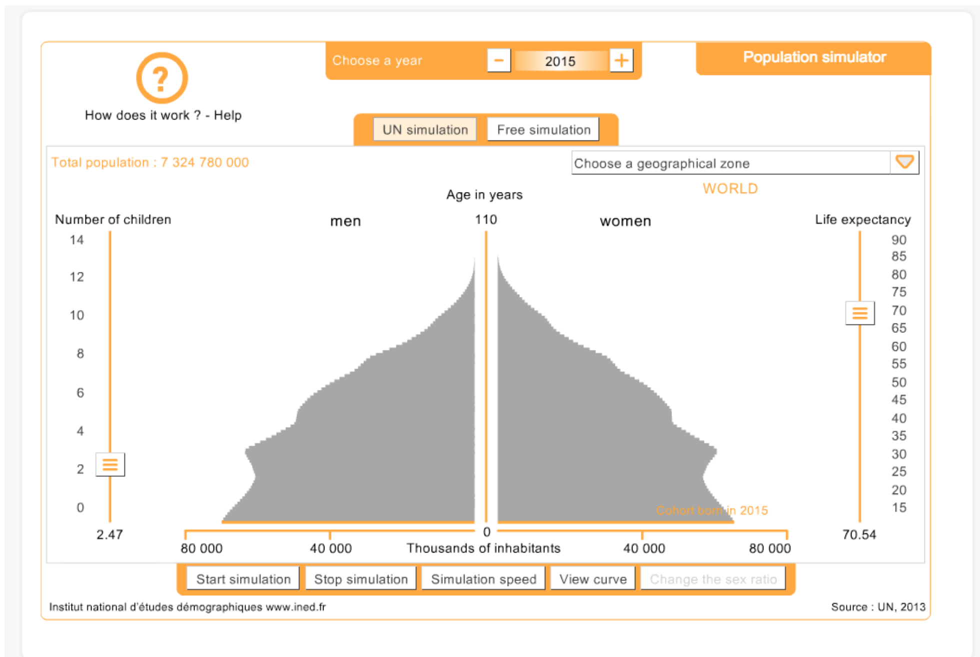


Plate 2.3: Ined Population Simulator - https://www.ined.fr/en/everything_about_population/population-games/tomorrow-population/

- ***To learn how to do something***
  - **Procedural:** The main focus of procedural is using the simulation to teach someone a process. A representation of the physical environment may be useful here, but it is important to note that procedural is teaching the student how to, rather than about something. A good example to use is flight simulation, where the learner is learning the processes involved with flying. Medicine and military use procedural simulations often because they help to

make processes automatic and provide safer alternatives to using real patients, or real environments and weapons.

- **Situational:** Situational is focused on management of a situation, and tends to be more about teaching behaviours and attitudes than the steps of a process. An element of randomness is common, as these simulations are often about people, who have less predictable reactions than machines or the physical world. Role-playing different approaches to the same situation can allow the user to explore differing perspectives. One industry that uses this kind of simulation is business, as customers can have an unpredictable nature. Students making decisions about imaginary products can often yield varying results due to the fluidity of customers. Other training fields, where situational simulations are useful, are parenting, teaching, counselling and dealing with patients. Situations where the trainee must deal with people at a social level are suited to situational simulations.

Categorising simulations in this way is helpful to the designing process, but crossovers typically occur. In the case of a business management simulation, elements of procedural and physical would comfortably fit into the teaching model. In order to improve the design process, it is best to examine the key learning outcomes and identify the category which with it best fits (Alessi & Trollip, 2001; Gibson & Baek, 2009). For example, if the business management simulation were to teach about customers' reactions to products, the best fit would be situational. However, if it were about maximising production then it would more likely use a procedural approach.

2.3.4 The Advantages and Limitations of Education Simulations

As mentioned earlier, digital simulations have the advantage over the live equivalent, by providing a similar experience in a safe and less costly environment. Simulations also have many advantages as education tools for situational learning above other teaching methods. Motivation is one area where simulations prove themselves superior to other teaching methods (Alessi & Trollip, 2001).

Motivation

Motivation to participate is far more likely to occur when students are actively involved in the learning environment, rather than passively observing. Motivation in the learning environment is described as a critical factor for learning to take place (Aldrich, 2005; Ames & Archer, 1988; Holzinger et al., 2009). While there are many reasons students might be motivated, Alessi et al. describes simulations as very effective at 'providing relevance' and 'challenge and fantasy' (Alessi & Trollip, 2001 p. 279). Many students see the relevance of their learning when the simulation provides the opportunity to apply the knowledge directly in the situation it was intended for. Knowledge relevance forms part of the authentic learning experience, discussed previously by Herrington (2010).

Many educational experiences provide a challenge, but simulations, along with other e-learning resources, have the capacity to ramp challenges to meet the students' exact needs at that time. This dynamic approach avoids students becoming overwhelmed or frustrated by the learning experience (Ames & Archer, 1988; Sweetser & Wyeth, 2005). Koster (2013) describes this ramping up of challenges as part of his 'theory of fun', to be imperative to maintaining a player's enjoyment in a game. Too hard or too easy and the player will lose interest in mastering the game, as with students who are trying to master new knowledge. Simulations' connections with games do not end with challenges. Fantasy in a simulation occurs when it provides the student with a world to be absorbed into. Much like games, students in simulations can imagine themselves doing the activity. This experience is highly engaging, and when designed correctly, can markedly increase learning (Aldrich, 2005; Alessi, 2000; Ambrose et al., 2010).

2.3.5 Scenario-Based Simulations

Scenario-based simulations will present a situation to the learner where they must interpret and decide which actions to take. Typically, a narrative evolves out of the actions taken. This kind of interaction is highly engaging and helps the learner to become more attached to the simulated world (Herrington et al., 2010). Including elements of empathy will help the learner to experience a stronger connection with characters who form part of the narrative components

(Sweetser & Wyeth, 2005). Scenarios, above other kinds of simulations, can build a richer world through the use of story. Consequently, the learner develops a deeper connection with the material due to the higher level of engagement (Holzinger et al., 2009). Medical simulations that involve treating an 'at risk' patient often require the students to feel empathy for simulated patients. This is to replicate a similar level of concern for the patient's welfare that they would have when dealing with a real patient. Replicating this emotional response assists with making the simulation a more authentic experience (Herrington et al., 2010, Holzinger et al., 2009).

2.3.6 Video in Simulations

Video has some specific properties that lends itself to scenario-based simulations and its narrative nature. Video is a widely accepted medium for telling stories; subsequently there is less resistance from the learner, compared with using other mediums. For example, 3D generated worlds, especially avatars of those worlds, can seem less real and require more effort by the learner to imagine them as real. Students expectations of the 3D characters to behave intelligently increases as the design of them becomes more realistic, whereas video does not carry this same expectation (Wagner, Billinghurst, & Schmalstieg, 2006).

The construction of the scenario-based world through video utilises all the nuances of the real world in its visuals. The real world provides all the tiny details we experience in reality with little effort on the creators part — something that a computer and 3D designer find very difficult to do. The downside of this is that video can only be two-dimensional in nature, and there are no practical solutions to allow a user to walk around in an environment created by video. This limitation may affect some scenarios, but in most training and teaching environments two-dimensional space is ample to give students a sense of the world they are learning in. The aforementioned is especially true for learning objectives that are not related to teaching students about the spatial environment, and are more about creating an engaging experience for the student (Carson, 2000).

The realism of a person in a video can help to generate a stronger emotional response from the student than a '3D modelled' character. This is an important factor in training students to work with real people, such as nurses dealing with patients. However, in order to elicit these kinds of emotional responses, some video may work better than others. Different angles of view can be achieved with video cameras. Subjective camera angles such as, ‘point-of-view’, which places the camera at eye level, helps the viewer place themselves into the situation. Lower, higher or other unnatural camera angles will weaken the viewer’s ability to place themselves in the scene. The more a student can imagine they are there, the more authentic the learning experience will be, and the more aligned it becomes with the constructionist approach to learning (Herrington et al., 2010).

2.4 Simulations in Health Education

Medical simulations are acknowledged as an effective tool for consolidating theory in a safe environment, which can then be applied in real world situations with greater efficacy (Moreno-Ger et al., 2008). Providing an online simulation allows the delivery of replicated environments without the need for face-to-face contact with individual students. The benefit of online delivery is that it greatly increases the ability to deliver content to a large number of students (Mathews, 2015). Education in this manner is reinforced with supportive educational material and educator contact. The educational impact is increased by choosing the most appropriate style of simulation for each specific education goal or topic (Cant & Cooper, 2010). Cant and Cooper (2010) explain, “Important components of simulation also include a need to match the simulation to clinical reality and the relevant curriculum” (p. 12). The components simulations can use could contain video, a virtual environment or text-based decision-making. A mixture of the learning objectives and production time and budget often determine the simulation components chosen. Highly realistic environments are achievable but come at a higher cost, and may require more resources when planning multiple branching scenarios. Herrington et al. (2010) explains that the highest level of fidelity does not always translate to the most effective method of teaching (p. 85). As part of a systematic review on simulation-based learning in nurse education, Cant and Cooper (2010) found one study of 798 students that compared different groups of students who used either no manikin, a low fidelity static manikin and high fidelity manikin. The study found all groups gained knowledge, but there was no significant difference between the groups learning. However, students using high fidelity systems showed statistically significantly greater confidence in their ability to perform, than the group with no manikin (p. 11).

A large amount of resources are required to dedicate to fidelity in simulations, so it is important to determine what learning objectives the simulation is trying to achieve so that its design can focus priorities. Limiting the simulation scope can also improve learning by keeping students focused on the tasks and techniques that need to be understood. In many cases, it is not necessary to achieve complete realism — an important consideration when choosing a simulation style (Norman, Dore, & Grierson, 2012). Norman, Dore and Grierson (2012) discuss examples where increased fidelity may not necessarily improve learning outcomes. They separate realism into 'engineered fidelity'; how real it looks, and 'psychological fidelity'; how well it represents critical learning objectives (p.637). They go on to suggest that careful analysis of the learning outcomes needs to be done to gauge the ideal level of simulation fidelity in order to maximise the impact on learning. This ideal level of fidelity can be different for every project, and while difficult to measure, an ideal level will try to find a balance between the highest fidelity and a high amount of learning for that project (Alessi & Trollip, 2001, p.234).

The medical industry is an avid user of video and 3D in simulations for teaching. It continues to push boundaries of technology and design for ever-increasing realism in simulations. Safety and the expense of running live simulations with actors or manikins, are the two main driving factors.

Medical simulations tend to involve a high level of instructional design and assessment. Realism is important, but only when it aligns with the learning objectives, with the accuracy of information being paramount. Learning objectives of medical simulations embody all of Trollip's categories: physical, iterative, procedural and situational. Many medical simulations are about learning a process, *'Learning how to do something',* using a procedural simulation experience. Procedural simulations allow students to practice and to learn the process of a particular technique safely. Surgical-science has created a procedural simulation called 'LapSim', which allows a student to practice their skills in a virtual environment *(Plate 2.4)*.

The use of haptic equipment allows the student to feel physical feedback from the virtual world. This example demonstrates that 3D realism is sufficient for the student to practice their skill without needing the emotional response that video realism might bring to the same scenario. This example highlights the need for the virtual world to allow for interaction, something that a pure video environment cannot achieve.

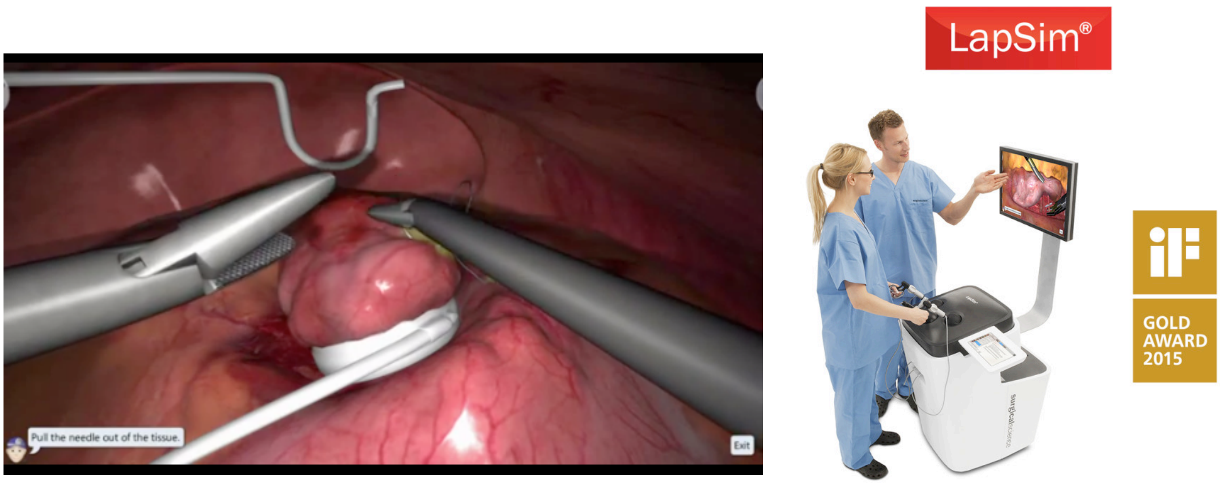


Plate 2.4: LapSim, Haptic surgical simulator - http://www.surgical-science.com/company-news/video-simulations/endosim-fundamental-endoscopy-skills-2-targeting/ (http://www.surgical-science.com/portfolio/haptic-system/

The Vitalsims patient simulator provides a 3D avatar of the nurse and a patient. The 3D world provides a view of the patient and nurse, and allows the student to work through the process of either fall prevention or ulcer detection *(Plate 2.5)*. It provides feedback and hints to suggest what steps the student needs to take. The targets highlight areas of concern on the screen and minimises the distractions of other devices in the busy hospital room. Minimising distractions allows the student to concentrate on the learning objectives for that training, maximising the efficiency of the learning process (Herrington et al., 2010). Creating a 100% realistic simulation may not be aligned with the learning objectives, and this is a major factor in deciding on the level of emotional connection needed for a simulation. Giving feedback related to a student's decisions will help to improve their process, but the lack of a realistic patient can only go so far in training the student for human-like encounters (Gratch, Wang, Greten, Fast, & Duffy, 2007).

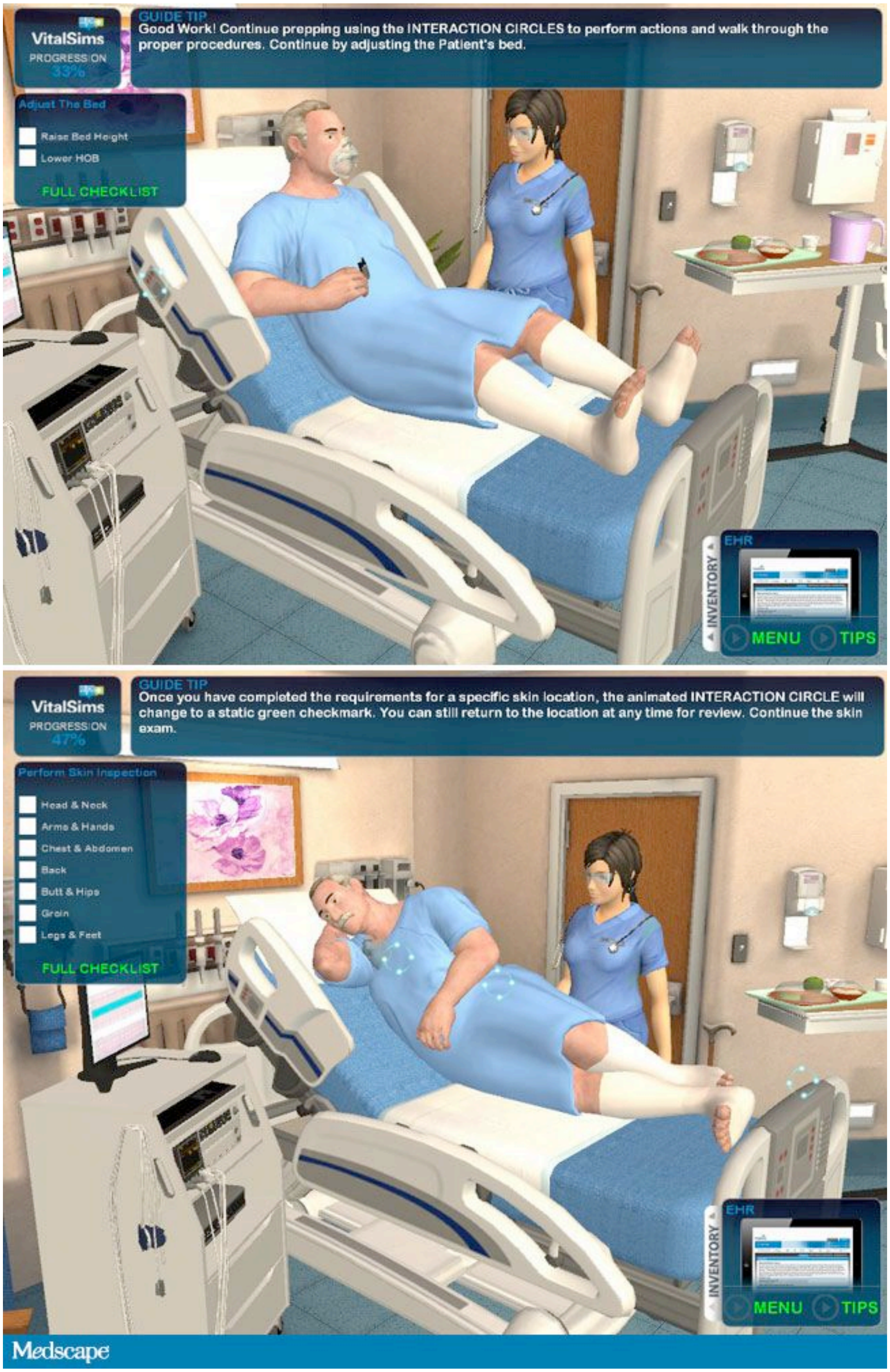


Plate 2.5: Medscape, VitalSims - http://img.medscape.com/article/780/819/780819-figure-1.jpg

One program that does add more emotional response is Virtual Heroes Zero Hour *(Plate 2.6)*. Students move through a game-like environment selecting equipment, receiving briefings and treating patients in an emergency response situation, such as an earthquake. While the characters do not look realistic, there are other elements such as music and authentic dialog that illicit emotional responses and create tension. These are techniques that both film and video games use to immerse the participant in the environment and story. Virtual Heroes, while excellent in delivering a sense of chaos, may lack transferability to long-term memory, as it uses popup menus to deal with equipment and application of treatments. Guides like menus are not available in the real version of this situation. In addition to this, the students' avatar does not realistically apply the stethoscope to the patient, and some vitals that are taken have no visual representation. It does, however, provide a 'point-of-view' camera angle, helping with the immersive nature of the simulation. Zero Hour demonstrates a procedural and situational simulation combined, which heightens the emotional experience while also teaching about process.

Plate 2.6: Virtual Heroes Zero Hour - http://www.virtualheroes.biz/zerohour/ image from: http://www.medscape.com/viewarticle/780819_7

Will Interactive has produced a video-based simulation called 'Partnering to Heal' *(Plate 2.7)*. This simulation addresses infection in hospitals and allows the student to choose from 5 roles involved with the hospital ward. Each character must make decisions that help reduce infection *(Plate 2.8)*. The use of dramatic film techniques and story telling evokes emotional connections with all the characters involved *(Plate 2.9)*. Students display more empathy with the people they encounter in the ward as they are more emotionally invested. The simulation has limited interactivity; instead, it guides the reflective process towards the learning objectives through carefully designed decision points throughout the story.

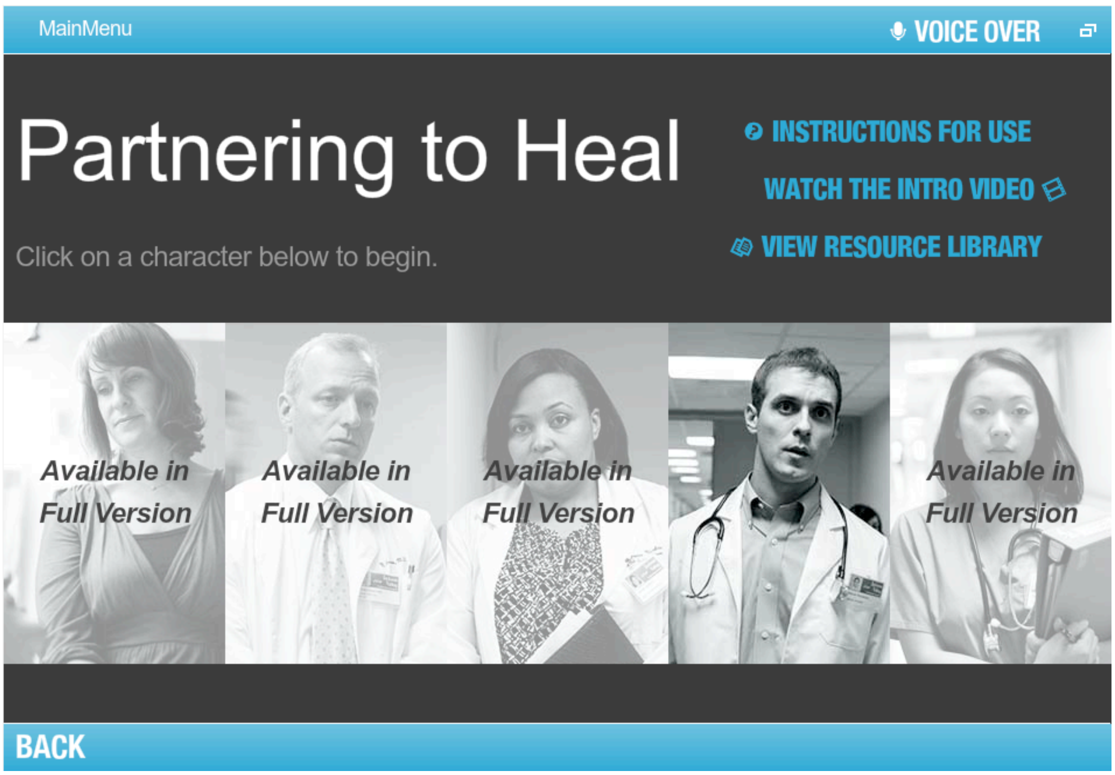


Plate 2.7: Will Interactive, Partnering to heal - http://willinteractive.com/products/partnering-to-heal

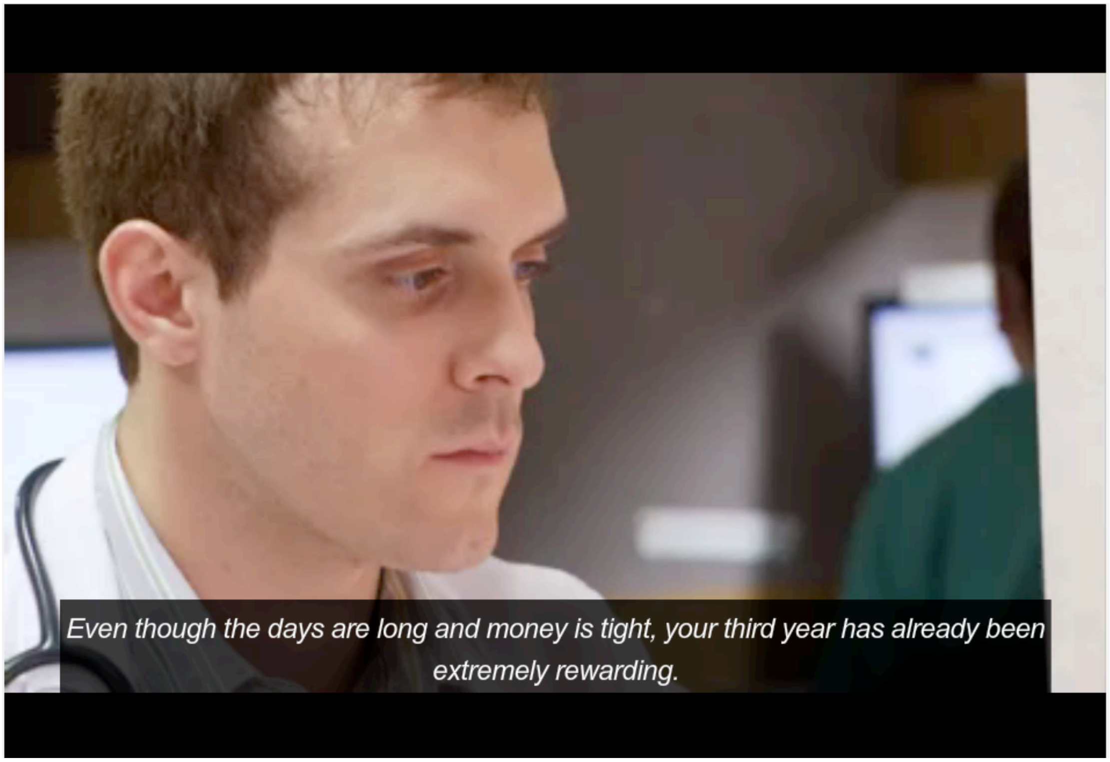


Plate 2.8: Will Interactive, Partnering to heal - http://willinteractive.com/products/partnering-to-heal

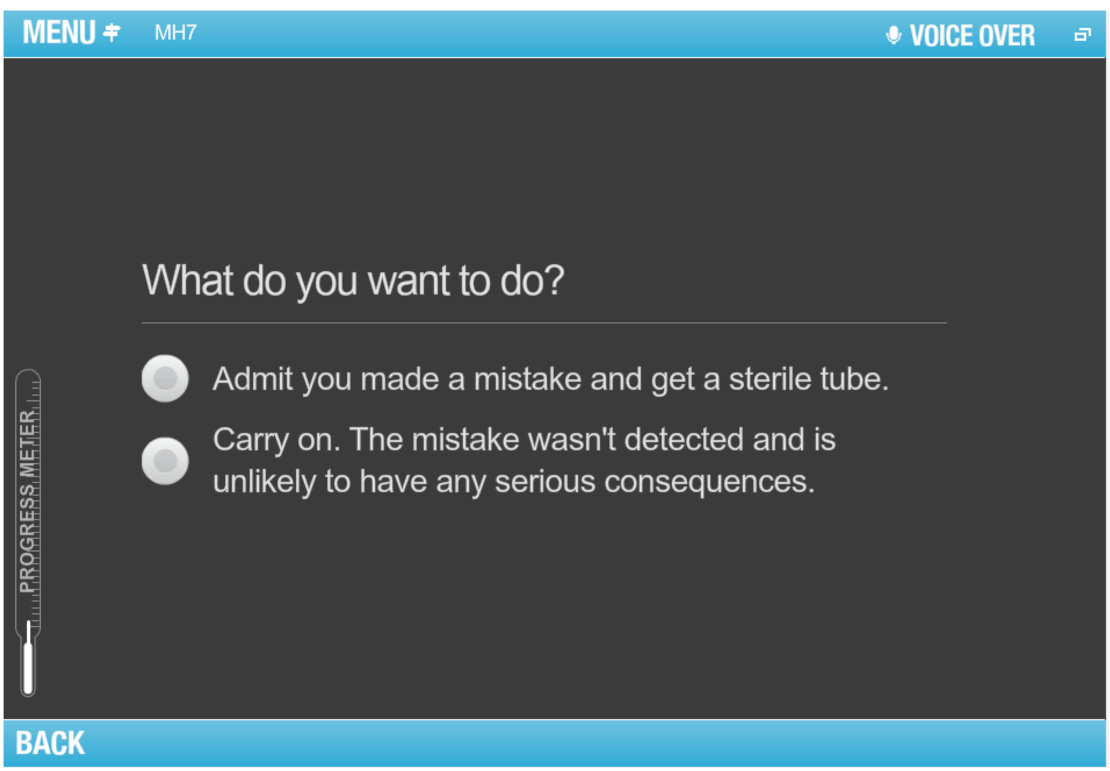


Plate 2.9: Will Interactive, Partnering to heal - http://willinteractive.com/products/partnering-to-heal

These examples demonstrate the broad scope of medical simulations. There are some defining characteristics in all of these simulations. Most medical simulations address life-threatening situations and focus on providing opportunities for students to practice how to operate in these scenarios. Online simulations often offer an alternative to clinical placement, or having a student practice on a human or mannequin patient. Typically, these simulations do not try to represent the physical or tactile experience, with the exception of simulations like 'LapSim' that include additional equipment. They are designed carefully to address specific learning objectives and minimise any other environmental distractions. Occasionally, they will use distractions if they form part of the learning objectives, such as to highlight common mistakes made by students in that situation. Finally, they offer reflection and feedback that can assist students in understanding what they have learned, both to indicate how well they have done and where they can improve.

Medical simulations try to offer a cost effective, safer (for both patient and student), accessible and repeatable training environment, which enhances readiness for clinical placement rather than replacing it (Moreno-Ger et al., 2008). The challenges that face development are many. Development can prove costly, especially as simulations become more game-like or realistic. The technology used can dictate project direction, rather than the learning objectives. Lastly, evidence of the education potential of individual simulation components is limited, especially as simulations move assessment away from human involvement and more towards autonomous computer systems.

2.5 Designing Educational Simulations

The focus of the educational design for simulations is making sure the learning objectives are reached (Akrimi, Rahimahmad, George, & Aziz 2013; Aldrich, 2005; Alessi, 2000). The learning objectives need to be carefully outlined in a clear and concise way. When designing, it is paramount to ensure that the simulation technologies used are aligned with the learning objectives (Gibson & Baek, 2009; Waterhouse, 2005). When designing simulations for education, a balance between learning material and student experience will best serve the learning objectives. Too great an emphasis on either area will reduce the students' learning potential. Gibson and Baek (2009) suggest that imbalance allows for distractions from the learning experience, where students start to focus on the wrong aspects. A simulation world that contains many non-essential elements may take focus away from the educational goals. However, a greater focus on delivery of educational material results in a simulation that is dull and less rewarding, and therefore, possibly reduces engagement and motivation.

This misalignment is common with poorly designed assessment tasks. If the only form of assessment is question and answer, it may prove disruptive to the simulation experience. Simulations by their very nature are situational learning tools and assessment should complement this. Assessments that aim to teach students about an experience are a good fit for situational learning models, and will likely be a more effective learning experience (Herrington et al., 2010).

Guidance during the simulation will also assist learning, and can exist as instructions on how to use the simulation or as feedback on student performance. Instruction on how to use the simulation reduces the cognitive load when using the interface so that students can better apply themselves to learning (Sweller, Ayres, & Kalyuga, 2011). Feedback in regards to performance also helps improve students understanding of a topic. As with most learning experiences, without appropriate feedback the quality of the student's experience drops dramatically (Herrington et al., 2010). Feedback in simulations can occur during a simulation through a student's interactions, guiding them when they are stuck or suggesting better options. Informative feedback loops make it easier for students to use the interface by showing the effects of their actions through the system responding (Shneiderman, 1998). It can also present itself upon completion of the activity, indicating performance, any weak or strong areas, and suggestions on how to improve. The detail of feedback can be very precise depending on the simulation design. The data collected, and how the system is designed to interpret that data, markedly affects the system's abilities. Designing this part of the process is difficult and requires expert knowledge of educational material and learning objectives. It also affords a high level of understanding of the abilities of the simulation system.

There are a number of guidelines that exist to help the designer achieve goals in instructional design. However, multimedia system design and digital simulation (or game) design remain relatively unstructured. These industries still lack the level of formal research required to devise evidence-based streamlined approaches to design (Gibson & Baek, 2009; Salen & Zimmerman, 2004). In saying this, Gibson & Baek (2009) summarise some methods specifically for simulations. The process, described in *Digital Simulations for Improving Education* (Gibson & Baek 2009), prescribes a mixture of game design elements such as rules, goals, objectives and outcomes, with common ISD (instructional system design) model elements. Elements shared across many ISD models include analysis, design, development, implementation and evaluation (ADDIE). These models, combined with cognitive psychology, such as Sweller's (2002) work on cognitive load and instructional design, may further aid the design process *(Fig 2.2)* (Paas et al., 2004; Sweller, 2002; Sweller et al., 2011).

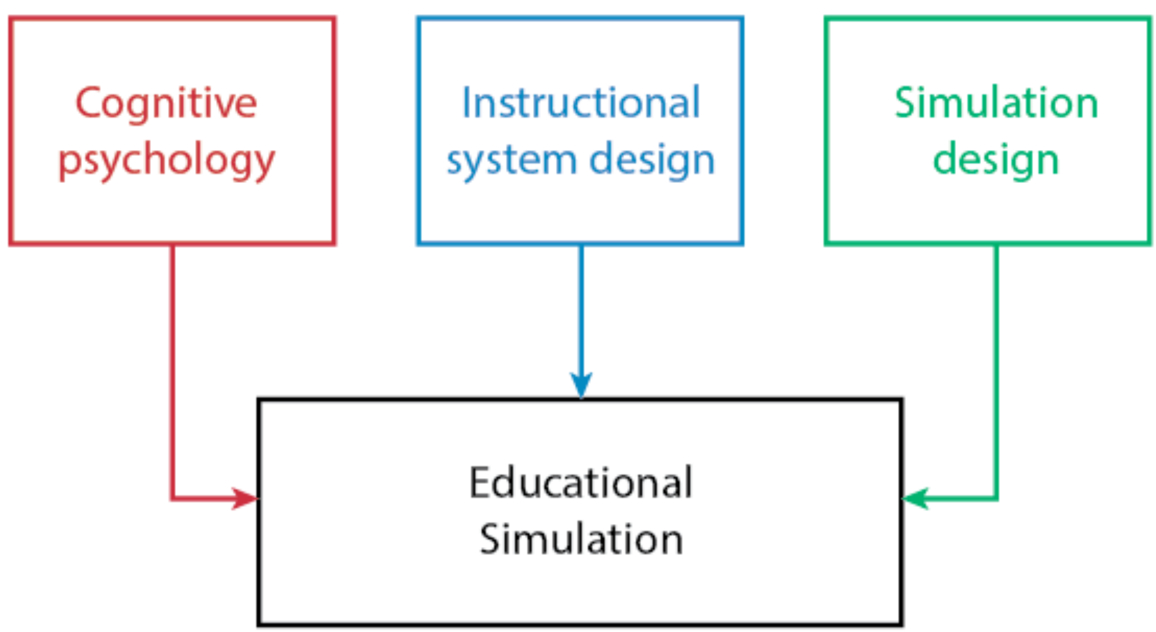


Figure 2.2: Adaptation of the Alessi and Trollip diagram *(Fig. 2.1)* combined with Aldrich's *Learning by Doing* (p. 80)

Educational simulations require an understanding of all three areas: cognitive psychology, instructional system design, and simulation design. The three areas blend during the development process, in a way that influences choices made about the others. This research investigates the interplay of these three areas, and the influence they have on simulation design processes. The better the understanding of the unity of all three during development, the better the educational experience. The design of an educational simulation follows a process similar to that of multimedia products, including games, websites and applications. The following sections outline the steps used in designing an educational simulation, and is a combination of suggested methods from a number of sources (Aldrich, 2005; Gibson & Baek, 2009; Peters, 2013; Sweller, 2002; Alessi & Trollip, 2001; Herrington et al., 2010; Salen & Zimmerman, 2004).

2.5.1 Starting Point

The starting point for both simulations and games is varied. Designers might decide to start with the type of simulation to use, as in, realistic or abstract. They could start with the type of user, for example, third year university students, CEOs or postal service employees. Alternatively, the starting point might be delivery technology: mobile, tablet or desktop computer. Whatever the starting point, it can considerably influence the outcome of the project. In regards to educational simulations, it is most important that a starting point aligns with the learning objectives. As an example, a simulation for teaching about measuring biodiversity in the field could be carried out in many ways. The learning objectives might be "How to lay out metre grids with string for measuring biodiversity", or "How to recognise different insects while mapping biodiversity". While they both belong to the same academic field, these two learning objectives might be presented in very different ways in order to maximise learning potential. Identifying clear and concise learning objectives is a strong way to lead an educational simulation design process (Gibson & Baek, 2009).

2.5.2 Design Team

An aptly chosen team of subject matter experts (SME), instructional designers and developers is essential to the success of the project. There should be support for the project from all members, but more importantly, the group must be well aligned with the project intentions. A simulation intended for pre-schoolers to learn maths likely would not progress well if the developer specialised in realistic first person shooters for the military.

2.5.3 Considering Students

As in the preceding example, the student whom the simulation is for is an important part of the design process. Clearly understanding the students' abilities, anxieties, prior knowledge and other characteristics, benefits design choices throughout the process. Aligning the expectations of the students with the appropriate simulation system is essential to achieving the learning objectives.

2.5.4 Rules and Limitations

As with most games, simulations require a set of rules. This is important as it defines the boundaries between the real world and the imaginary world (Salen & Zimmerman, 2004). Students need to be able to define where the imaginary world begins so that they can better engage in simulation by voluntarily acknowledging the existence of the alternate reality. They will accept the imaginary rules of the new world because they understand that it is not reality. This phenomenon occurs in other forms of media, as well as games. Rules help to confine the space to the limitations necessary, to make that world manageable. In a flight simulator, the rules would be that sky-height is limited, and ground level does not contain all the earth underneath it. There may also be other limitations such as the physics of real light, and the captain not being able to walk around the entire plane. The student accepts these limitations and the rules keep the student focused, while also making the simulation easier to use and to build.

2.5.5 Goals and Learning Objectives

Rules help students to reach their objectives and goals. As mentioned earlier, the learning objectives must form part of the starting point of the design process. However, they should remain a focus throughout the whole development lifecycle. Success for any educational simulation must be measured against the achievement of these objectives. Clearly outlining these is necessary, but designers need to remember that they might not only be academic in nature. The learning objectives might go beyond the simple acquisition of facts. As simulations are a type of situational learning, everything from the experience of the environment, time and space, and even muscle memory might be included in the learning objectives. In the case of a flight simulator, the student learns the entire process of flying. The visual space around the plane and cockpit, the time it takes to prepare and land a plane, the pressure of trying to land with a strong cross wind, all form part of the learning objectives. To measure these experiences as learning objectives is difficult, but they are none-the-less learning objectives and consideration is crucial.

2.5.6 Feedback and Evaluation

In any learning experience without appropriate feedback, the learner will struggle to gauge their progress. Feedback affects motivation and the ability of the student to learn efficiently. Feedback in a simulation can come in many forms. Most typically, it is a written description of the student's performance after the end of the session, which may include details about how to improve. Other forms of feedback can occur during the simulation and could be hints and tips, guidance about what to do next, or explanations about how to use the system. Finally, reactive feedback about actions and decisions made by the student might exist, in the case of a flight simulator; this could be the plane flying upwards when the student pulls the joystick back. Noises, vibrations and other kinds of physical feedback might notify students that an activity is complete or that an issue needs to be addressed. Immediate or reactive feedback can help students internalise a process, and summative feedback allows a student to reflect on performance and try to improve future attempts (Herrington et al., 2010).

2.5.7 Interaction

In order to make a simulation engaging, immersive, and provide valuable feedback, the student must interact with the system. The degree of interaction required is guided by the learning objectives, and then measured against the limitations of students and technology. Reading a book or watching a movie has limited interactivity, and is largely a passive experience. Interaction design for simulations allows the student to influence the outcomes of the simulation through their actions. Interaction should aid the learning outcomes, but conversely, limit the number of distractions. For example, if the learning objective was to land a plane, the flight simulator can take over the aspects of flying that are not involved in landing, leaving only interactions the student needs to learn for that particular process. Reducing the cognitive load for the student means they can commit more mental capacity to learning that specific process (Sweller et al., 2011).

2.5.8 Cognitive Psychology and Interfaces

Understanding the role cognitive psychology has on the learning process is relevant for all learning situations. However, it is paramount in simulations that produce a great deal of extraneous cognitive load, where students dedicate much of their mental capacity on just using the simulation interface (Sweller, 2002). For a better learning experience, the student needs to commit more cognitive resources towards learning the material and less to learning the interface. One way to reduce extraneous cognitive load is to build on prior knowledge, or schemas, to help students quickly learn new concepts. Simulation design that uses existing mental models, by using familiar interface design, produce smaller cognitive burden (Butow, 2007). Building interaction on established mental models of other conventional technology helps the students to scaffold the new simulation interactions on ones they already know. The student applies pre-existing experience to learn the interface and interactions of a new simulation environment more quickly. Designing the simulation so that it matches the students' expectations reduces cognitive load as well as anxiety a student might feel when entering a new environment. Reducing extraneous cognitive load improves both the learning and enjoyment of the students use of the simulation (Paas et al., 2004). Investigating best practice in interface design can help simulation design to reduce extraneous cognitive load. A better understanding of the relationship between interface and cognitive load will improve the design process for educational simulations.

2.5.9 Interface Design

The interface design forms part of the way students interact with a simulation, and the design of this should follow the widely accepted principles outlined by Shneiderman (1998). The eight guidelines of Shneiderman (1998) are repeated throughout many other design models and support both learning and user experience principles (Butow, 2007; Hoekman, 2008;

Peters, 2013). The eight guidelines listed below are edited to better align with simulation learning. Some are more relevant than others, but all have been included for thorough exploration of the concepts.

1. **Strive for consistency.**
   All interactions should react in a way the student expects from previous experience with using that system. This reduces cognitive load and decreases frustration when using the interface.
2. **Enable frequent users to use shortcuts.**
   If possible and relevant to the learning objectives, include shortcuts to regular actions to allow students to move quickly through material that is understood.
3. **Offer informative feedback.**
   There should be appropriate feedback given for every operator action. Students should have actions confirmed as both operational feedback (to notify that an action has been executed correctly) and evaluation feedback (that assists with their understanding of the educational material).
4. **Design dialog to yield closure.**
   As with point three, the feedback should be clear in indicating an activity has been completed. This feedback helps students feel that they are progressing and can move onto the next topic or step in learning, thus helping with motivation.
5. **Offer simple error handling.**
   While allowing students to fix errors is satisfactory, prevention of errors is preferable. However, in some instances it might be necessary to include some errors for education reasons. This guide is more for usability issues; the fewer bugs in a simulation, the better the experience for the student.
6. **Permit easy reversal of actions.**
   Similar to point five and only relevant if it aligns with learning objectives.
7. **Support internal locus of control.**
   Students should feel their choices matter. A simulation should make the student feel that it reacts to their decisions, rather than the student reacting to the system.

Implementation depends on the learning objectives, but in most instances, the experience for the student will be more engaging if they feel their choices matter.

8. **Reduce short-term memory load.**
   Keep the interface simple, minimise depth of navigation, and design the system on existing mental models. Good design reduces the training time for learning the interface, and allows student to move quickly from a novice to a master.

Some interface design methods have altered as the way people interact has changed, namely, direct manipulation through a touch screen. Nevertheless, these guidelines still apply. Over time, they may become less relevant and would require a review. The key design principles for education simulations would centre on keeping the interface simple and using consistent interactions, whilst also giving appropriate feedback to students for both learning and operation.

2.6 Impact of Learners

Learning may be impacted by the simulation design, instructional design and student cognition factors. However, the varying learners' attributes should also be considered. While all learner attributes impact learning to some degree, recent research shows the student experience of the content can considerably impact the teaching effectiveness of a simulation (Khawaja, 2013). The study, using the Adaptive Mechanics Portal, investigated the difference in improvement between high and low performing students based on cognitive load theory (Sweller et al., 2011). The instructional method can impact learning differently for high and low performing students. The report shows progress over a number of years, where in each successive year, the number of simulations a student needed to complete and its relative difficulty, were increased. In the final year, data showed that improvements for high-performing students had continued to rise while low-performing students declined. Other factors may have impacted results, including overall lower performance in the final year, but the research does support Sweller, Ayres and Kalyuga's (2011) theories in cognitive load. Sweller et al. (2011) discusses that learning becomes inhibited when the material becomes too advanced for the students' abilities. In game design, this is known as the challenge difficulty. If the challenges ramp up too quickly, the player will get frustrated at its difficulty and will often give up playing (Koster, 2013). To meet the changing needs of the user, simulations (like games) have the ability to scale the challenges dynamically. This functionality is easier to achieve in digital, more dynamic environments, whereas static teaching methods find this more challenging. Although there is much debate as to the merits of learner attributes influencing learning, consideration of the students' academic abilities is worth including in the design process.

Self-efficacy can be an indicator of students' potential academic abilities (Ames & Archer, 1988). Ames and Archer discuss how a student's level of self-confidence can influence their approach to learning, suggesting a higher self-confidence can make a student more willing to take risks, as well as using more effective learning strategies (1988, Bandura, 1982). Students' with high self-efficacy will likely perform better and be more engaged with an activity such as a simulation, especially one that puts a student under pressure, than students who are less confident in their abilities.

Bandura suggests that as self-efficacy increases so does self-confidence (1997). For procedural and situational learning, where students are learning how to do something, increasing a student's self-confidence is likely to translate into better performance when in an equivalent real-life situation (Cant & Cooper, 2010). It is important to consider how self-efficacy may impact the students' ability to learn during design of simulation. Ames and Archer suggest that a learning design with a focus on mastery type goals, such as improvement over time and acceptance of errors, can mitigate some of the impact that self-efficacy can have on student results (1997). Where as performance type goals in learning design, such as high grades as a measure of success and comparing results against others, may exacerbate the effects of self-efficacy on student results. A simulation design must consider the effects of student self-efficacy on engagement, motivation and learning outcomes.

2.7 Summary

There is compelling evidence that highlights the effectiveness of using simulations in education (Vogel et al., 2006; Aldrich, 2005). Vogel et al. (2006) meta-analysis showed evidence of improved learning with simulations over traditional methods of teaching, reviewing over 4 decades of experiments. While using only a small sample (13%) of the total examined literature (n=248) may have weakened comparisons between simulations and traditional teaching, the learning benefits of simulations are still evident. Proper analysis of the development process and investigation of the effectiveness of individual features of a simulation may reveal further insights.

The design models currently used for instructional system design do vary according to concepts outlined above, but all demonstrate robustness in sharing the ADDIE approach with many other design methodologies, such as games and websites. The ADDIE method is useful for instructional design, but simulation design would include Alessi and Trollip's Knowledge, Learner and Simulation attributes (2001, p. 232). The combination of the two could yield a more learning objective-focused design strategy and will be applied for the design of the artefact. Shneiderman's rules for interface design are widely accepted and will also be applied during design of the interfaces (1998).

Using more effective design strategies allows the focus to shift towards identifying simulation components that best suit learning objectives. The design techniques are well established for creating content like video, 3D and interactive. However, the impacts of such elements on education are somewhat unclear. Successful educational simulations rely on developing effective tools to educate students. Evidence-based relationships between how these elements educate, to what degree they are effective, and under what circumstances, would considerably aid this process. Clarity of the correlations between learning objectives, education simulation design and the simulation components would greatly assist the design process, and yield better educational outcomes. This research aims to assess current educational simulation design processes and report on how these processes might be improved to produce better educational outcomes.

The following chapter will describe the design process used to create the scenarios for the First2Act online training program, which was used as the artefact for this research. It discusses the aims for both this research and the First2Act Project, as these project aims influence this research. The chapter outlines the learning objectives, the interactive design applied, and the data to be collected.

Chapter 3: Design of the Online Simulation

3.1 Introduction

In the previous section, the discussion covered the different types of simulations and their educational merits. The design process outlined included a number of factors that should be considered during early stages of design. This chapter discusses the aims and processes used to design the artefact, and explains the reasoning for design decisions.

The First2Act 'online program' encompasses a series of eight-minute interactive video-based scenarios, representing different deteriorating patients in a hospital bed. Nursing students must correctly assess and treat the patient within each eight-minute period in order to help the patient survive. The eight-minute period is significant because this represents the typical timeframe a real deteriorating patient has until serious and potentially irreversible complications may develop (Endacott & Westley, 2006). A score is calculated using choices students make, after which additional feedback advises the student on the proper course of action. The scenarios provide options for many of the common actions, or interventions, a nurse can take in these situations (Cooper et al., 2010).

The First2Act 'online program' includes an eight-step process outlined below:

1. a questionnaire on participants' demographics,
2. a multiple-choice quiz on theory to establish a baseline,
3. a short video presentation of the First2Act material,

4-6. three interactive video scenarios (the simulation),

7. a final multiple-choice quiz on the theory (identical to step 2),
8. and finally a student evaluation of the First2Act online training program.

Students work through each step systematically, not progressing until the previous step is completed. The steps are delivered via a website, and include quizzes using standard web technologies, such as HTML and interactive video scenarios delivered using Adobe Flash embedded in the web page. Quiz and simulation scores, plus interaction data, are recorded into the website database. The website quizzes, simulation scores and interactions are utilised to measure performance and track the learning objectives and other aims of the project. It is important to note here that aims of the First2Act project differ slightly from the aims of this research, so for clarity, a description of the project aims follow.

3.2 Aims of the First2Act Project

The First2Act project has a number of aims. However, the main aim is to address gaps in nurse training when dealing with deterioration of patients (Buykx et al., 2011). A key part of solving this problem is providing an opportunity for medical students to practice providing care and treatment of a patient who is deteriorating in a safe simulated environment. Real patient deterioration often occurs unpredictably and in a high-pressure situation, making it difficult for medical students to practice and experience the best course of action. The program provides a safe environment while maintaining an element of the pressure, allowing the students to practice the theory and identify best practice before experiencing a similar situation in the working environment.

3.2.1 First2Act Initial Face-to-Face Trials

The First2Act program was first applied in face-to-face simulations delivered over five, one and a half-hour sessions. Patient-actors were employed to be the sick patients and instructed, by assessors, on how to behave, and when. Students administered ‘pretend’ interventions with the actors responding accordingly. The staff running the live simulation would assess performance at the end of the session, and advise students, giving appropriate feedback for each student.

3.2.2 First2Act Issues, Aims and Learning Objectives

The online version of the First2Act project evolved from a face-to-face trial involving 97 nursing students. The assessment of these trials was used to inform design decisions for the web-based version of the First2Act live simulations (Buykx et al., 2011). The face-to-face trials highlighted deficiencies in student performance during live simulations. The First2Act team reviewed the student performance and identified key issues. Based on the results of these trials, the main student issues identified are as follows:

- Students quickly forgot important tasks once the situation increased in intensity
- Students became fixated on one issue/problem
- Students did not chart vital signs and pain score often enough
- Students did not provide adequate oxygen therapy

Using these issues, and the First2Act manuals' learning agenda, the main aims of the online program could then be created. Each aim tries to address students' gaps in learning. The main aims of the First2Act online program are to:

- provide scenarios that make students feel pressure similar to what they may experience in reality,
- make students realise the time limitations of a deteriorating patient,
- make students consider the many options available and correctly identify the next action to take,
- encourage students to chart more vital signs and other records,
- encourage students to identify the medical issue of the patient (known as presenting condition) correctly,
- show students that there are some systematic approaches to patient care in these situations and that when applied can greatly increase the patient's survival chances.

The aims listed above are used in this research to construct the learning objectives by which the simulation's success will be measured. However, some additional aims were required as part of the funding arrangements for the First2Act online training program. These focused on replacing face-to-face training with an online equivalent. As a result, the research required that certain conditions be met through the tracking of the performance of the students in the online simulation. The requirements are:

- To assess the process students used (choices and the timing of choices, by logging button clicks)
- Measure progressive result changes between the scenarios
- Measure accessibility of the program to students, such as working in multiple browsers and operating with limited bandwidth

These aims were implemented to measure the technical performance of the online system, as well as instructional design elements. Interaction data (click data) was also incorporated to detect simulation features that impact learning. The aims dictated the development of the First2Act online program and its learning objectives. Clarity of the First2Act programs' learning objectives is paramount to the success of the project. Understanding how these learning objectives are achieved using a simulation forms the basis of this research.

The First2Act project identified the following key objectives; theoretical, behavioural and technical, to determine the success of the project. Based on the aims outlined above, the learning objectives are:

- Primarily to teach the principles in the First2Act manual outlining appropriate response to a deteriorating patient
- Conveying key theories in treating patients
- Correct order of treatment
- Appropriate monitoring and testing of patient condition
- To learn to act under pressure
- To correctly identify the condition
- To correctly treat patients with those conditions

The key learning objectives are to be measured by the multiple-choice quizzes, but also through the performance data collected in the three scenarios. Further data from student evaluations in the final step of the program provides qualitative information. The learning objectives are guided by the design of the interactions and the presentation of content in the scenarios.

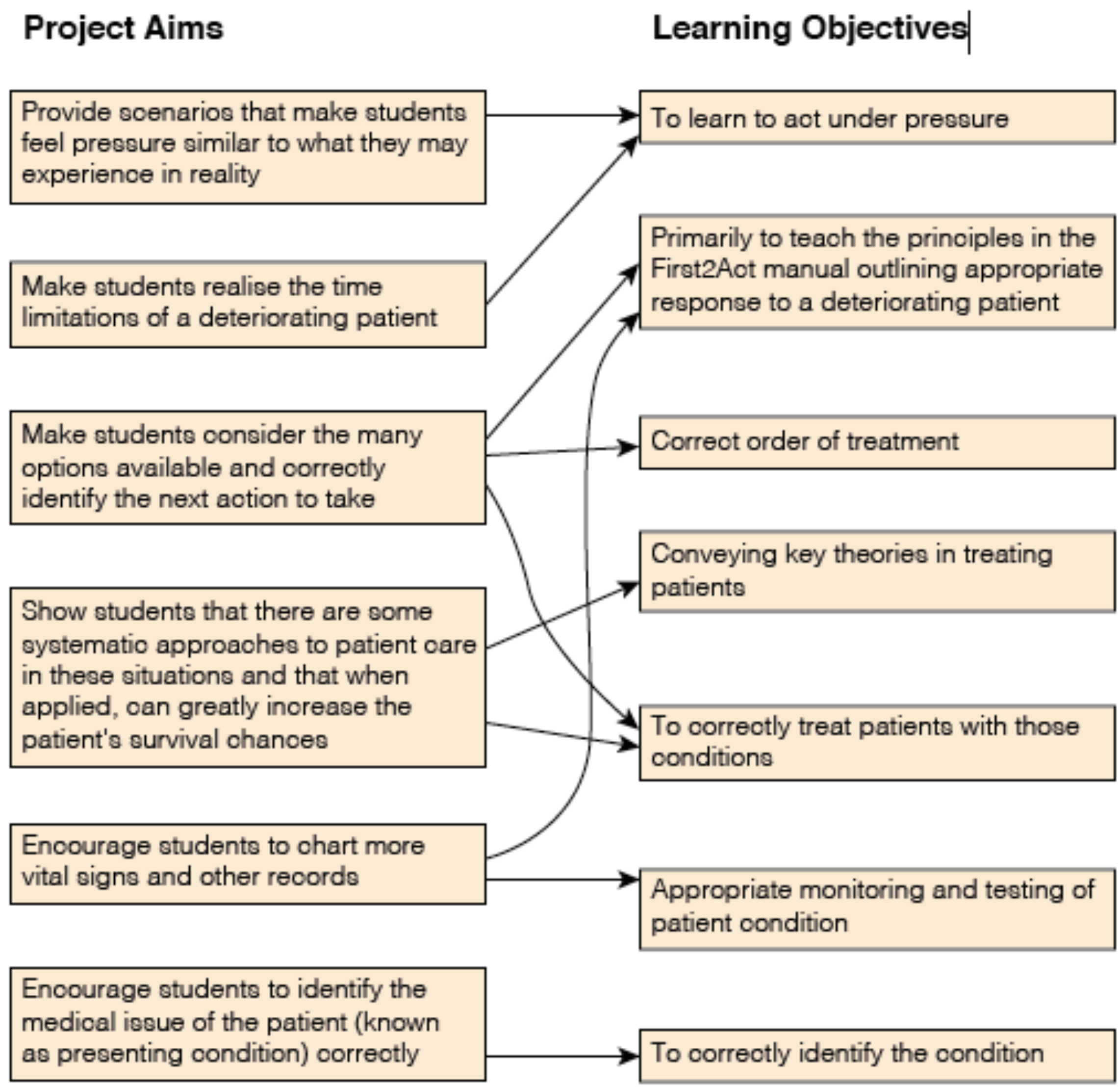


Figure 3.1 The project aims that are addressed by their corresponding learning objectives.

3.3 Content Domain

Learning objectives for this research are culminated directly from the First2Act manual and the face-to-face trial. The First2Act manual provides guiding principles for dealing with a deteriorating patient. The medical practitioners' choices in these situations can severely affect survival chances of a patient. Failure to act appropriately, in the short eight-minute period, often results in severe complications or even death of the patient. The way medical practitioners deal with patient deterioration is known to be problematic for students. Often, essential steps are performed out of sequence, or simply forgotten during this high-pressure situation (Endacott et al., 2012; Harrison, Jacques, Kilborn, & Mclaws, 2005).

The First2Act online program delivers an eight-step learning experience designed for nursing students. A team of academic staff and medical professionals planned the content and processes of First2Act. The online program is based on the face-to-face program, with the patient-actor components replaced with an interactive video equivalent. The eight steps are designed to help students, and capture the data necessary for the First2Act project and this research, to accurately measure the impact on learning. The eights steps are as follows:

1. Enter demographic information (age, education etc.)
2. Answer a multiple-choice quiz (based on patient deterioration theory)
3. Watch video presentation on First2Act procedures and techniques
4. 1st Interactive Video Scenario
5. 2nd Interactive Video Scenario
6. 3rd Interactive Video Scenario
7. Answer a multiple-choice quiz (based on patient deterioration theory) – Same questions as step 2
8. Complete an evaluation form, giving rated and open comments on user satisfaction of the program

Step one captures important demographic information about the cohort. Steps two and seven measure the learning of eleven specific areas, such as oxygen use and needle gauge. Steps three to six form the part of the simulation that teaches the students, and the final eighth step collects feedback from students about their experience. All the steps are used to measure the impact the simulation has on meeting the learning objectives of the project.

3.4 Learning Objectives and Success Criteria

The learning objectives identified were self-rated by the First2Act team out of five, for their likeliness to be completed. Ratings are kept simple (out of five) to avoid any misperceptions of accuracy, as these ratings are to act as a guide only for deciding on which objectives to pursue. By prioritising learning gaps recognised in the face-to-face trials, the design process will better align the outcomes of the simulation with the education goals. Minor objectives were created as measurable sub-tasks, which could be used to achieve the project's major objectives. All minor objectives are rated for two considerations.

1. Necessity (how essential they are to the success of the project)
2. Resources (the use of resources required to achieve the objective)

Necessity highlights how important the objective is in terms of the projects' overall success (1=non-critical, 5=critical). Resources estimates how resource intensive it is to produce; such as use of the team and the capacity of the technology available or the financial cost (1=limited resources, 5=ample resources). A rating with a more positive outlook has more stars. For example, five stars for each column would be paramount for the project's overall success, having ample resources available, and making it highly likely to be completed. By using a simple rating system, quick judgements can highlight aspects that are unlikely to succeed, or identify objectives that are under-resourced, or are perhaps not even necessary. The simple five-star rating is an initial guide only; further investigation can occur for the objectives that need more clarity. This technique is helpful during development, as the team can concentrate on the most necessary items and the ones most likely to be completed, before allocating resources to objectives that are less necessary, or extremely difficult to produce. Figure 3.2 shows how objectives could be associated with their importance to the projects success.

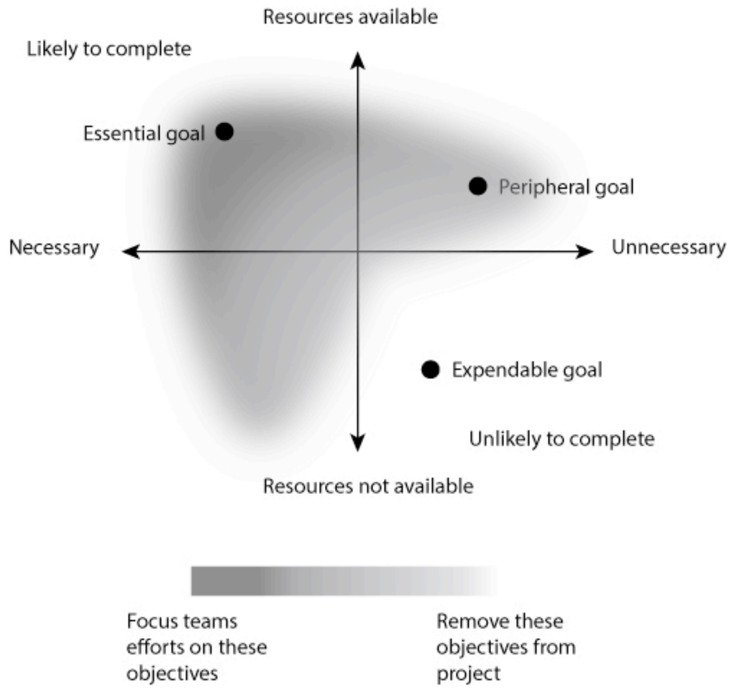


Figure 3.2: How to concentrate efforts on achieving project goals for successful development.

Table 3.1 rates the learning objectives. Tables 3.2 and 3.3 rate the project success and technical criteria. There are both minor and major objectives. Minor objectives are utilised to fulfil major objectives. The method below outlines how the minor objectives are to be achieved. The requirements are the activities that need to occur for minor and major objectives to be completed effectively.

Table 3.1: Key learning objectives for the First2Act online program

Minor objectives	Method	Major objectives	Requirements	Necessity	Resources
Key Learning Objectives					
Students do not focus on singular intervention	Students work through taking vitals and other interventions in a systematic way by using the simulation. It is reinforced through repeated use in order to commit to memory	Produce an evidence based online learning package to enhance nursing students' management of deteriorating patients Provide excellence in teaching	Clear and consistent communication between education and technology professionals	★★★★★	★★★★☆
Students systematically treat/manage patient				★★★★☆	★★★☆☆
Students gain key knowledge for specific treatment of patient deterioration				★★★★☆	★★★☆☆
Students need to recognise a deteriorating patient	Students are presented with information and then apply this in the simulation			★★★★★	★★☆☆☆
Students need experience in the pressure associated with patient deterioration	Simulation has a limited timeframe (8 minutes) and patient is noticeably distressed			★★★★★	★★★☆☆

Table 3.1: Key learning objectives for the First2Act online program

Table 3.2: Project success criteria for the First2Act online program					
Minor objectives	**Method**	**Major objectives**	**Requirements**	**Necessity**	**Resources**
Project Success Criteria					
Website and content accessible for 5 years in a sustainable way	Choose appropriate web hosting and content management system, to minimise management costs	Complete OLT grant conditions	Adequate IT support is supplied to ensure efficient construction, running and maintenance of the project	★★★★★	★★★★☆
To supplement education resources as a part of nursing higher education	Make accessible to students and provide mechanisms for teachers/students to access results		Technology assists in delivery of content and assessment	★☆☆☆☆	★★★☆☆
Report outlining the results of the program	Collect data and create report to give to OLT		Program tracks user interactions and results	★★★★★	★★★☆☆
Analysis of students' results and interaction (data) with the program	Collection of adequate data to enable effective analysis for research, reporting/papers and further development of the program	To improve the resource and provide Monash University and Queensland University with an education and research asset		★★★★☆	★★★☆☆

Table 3.2: Project success criteria for the First2Act online program.

Table 3.3: Development success criteria for the First2Act online program

Minor objectives	Method	Major objectives	Requirements	Necessity	Resources
Project Development Success Criteria					
Learning outcomes drive selection of technology	Ideal choice of delivery (e.g. video for showing patient in bed)	Provide the best learning outcome through appropriate selection of technology	Selection is based on collaboration between academics and developer	★★★☆☆	★★☆☆☆
Technology used adds value to teaching and learning	Technology improves understanding of material			★★★☆☆	★★☆☆☆

Table 3.3: Development success criteria for the First2Act online program.

Each objective was examined independently to form early predictors of what is likely to work and what was best avoided. An assessment of existing design processes helped to inform the likelihood of success of objectives, both educational and technical (Aldrich, 2005; Alessi & Trollip, 2001; Gibson & Baek, 2009; Herrington et al., 2010; Peters, 2013). The associated costs in resources, including human, time and monetary, plus the likelihood of success based on those resources, surmised the difficulties of achieving each objective.

3.5 Interface and interaction design principles

Moreno-Ger, Blesius, Currier, Sierra, and Fernandez-Manjón (2008), Shneiderman (1998) and Tognazzini (2003) delineate interface and interaction design principles that are largely accepted by the interface and interaction design community. Their principles have guided the design process for this project. Reflecting on the aims of the project, the design principles used are aligned with either achieving learning objectives or usability requirements, or both.

Interface and Interaction Design Principles Employed

The interface of a simulation, or any interactive environment, should have a minimal impact on the users' cognitive ability. Sweller et al. (2011) describes this as extraneous cognitive load, where using the interface consumes the individuals working memory and in turn inhibits the capacity to learn. Shneiderman (1998) has devised design rules that can minimise the impact the interface will have on the user. These rules are outlined below:

- Consistency in design of colours and 'look and feel' – make interface predictable
- Consistency in design of action/feedback loops – make interaction predictable
- Spatial positioning of objects to create balance in design – stop the user being overwhelmed by information and graphics
- Simplicity in design – minimise confusion
- Text/icon mix on buttons – employed to consolidate the buttons' function/action and convey ideas quickly, identify button function easily without requiring them to re-read text

These methods above have been adopted in the scenarios' design. Examples below were used in the scenarios to maximise usability and reduce extraneous cognitive load, which could impact students' ability to learn:

- Focus with vignette – The video occupies the majority of the screen real-estate. When students engage with the menu items, a vignette is applied over the video to simulate that they are not engaged with the patient directly.
- Audio alerts – let students know when specific events occur, buttons click, actions are complete, results given for a test, etc.
- Visual alerts – a highlight colour draws attention to a specific event/change in the system.
- Using mental models consistent with other systems – for example, a red close button.

Minimising the impact of the interaction and interface design is an important step in assessing the impacts of the simulation on learning outcomes. By keeping cognitive effects of the interface to a minimum, the research can better assess the simulation features and instructional design elements that impact learning outcomes.

3.6 The Artefact

This section discusses the three scenarios and how the students experience them. An explanation of each design decision is linked to the design principles in the previous section. The aims, education goals and target audience suggested a simplistic interface design with simple cause and effect feedback responses. In the first instance, students are greeted with an instruction screen that explains each aspect of the interface, and what to expect in the scenarios. This scenario does not progress unless the user clicks "START". The student gains 'locus of control' by allowing the individual to choose the duration required to understand the interface (*Plate 3.1*).

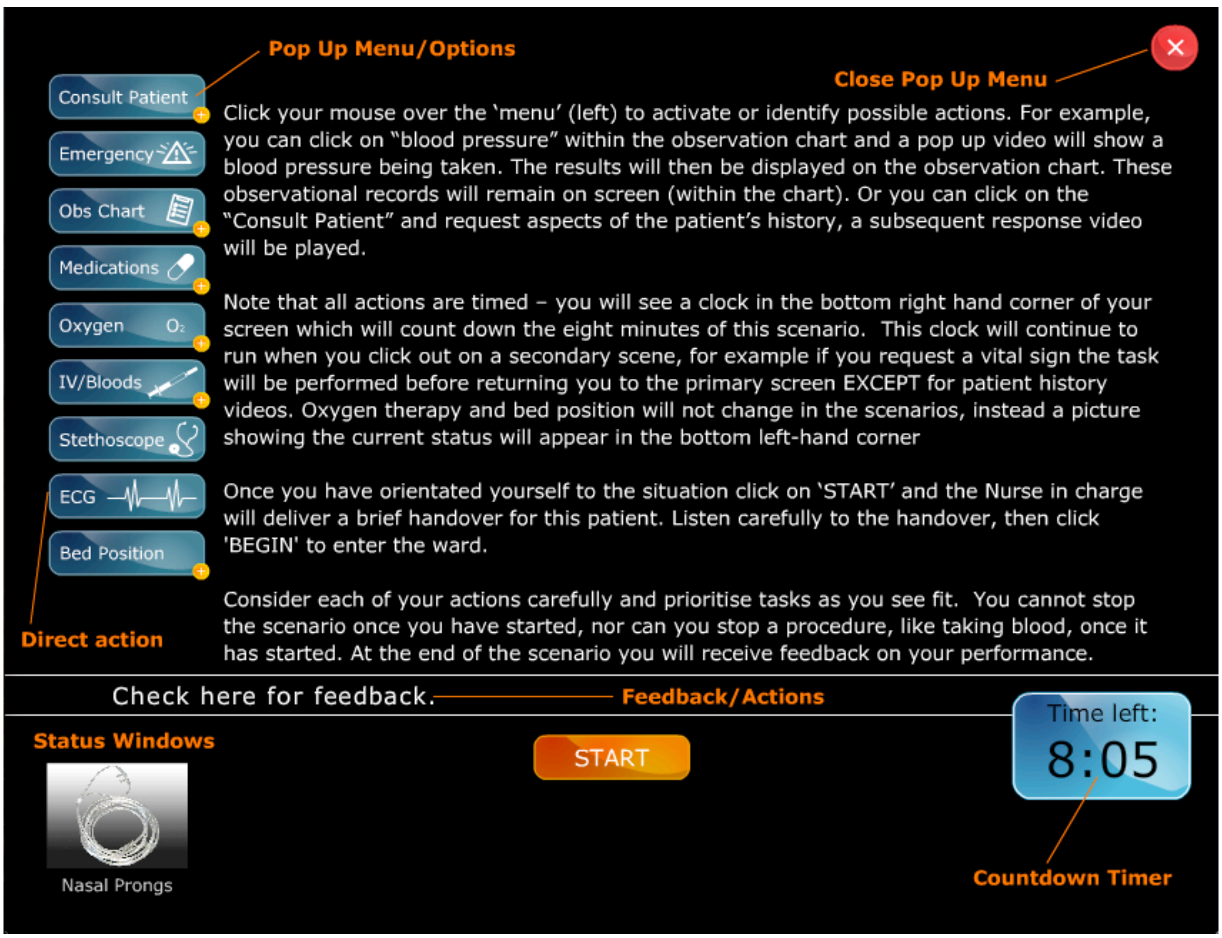


Plate 3.1: Screen instructs the students on how the scenario works, waiting until they are ready to move on

The instructions screen informs them and begins establishing mental models, some based on existing mental models and some are new mental models. This is important due to the short timeframe students have (eight minutes), and the high number of interactions they are required to perform; the interface needs to be easily understood.

The handover sequence follows and instructs students on the current condition of the patient and is delivered using video of a nurse talking to the camera. The additional information is a typical occurrence in a hospital and provided before a nurse would see the patient. This short video provides essential information and must be viewed by the student. The button to 'BEGIN' is faded, and no hand cursor will appear, so the student does not get the impression they can click *(Plate 3.2)*. The faded button helps to establish the mental model that faded buttons are disabled buttons. A faded button is a common feature amongst other computer programs, where it indicates disabled buttons. Throughout the scenarios, all faded buttons are disabled. Once the handover video completes, the button will become highlighted and active, indicating to the student they can now continue. The text instruction changes from “Please wait!” to “Let’s go see the patient.” to encourage the user to continue and indicating that further action is needed *(Plate 3.2 & 3.3)*.

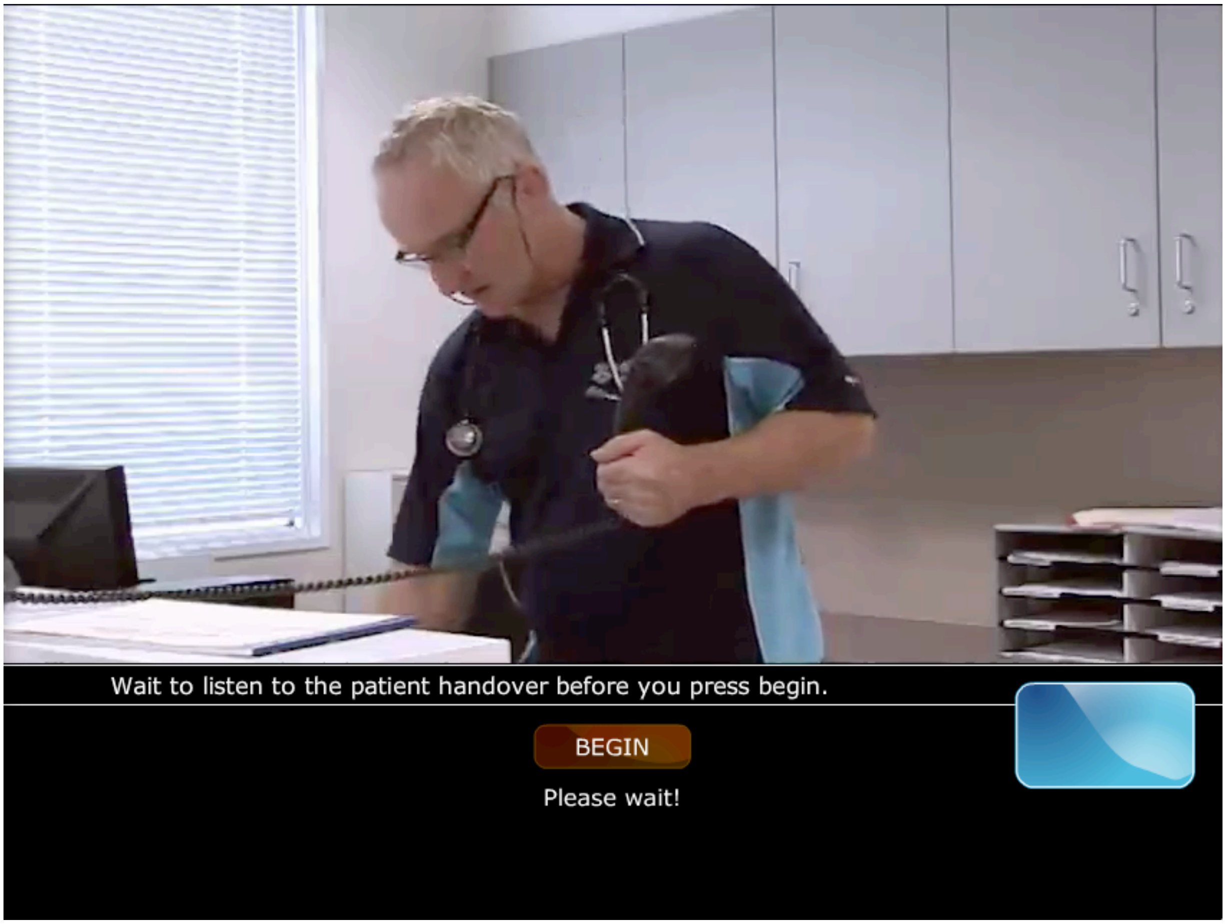


Plate 3.2: Handover video is a typical hospital occurrence. The faded button is a common mental model for disabled buttons

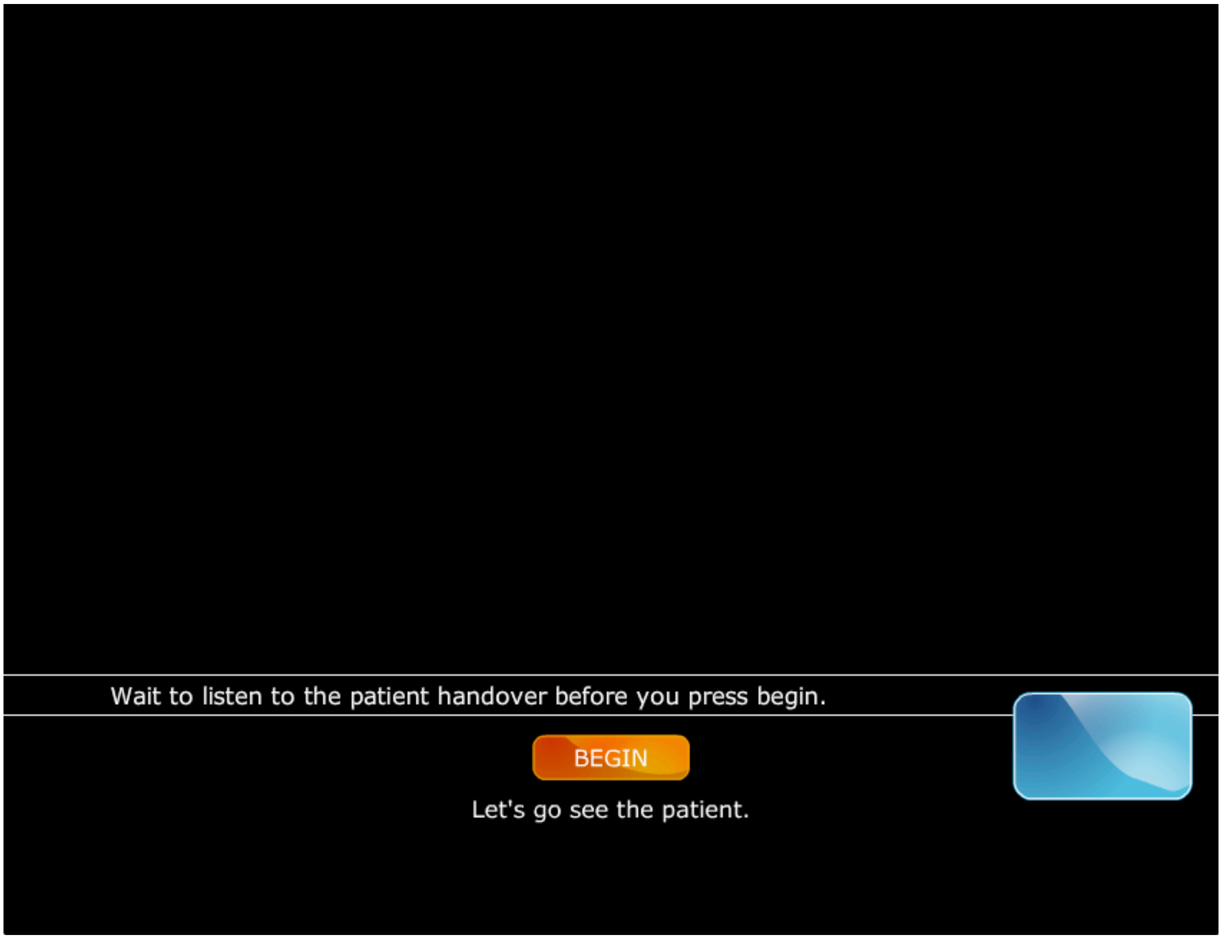


Plate 3.3: When the handover video completes the button highlights and instructions appear indicating that action is required

Just like faded disabled buttons, each interaction type should be obvious from the outset without requiring exploration of the interface. The support of existing users' mental models occurs by making the button's function obvious, with icons and text that represent the intervention related to that button. Utilising existing mental models helps to reduce extraneous cognitive load, such as a red button with an 'x' for closing a window, often used in software programs *(Plate 3.4)* or faded buttons to show they are no longer functional.

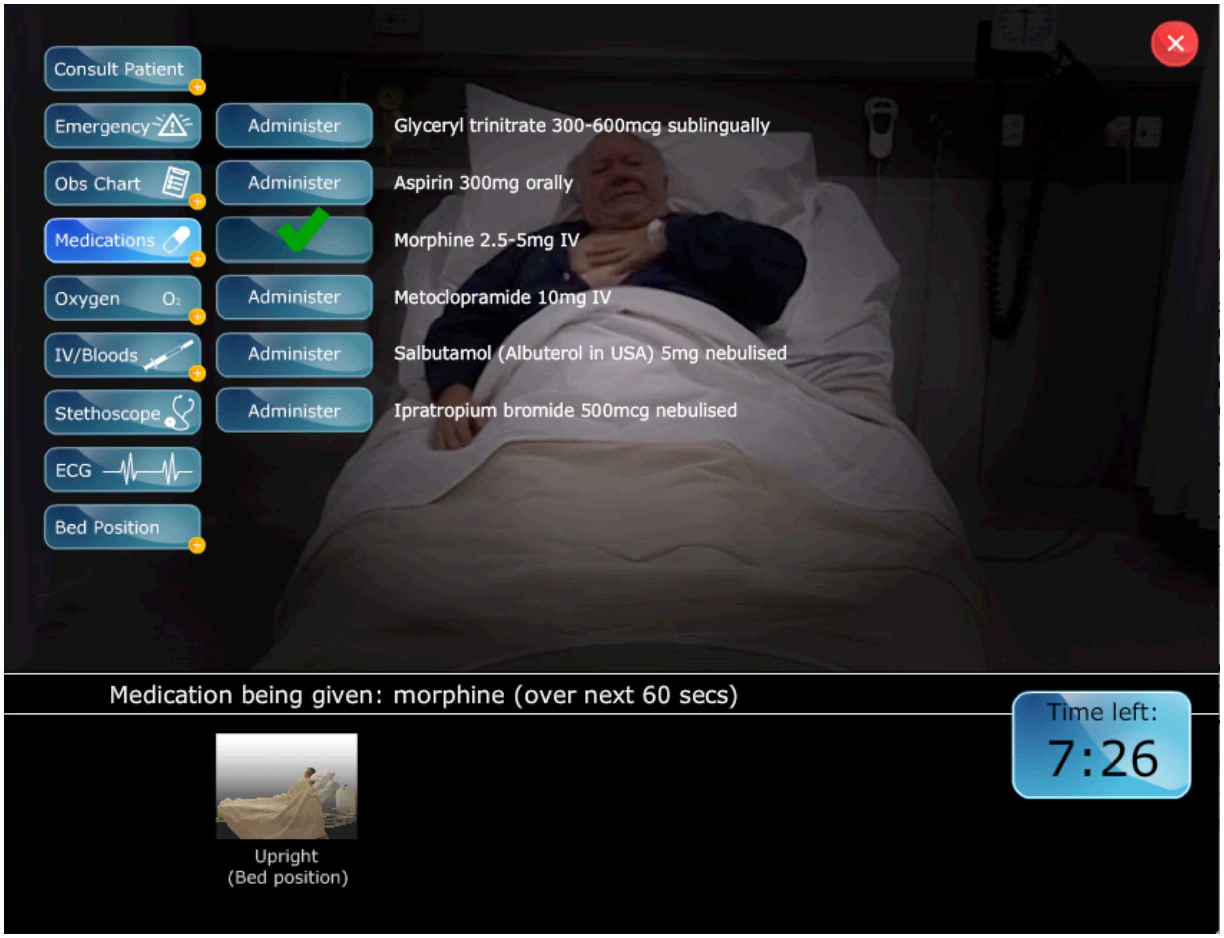


Plate 3.4: Screen and interaction design utilising established user mental-models

Buttons with text and icons (where space allows) speed up recognition of buttons. Students will read the text initially, and create associations with the icon. When clicking on future occasions students quickly recognise the button using the icon, negating the need to re-read the text (Houts, C. C. Doak, L. G. Doak, & Loscalzo, 2006). The design and layout remain consistent throughout, with buttons always to the left, and sub menus directly to the right for that selected button. Some sections require images to clarify terminology, such as the bed position *Orthopneic*, which has an alternative definition *Trendleberg (Plate 3.5)*. The images also reinforce the communication of the bed position through the visual representation, reducing cognitive load produced by trying to recall each bed position terminology. The use of images in this way also strengthens the scenario's connection with real world decision-making. When changing the bed position for the patient, a nurse would not normally recall the terminology of the position (word), but rather generate a mental image of the bed position (Carney & Levin, 2002).

Plate 3.5: Menu employs imagery to clarify terminology and reinforce recollection

In order to make the scenario more realistic, video cut-scenes represent the procedure that the nurse chose. While in reality the nurse may be able to do two things at once. One of the educational outcomes is to help students appreciate the finite timeframe that they have. Students should learn that not all actions are possible in eight minutes, and they must prioritise the most critical. To highlight the limitation, all actions are disabled when a cut-scene video plays, by hiding all buttons and locking features *(Plate 3.6)*. This indicates that there are no possible actions to take until the video has played out and the procedure is completed. Students cannot cancel an action once it starts. To prevent students thinking the scenario is broken, instructions at the beginning explain that this will occur *(Plate 3.1)*.

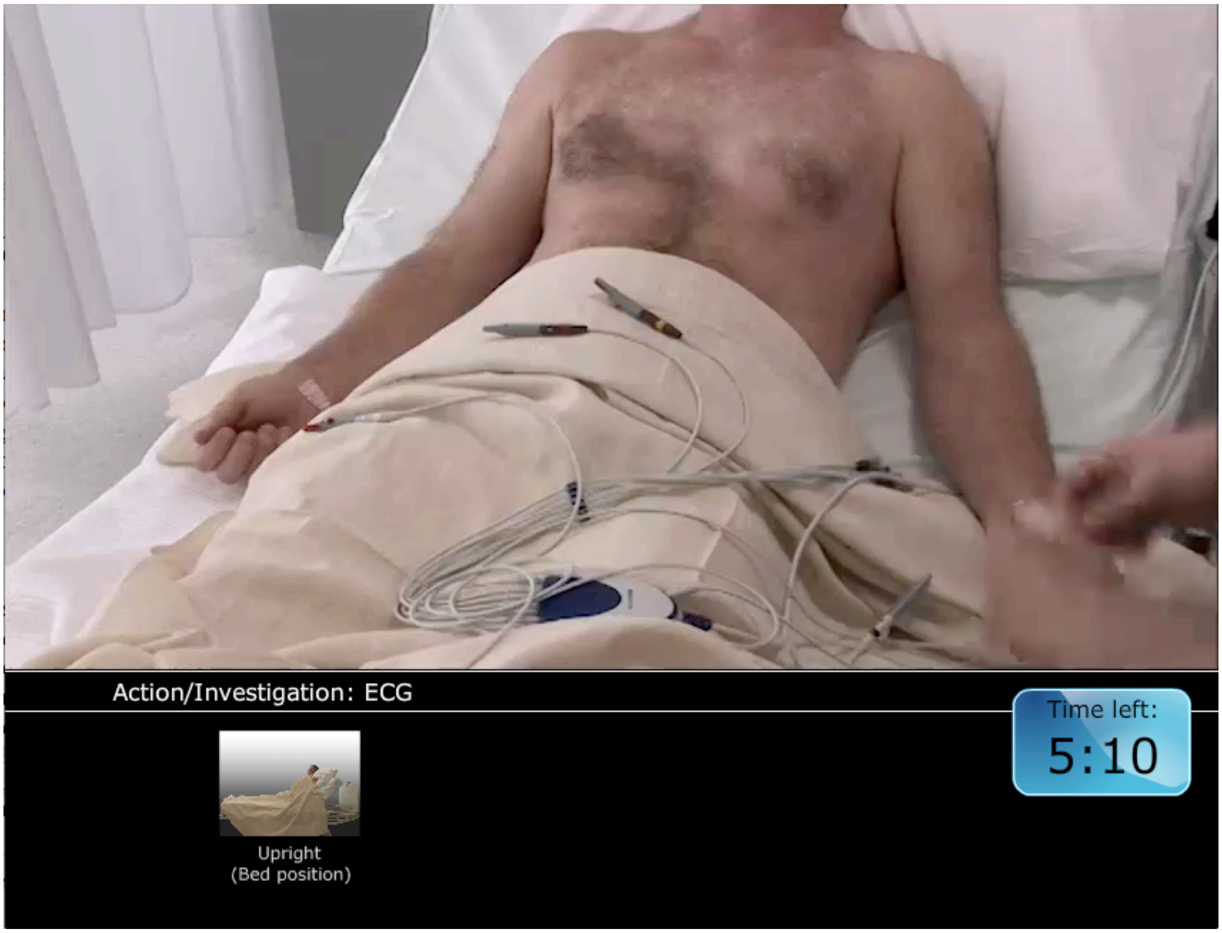


Plate 3.6: Buttons are hidden preventing the student from interacting

Some cut-scenes are shortened slightly when compared with their real world equivalent, which compensates for the fact that nurses can often do more than one task at once. However, for the patient dialogues the timer will pause, as nurses often talk with patients while working on other tasks.

Nurses also have the ability to re-read charts and vital signs. In the case of an ECG, the printout (chart) will load to the screen for the students to re-examine. A small message under the chart shows that it can be closed and reviewed later *(Plate 3.7)*. In certain unique cases, like the ECG chart, a simple text instruction will be better than establishing a new user mental model for that one type of interaction.

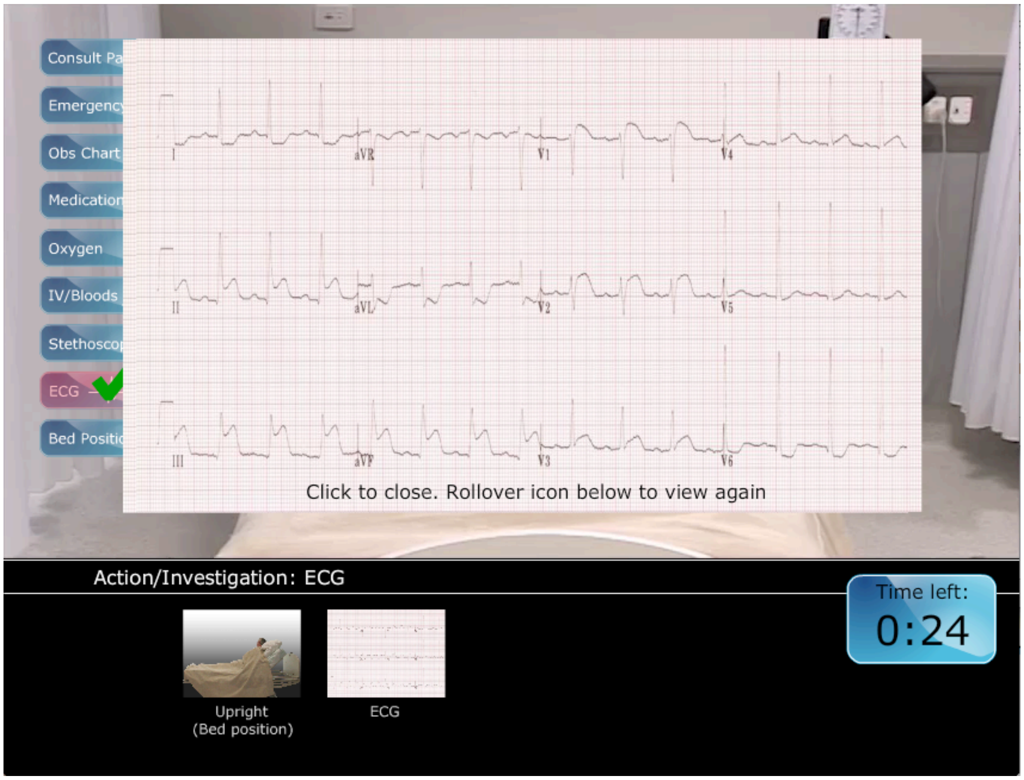


Plate 3.7: Pop-up ECG mimics the nurse's ability to re-examine a chart. Help text guides possible interactions

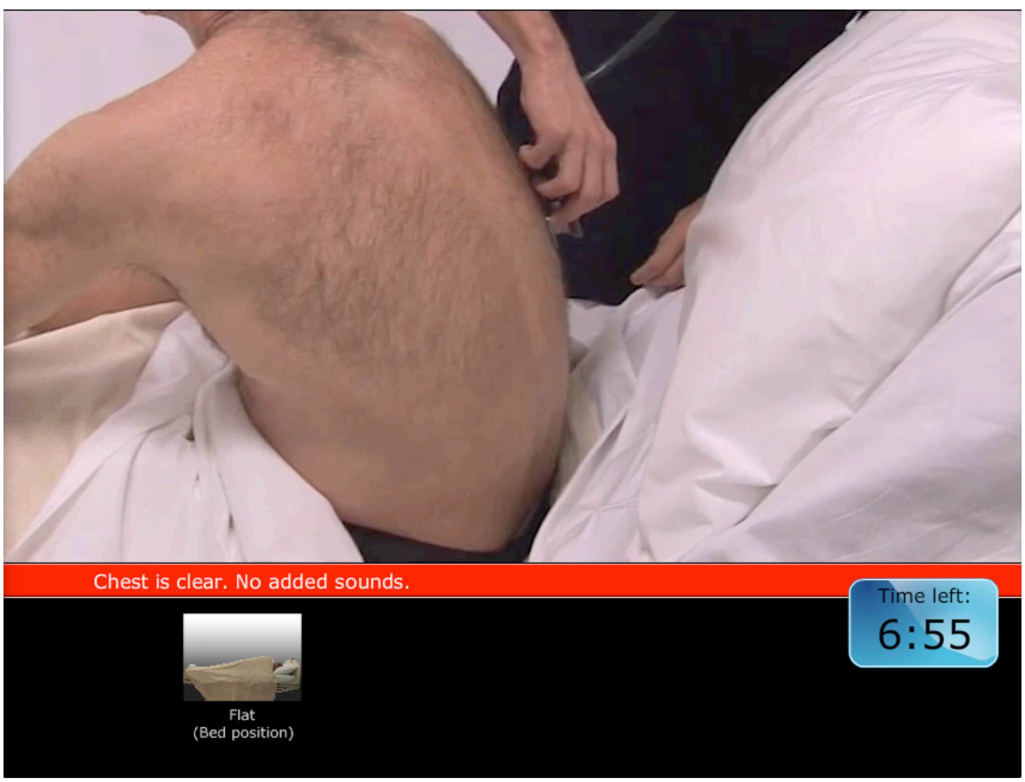


Plate 3.8: A red bar flashes and an audio cue indicates that information is being disseminated to the student.

During the scenario, meaningful feedback is provided about particular interactions such as a measurement or other essential information. A red bar flashes in combination with an audio cue in the form of a beep, similar to sounds found on the hospital equipment *(Plate 3.8)*. This cue is first given in the handover screen *(Plate 3.2)* and establishes a mental model that continues throughout all scenarios.

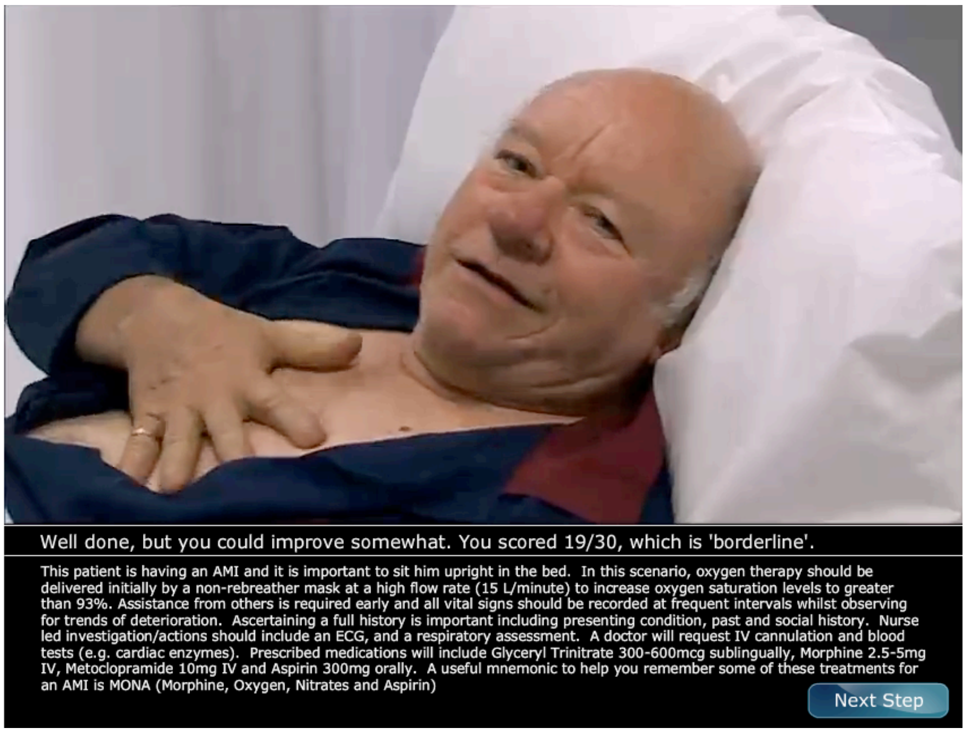


Plate 3.9: Final screen with thank you from patient, score and detailed feedback

On completion of the scenario a feedback window includes a description of the condition and recommended treatment *(Plate 3.9)*. This includes a thank you video from the patient, and a score that indicates: a fail (<30%), borderline (30-60%), or distinction (>60%). This window clearly indicates the completion of the scenario and yields closure for the student.

3.6.1 Online Simulation Design Process and Testing

The previous section discussed the experience of students when using the scenarios. The design, development and testing of the scenarios followed a specific process. First, designing one scenario as a model for the second and third. Table 3.4 outlines the design process followed for the development of the interactive video scenarios.

Table 3.1: Development lifecycle of interact active scenarios
Develop and test initial functionality; a rapid prototyping technique to test key functionality, assuring each part can be created and works with the entire system.
Develop the end goal objectives using programming; create and test key technical objectives, namely generating and storing data such as scores and tracking/click data.
Create a theme for the interface; generate an initial interface design. Collect feedback and test walkthroughs of the interface to make sure key interactions are easy to perform and that navigation is a smooth experience.
Design interface; complete an interface design, based on information collected from the previous step and prepare graphic assets for integration into the system.
Implement interface with functionality; integrate the graphic user interface with the core system functions, such as storing data in the database, loading videos from the server, running on multiple operating systems and browser types.
Test with a pilot group of professionals; this group largely consists of medical professionals. The system will be open to a selection of people to give advice and feedback on how the system runs. For example, inaccuracies in the content, any errors experienced, and general usability issues.
Note changes requested; all the feedback from the pilot is analysed and assessed for its need against how difficult it will be to implement.
Make improvements to design, functionality and material; changes are implemented based on the information gathered from the last step.
Create other two scenarios; create two more scenarios using the first scenario as a template.
Test system with student pilot groups; two class-based trials using a group of 4th year nursing students. Technical assistance given directly as students run into problems on site.
Note issues; notes of the student pilot group sessions and data collected from the system is analysed after the session. Changes made are based on their need and how difficult it will be to implement.
Final changes; final changes to the system and content are made based on the previous step.
Implement full-scale program; program becomes available to a number of student cohorts from a range of institutions. Future issues with the system dealt with as they arise.

Table 3.4: Development lifecycle for the interactive scenarios

The steps above describe the method used to create the scenarios and involved consultation with stakeholders in the First2Act project, namely the project lead, Cooper, and Porter. Each step relied on information gathered from previous steps and development followed an iterative process of rapid prototyping to constantly test changes. Adobe Flash was used to create the scenarios making the iterative method of development preferable. Adobe Flash is useful for rapid deployment, but includes some limitations as a development tool.

3.7 Limitations for Developing the First2Act Online Program

Technical limitations resulted from the utilisation of Adobe Flash as the core delivery mechanism for the scenarios. Due to tight timeframes, created by delays in the broader project, the use of Flash for development was the only option. While Flash provides a stable and rapid development lifecycle, there are some accessibility limitations due to incompatibility of Flash video streaming with Internet Explorer browsers and some mobile devices. Flash also reduces the simulation's capacity to track all the website activity when using an analytics engine, like Google analytics.

Another limitation was related to content creation, as all video assets were created prior to technical development of the scenarios. Creating content well in advance of any formal system design, resulted in limiting the range of options available to the interactive video-based scenarios, such as multiple narrative pathways. Having a more unified design process involving technical aspects and content creation simultaneously, may have allowed for a more dynamic approach to video narrative and its technical integration.

3.8 Designing the First2Act Online Program to Collect Data

First2Act program utilises a mySQL database to store the collected data. The website is designed using the Wordpress Website Engine and utilises PHP programming language to record and retrieve the data from the database. All surveys and questionnaires are generated in Wordpress using plugins, in combination with some custom programming. The answer and question combinations are recorded into the database in the same data string. Combining the data in this way makes sure that answer data is always aligned with the correct question. Data is only recorded when the user clicks the submit button, so no half completed data sets are ever recorded.

Scenario interaction data and scores are also recorded into the database using PHP code. The data are stored in a log file in the Flash program itself, collecting both the action and time in seconds. All clicks related to actions are recorded. A score for the scenarios is generated based on this log data, and both the clicks log and final numeric score is recorded into the website database. The results from the scenario are only recorded when the scenario is finished. No half completed scenario data is recorded.

3.9 Summary

This chapter began by providing an overview of the proposed online system with regards to its face-to-face equivalent. The online system was designed to provide a similar experience to the face-to-face trial while consuming far fewer resources. In Section 3.2 an outline of the key objectives of the program are highlighted, and their actuation will mark the success of the project. The following sections then discuss the design of the new online system, breaking down the process into interaction design, interface design and system design. The process was summarised by the limitations of the system and the technology used to collect the data.

The following chapter, Chapter 4 Methodology, outlines the research framework, methods and experimental procedures used to determine if the proposed First2Act system adequately achieves the project goals, and to answer the research questions.

Chapter 4: Methodology

4.1 Introduction

Design Science will provide a solid framework for the methodology of this research. While analysing existing simulations is possible, creating a unique system (artefact) is an effective way to review each step of the design process, while also collecting specific data to help answer the research questions. Understanding the underlying development of the simulation will provide a better perspective when analysing interaction data and detecting reasons for certain patterns or anomalies. As it is hard to predict the patterns that may emerge from users interaction with a simulation system, being able to collect a broad range of data about users is important. The system will be designed to assess information about learning, but will also collect data such as demographics, feedback and user interactions. This will allow the exploration of patterns in interaction that may offer answers on how to improve future simulation development processes.

4.2 Conceptual Framework

The research methodology used is Design Science, as this will afford the best means of acquiring the level of data necessary to provide the greatest opportunity for analysis (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). Design Science supports the creation of an artefact to test and measure in a controlled and designed environment, and the artefact can be utilised to automatically collect data. Design Science is also useful if there are limited options for a real world environment that replicates the conditions of the experiment or if the use of such an environment would make it difficult to control the variables.

The research focuses on the development and evaluation of an online educational simulation aimed at educating nursing students. The process of designing and evaluating the simulation has the intention of improving the design and development process of similar simulations as well as investigating how well the simulation operates as an educational tool. Design Science research can be applied to a range of contexts that require the creation of artefacts, including algorithms, human-computer interaction, design processes and languages. This research investigates the design process with a particular focus on education and the effective design techniques that maximise the educational outcomes. Design Science is common in Information Technology and Computer Science disciplines and should align well with the research goals.

The Design Science guidelines defined by Gregor and Hevner (2013) require the creation and evaluation of an innovative, purposeful artefact for a specific problem domain, which contributes towards solutions in that same field of study, the results of which are useful and easy to comprehend on both a technological and management level (Gregor & Hevner, 2013, p.341-342).

Table 4.1: Design Science research contribution types

	Contribution types	**Example Artefacts**
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↑↑↑ ↓↓↓	Level 2. Nascent design theory – knowledge as operational principles/architecture	Constructs, methods, models, design principles, technology rules.
More specific, limited and less mature knowledge	Level 1. Situated implementation of artefact	Instantiations (software products or implemented processes)

Table 4.1: Adapted from *'Design Science research contribution types'* Gregor and Hevner (2013, p.342)

This research contribution largely focuses on the Level 2 of Design Science research contribution types outlined in the table above *(Table 4.1)*. Level 2 describes creating an artefact, where the design process is carefully monitored throughout and—once completed, the effectiveness of the process and artefact's outcomes are measured and analysed. This research will follow the Design Science methodology outlined by Peffers, Tuunanen, Rothenberger and Chatterjee (2007) described best by the sequence presented in the following diagram *(Fig. 4.1)*.

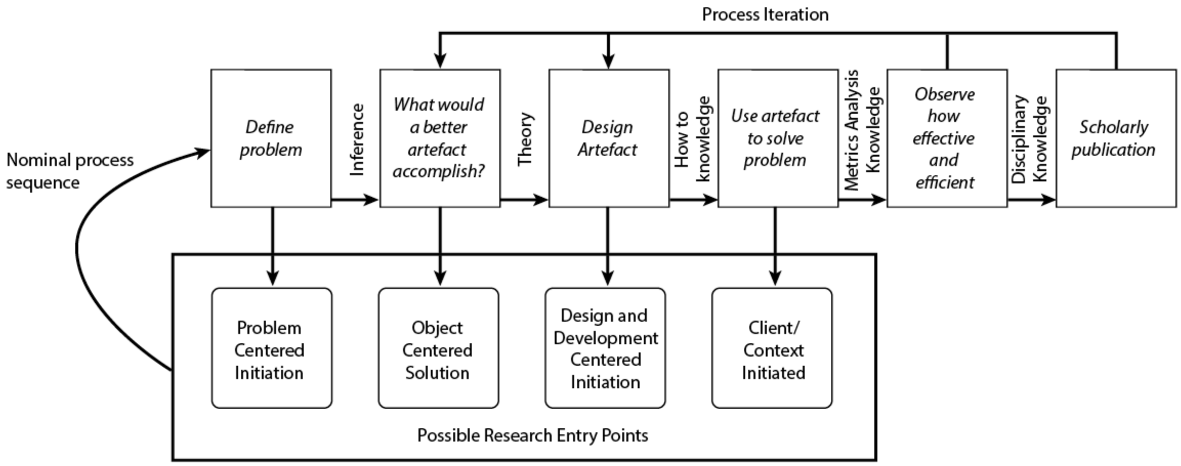


Figure 4.1: Adapted from Design Science Research Method Process Model (Peffers et al., 2007)

The following sections of this chapter will describe in detail how the research will be undertaken, linking to the steps in the diagram above.

4.2.1 Research Artefact and the First2Act Program

This research forms part of a larger project. The project team, Cooper, Beauchamp, Bogossian, Porter, Hopmans from Monash University and Queensland University collectively, designed the research instrument. Aspects of the eight-step program are based on the First2Act face-to-face sessions, where simulated patients (specially trained actors) in a simulated physical environment had teams of students treat them. This experiment ran with 97 participants and established key methods of delivery, as well as recognising areas where students needed further assistance. The First2Act manual was created as part of the face-to-face program. This research forms part of phase two and three, of a four-phase project, with face-to-face and the First2Act manual being part of phase one. When creating the research instrument for this experiment, the demographics questionnaire *(Appendix A)*, pre and post multiple-choice quiz *(Appendix B),* and evaluation questionnaire *(Appendix E)* were created by Cooper, Porter and Bogissian. The technical components of the three scenarios *(cardiac, respiratory and shock)* and click data collection were created by Hopmans with educational contributions made by Cooper and Porter on methods of scoring and interaction, names, and educational content *(Appendix C, D)*. Collaboration between all members was constant, and changes were made to all parts of the experiments from suggestions by each member. Hopmans created all the technical aspects of the online research instrument, including the scenarios, website and quizzes. The eight-step program outlined below shows the typical experience for the student:

1. Sign up and Demographics
    a. Student signs up to the program with an email address
    b. Student receives an email with instructions on how to access the program
    c. Student logs into the website
    d. Student answers a questionnaire asking for demographical details; age, course type, previous industry experience etc. *(Appendix A)*
2. Prior Knowledge – Pre Multiple-choice Quiz
    a. Student works through an MCQ that asks questions specific to information in the First2Act Manual *(Appendix B)*
    b. Correct answers are not given to the student and they continue to the next step
3. Presentation
    a. Student presented a video that outlines First2Act principles
    b. Video outlines appropriate response to make in a range of situations
    c. Video outlines how to recognise certain conditions based on readings taken and patient responses
    d. Student can download a document version of the presentation video slides
4. Scenario 1 (cardiac)
    a. Student interacts with the eight-minute scenario of a patient suffering a cardiac condition
    b. All student clicks are recorded: the time and action that was selected (button clicked)
    c. Upon completion, students are given feedback indicating the correct course of action for this scenario and a numeric score and a grade of 'fail' (<30%), 'borderline' (30%-60%) and 'distinction' (>60%) *(Appendix D)*
    d. The score is calculated, based on the last click in each category, regardless of prior clicks that may have been correct/incorrect. *(Appendix C)*
5. Scenario 2 (respiratory)
    a. Same as Scenario 1 (a-d) however patient is suffering a respiratory condition

6. Scenario 3 (shock)
    a. Same as Scenario 1 (a-d) however patient is suffering from shock
7. Post Multiple-choice Quiz
    a. Student works through the same MCQ as previously *(Step 2)* that asks questions specific to information in the First2Act manual *(Appendix B)*
    b. Upon completion, student is given answers to the questions
    c. Student is emailed the answers to the questions
8. Evaluation Questionnaire
    a. Student answers questions about their experience, overall confidence, and then rates their knowledge and understanding of the material *(Appendix E)*
    b. An opportunity to give open comments about the project is given
    c. Upon completion, student can download a certificate of participation
    d. Following on from this, student can download the First2Act manual
    e. Student is emailed the certificate as a secondary record of completion
    f. Student will receive a certificate, regardless of their grade

The eight steps above collect both qualitative and quantitative data from participants. Qualitative surveys *(Appendix A – Step 1d)* ask questions about age and gender, as well as details about study and industry experience. A theoretical multiple-choice quiz also collects before and after knowledge *(Appendix B – Step 2a, Step7a)*. Finally, an evaluation questionnaire *(Appendix E – Step 8a,b)* gathers feedback from the students about their experience. Most questions require answering, however in the demographics survey, some free text questions only needed to be answered if the choices provided did not adequately describe that student's situation. Free-text options allowed for a more detailed picture of student profiles. The final open comments question was also optional *(Appendix E – Step 8b)*, so students do not feel compelled to write something. Quantitative data collected includes the results of the theoretical multiple-choice questions *(Appendix B – Step 2a, Step7a)*, the interaction data from the scenarios (including clicks and final scores) *(Appendix C – Step 4b,d, Step 5b,d, Step 6b,d)* as well as the student Likert evaluation ratings for the program *(Appendix E – Step 8a)*.

The data gathered for this research is collected from all participants. The program targets third-year or final-year nursing students, who are invited to participate and then voluntarily subscribe with informed consent. The program can be exited at any point in time, reducing the likelihood of any lasting distress for participants. All data collected is made anonymous before being analysed or published.

4.2.2 Data Collection

The data collected from the experiment will primarily come from the three scenarios. Log data, measuring each individual click and when it occurred in the eight-minute period, is recorded. The time of the last click of each intervention, and a score based on the action, is tracked as a summary of the interactions the student has had.

Data is collected during a pre and post multiple-choice quizzes (MCQ), containing questions about the core principles of First2Act. The pre-MCQ is given before any information is provided. This provides a benchmark for measuring gains/losses made by each student after working through the scenarios. Results from the post-MCQ will act as a measure for the specific content areas where learning has or has not occurred.

Further data is collected via a demographics questionnaire and can be paired with changes in the pre and post multiple-choice. This data is used to highlight any potential anomalies. For example, students might perform poorly in the multiple-choice (largely written), but perform well in the scenarios (largely visual), due to language issues (i.e. English as a second language).

Finally, feedback is collected to cover areas of research interest that cannot be covered by the quantitative data, such as how stressed the student felt or if the student's confidence improved. This data allows analysis of the learning experience beyond the metrics of fact-based learning objectives, and helps identify experiential features that click data alone will not demonstrate.

The table below outlines the data used for this research.

<table>
<tr><th colspan="5">Table 4.3: Summary of data collected by research</th></tr>
<tr><th>Data</th><th>Research Instrument</th><th>Qualitative</th><th>Quantitative</th><th>Appendix</th></tr>
<tr><td>A</td><td>Demographic survey: collecting age, gender and education level as well as prior experience in similar situations.
Example: At which institute are you studying?</td><td>✓</td><td>✓</td><td>A</td></tr>
<tr><td>B</td><td>Pre multiple-choice quiz: testing four main areas of learning based on the First2Act manual (this test is done before any teaching material is given). Questions are the same as post multiple-choice quiz (E) Four choices given for each question.
Example: A patient with hypoxia is likely to be:
1. Confused
2. Hot
3. Happy
4. Pink</td><td></td><td>✓</td><td>B</td></tr>
<tr><td>C</td><td>Scenarios 1,2,3 (Cardiac, Respiratory, Shock): total numeric score devised via correct treatments applied to the patient, and the time at which they were applied. Each clickable action is recorded with an individual score of a value from 0-3 (scores depend on the maximum score allowed for that action).
Example:<table><tr><td>respiratory rate</td><td>iv cannula</td><td>pain score</td></tr><tr><td>1</td><td>1</td><td>2</td></tr></table></td><td></td><td>✓</td><td>C</td></tr>
</table>

Data	Research Instrument	Qualitative	Quantitative	Appendix
D	**Scenario click logs (for all three scenarios):** indicating what interface menu (category) and button (action) was clicked, and at what time in seconds (counting down from ≈480 seconds). *Example: bed_position~flat~485^patient_history~social~469^patient_h…*		✓	L
E	**Post multiple-choice quiz:** testing four main areas of learning based on the First2Act manual (this test is done after all teaching material is given). Questions are the same as pre multiple-choice quiz (B)		✓	B
F	**Evaluation questionnaire:** asking for feedback on the scenarios and the program as a whole. Questions will ask students to rate the usefulness of the program, whether they understand the material better, and their general confidence about their abilities. Students will use a Likert scale to make those ratings. Open comments will allow for any general comments about the program outside of the preset questions. *Example: Before the online activities, my perceived ability to: Recognise a deteriorating patient* Not at all To a large extent 1 2 3 4 5	✓ 5	✓	E
G	**Stakeholder feedback:** open comments based on initial proposed ideas	✓		-
H	**First2Act learning materials:** learning outcomes derived from First2Act manual and academic staff input	✓		-
I	**General usability data and email responses:** statistics that indicate success and failure in simulation design and implementation	✓	✓	-
J	**First2Act face-to-face:** research and results with recommendations	✓		-

Table 4.3: Summary of data collected by research

4.3 Methodology and Research Questions

By looking at current development practices, and analysing the learning efficacy of each of the simulation features, it may be possible to identify which features have the greatest impact. In discovering this, developers can focus their efforts on the most efficient features associated with that particular learning situation. Developers and designers can then maximise the often-limited resources available to them. Understanding the impact that each feature has on achieving different learning outcomes will be useful to any developer or designer when creating online educational simulations. To guide the investigation, a main research question and several research sub-questions have been devised. The main research question will address the problem domain in its entirety, and the sub-questions will seek to clarify the many aspects that realise the main question.

What are the critical aspects of designing an online learning simulation that assists nursing students in patient diagnosis and management?

Recognising the main objectives of a simulation project is critical to its ultimate success. However, without appropriate application this is very difficult to achieve. Being able to recognise how best to achieve those objectives is an important factor in how successful a simulation is in delivering key learning objectives to its audience. Investigating the processes involved with developing and implementing a simulation, and analysing the resulting data, can potentially identify critical factors in the development, design and implementation of a simulation. The discovery of features of a simulation that play a crucial role in its effectiveness as an online learning tool will help to understand what works to improve student performance. However, it is also likely to reveal features that are benign or may even hamper students in their learning. Looking at a range of data covering both technical aspects, such as usability, as well psychological such as user sentiment, should give a broad-spectrum understanding of online simulations. Further analysis of the data with a focus on learning outcomes will allow the identification of key features that have either positive or negative effects on learning.

To better understand the online simulation's critical features, the following sub-questions have been devised. These sub-questions fall into three main areas of interest.

1. An understanding of the design and development process for a simulation and which factors are important to the success of this early stage *(S1, S2)*;
2. An investigation into the student sentiment, to better understand what students consider critical to their understanding *(S3, S4, S5)*;
3. An analysis of simulation features to understand the connections between how students use the simulation and how this impacts on their learning *(S2, S6).*

Once conclusions in these areas are drawn, examination of how all three areas contribute collectively to students' learning will help to identify key areas of the online simulation that need improvement. Outlines of the research sub-questions are detailed below:

S1: What steps are required to design an appropriate learning simulation?

To measure the success of an online simulation would require establishing guiding principles of development. An investigation into the current best practice for online simulation development would help to determine the ideal process to follow for success. The ability to identify the key learning objectives is essential in isolating critical development features and setting the metrics by which success can be measured. Exploring and consolidating the key learning objectives requires close examination of feedback from both the team developing the learning material and other stakeholders involved in the project. Once the objectives are established, they must be mapped to the resources available for the project's development and other project requirements. Then an ideal list of project goals can be determined using these factors. By examining the outcomes of the project goals the research should identify how goals performed and what led to their success or failure.

S2: How do students' interactions with the system relate to improvements in their performance?

The interaction with the simulation can potentially impact a student's ability to understand the key learning objectives. Understanding which interactions have a positive impact on learning can help establish guidelines for design and development. A clear breakdown of key objectives is important as different interactions may impact different learning objectives in different ways. For example consider these two learning objectives:

a. to appreciate the time constraints involved with patient deterioration and,
b. to recognise the vital signs that indicate a patient is in a state of deterioration.

The former objective might be best served with a design that places time pressure on the student, whereas the latter might be negatively impacted under those conditions. It is important to recognise that each learning objective will have different needs, and a single method will not likely serve all objectives appropriately. Analysing students' pre-MCQ and post-MCQ answers and isolating students who performed extremely well and extremely poorly should reveal patterns in the student interactions (steps 2 and 7). These patterns will likely show the differences between the way the two sets of students use the interface (steps 4-6) and, hopefully, establish certain patterns of use that might be encouraged with changes in the design. This analysis should be done initially on the collective score of all multiple choice questions *(Appendix B)*, and then drilled down into each questions average score. Patterns are then more likely to emerge from specific areas of the simulation design, such as the structure of a sub-menu or at which point instructions are given to students.

S3: What characteristics of the simulation align with improvements in the students' perceptions of their confidence with the subject matter?

Understanding the impact a simulation has on a student can be measured in many ways, and can depend on what the key learning objectives might be. For example, simulations are known to improve student confidence in performing under pressure and improving the student's ability to perform in a similar real-life situation (Aldrich, 2005; Bambini et al., 2009). Examining the interactions of students who feel greater confidence after the simulation, and thematically reviewing the feedback, should establish key characteristics that improve students' feelings of confidence with the subject matter.

S4: What characteristics of the simulation align with decreases in students' perceptions of their confidence with the subject matter?

Conversely, students who feel less confident with the subject matter after using the simulation may have had negative experiences. Lower confidence would most likely indicate confusion with the material, or confusion with the interface, or other technical problems. Minimising the impact of any one of these outcomes is significant to the success of learning the key objectives. By examining interactions from students whose confidence fell, it is likely that patterns may emerge, revealing the key causal factors. The data of students whose confidence fell would be mapped against their pre-MCQ and post-MCQ scores, the interaction data, and technical issues they faced. Results should highlight simulation characteristics that align with decreases in student confidence with the subject matter.

S5: What was the student reaction to the simulation experience?

The experience that students have in a simulation, whether it results in improved confidence or not, is meaningful to the success of a project. The level of students' ability to engage can impact their capacity to learn. Carini et al. (2006) describe that poorer performing students benefit the most from engagement (p. 16). Aldrich (2005) furthers Carini's (2006) point by stipulating that engagement is an integral part of simulation experience. Knowing which simulation features are most relevant and engaging to students will improve the reception of the simulation and, in turn, its ability to educate. Understanding that different interactions can influence learning in different ways, it is important to investigate which engagements work best in a simulation environment. Student feedback about the experience is an effective way to ascertain their reaction to the simulation. Examining the themes in the open comments can identify simulation characteristics that align with positive or negative experiences for students.

S6: What features of the simulation need to be improved?

When examining all of the sub-questions above a definitive list of features, we can see which have a positive, neutral or negative impact on users. These features could be further broken down into impacting learning, experience/engagement, student confidence and useability. The feature list could then be applied to future versions of the simulation, recognising which changes are essential, worthwhile or of little impact. This could also be used as a guideline for deciding which features have the greatest impact on any one of the four categories: learning, experience/engagement, confidence and useability. This could be particularly useful for projects where resources are finite, and where all features cannot be implemented.

4.4 Experimental Design

This section describes the design plan for the experiment. Each sub-question will address a specific problem domain that will help to improve simulation design, but all sub-questions will address one or more fields of investigation. The areas of investigation are listed below to give an overview of what the research will address.

- Establish critical factors in successful simulation design through analysis of current methods, stakeholder input and project resources
- Investigate how student performance connects to the interactions with the simulation
- Investigate the relationship between student confidence and ability to learn from the simulation in either a positive or negative way
- Investigate what impact the simulation experience has on the students' perception and engagement
- Investigate features of the simulation that are ineffective and how they could be improved.

These areas closely link with the aims of the research questions. Collecting data to examine these areas, and for the analysis there of, is outlined in the next section. Data collection will occur within the simulation to track user interactions. A pre-MCQ and post-MCQ on the theory will test for changes in learning. Demographics of students will be collected for participant analysis. Lastly, an evaluation questionnaire will collect student thoughts about performance and confidence, and their perceptions of the experience.

4.4.1 Research Questions and Experiments

The method to answer each research sub-question is outlined below. The table summarises the experiments necessary for each research sub-question *(Table 4.2)*. Some sub-questions rely on data from other sub-questions and will be noted by using the sub-question number and data letter value in parenthesis such as (S2:b) – sub-question 2:data ‘b’. Each question includes a number of objectives that will help to answer the question, followed by the data required to answer it and the method of analysis being implemented. *(Table 4.2 spans multiple pages)*

Table 4.2: Research Questions and Experiments

Main research question: What are the critical aspects of designing an online learning simulation that assists nursing students in patient diagnosis and management?

Objective	(a) Identify essential features for online simulation to be an effective learning tool.	(b) Identify the impact each feature has on learning.	(c) Create a framework for the development of simulations in a learning context.
Data	Results from all data	Results from all data	Results from all data
Method	Examine the results from the click data and pre and post MCQs, to recognise where a failure in one of the components resulted in lower end grades. Compare this with the average, cross-referencing with the general feedback. Observe general feedback of students, establishing themes of major issues.	Examine student results against key learning objectives to identify which areas changed, and link this to the features in the simulation.	Examine results from (a, b) and revise design principles to consider simulation features and learning objectives as a priority.

What steps are required to design an appropriate learning simulation? *(S1)*

Objective	(a) Find the key learning objectives.	(b) Examine the most appropriate development framework for medical simulations.	(c) Effectively align key learning objectives with real world experiences.	(d) Define the ability to complete key components of the project based on resources available for this project.
Data	First2Act Manual (Qlx) Written feedback from key stakeholders. (Qlx)	Investigate development frameworks with similar simulation systems. (Qlx)	First2Act face-to-face scenarios. (Qlx)	Project resource list. (Qn)
Method	Analyse comments from key stakeholders and establish themes, examine manual, and identify key learning objectives. Map themes to key learning objectives to see if they correlate.	Examine frameworks and discuss pros and cons in reference to the intended system.	Discuss the findings from the face-to-face trials.	Examine the resources required based on techniques discussed in (b), and simulation requirements discussed in (a, c).

How do students' interactions with the system relate to improvements in their performance? *(S2)*		
Objective	(a) Examine where students' gained knowledge.	(b) Investigate the students' experience.
Data	Pre and post MCQ results (Qn) Click data of how students moved through the simulations (Qn) Final scores from the simulations. (Qn)	Feedback about their experience. (Qlx)
Method	Identify correlations between click data with improvement scores and multiple-choice test results, specifically where improvements have occurred.	Investigate feedback given about their experience with the system and perform a thematic review.

What characteristics of the simulation align with improvements in the students' perceptions of their confidence with the subject matter? *(S3)*			
Objective	(a) Investigate student confidence with the material.	(b) Investigate relationships between perceived confidences and with actual knowledge improvement.	(c) Identify the main characteristics of the simulation that align with highest improvement rate areas of students.
Data	Feedback/ratings from students about their confidence of understanding the material before and after (1-5) (Ql)	Pre and post MCQ results (Qn) Data from (a).	Click data of how students moved through the simulations (Qn).
Method	Analyse if there is an improved perceived confidence of understanding through utilising before and after ratings.	Find relationships between (a) and the improvements in the pre and post MCQs, looking at each specific area by grouping MCQs into key learning objectives.	Investigate the correlation's interaction between the system and improvements.

What characteristics of the simulation align with decreases in students' perceptions of their confidence with the subject matter? *(S4)*

Objective	(a) Identify simulation characteristics that align with student confidence decreasing.
Data	Results from (S3:a S3:b S3:c)
Method	Examine correlations between decreases in student confidence and interactions and see if any relationships exist.

What was the student reaction to the simulation experience? *(S5)*

Objective	(a) Identify which features impacted students experience the most.	(b) Find out if students found the simulation a worthwhile learning experience.
Data	Results from (S2:b)	Results from (S2:b) Feedback related to the learning experience with 1-5 ratings.
Method	Indentify positive and negative themes of student experience using the simulation.	Indentify themes in student feedback in relation to the relevance they felt of the education experience, and weigh the results as either positive or negative.

What features of the simulation need to be improved? *(S6)*

Objective	(a) Identify which technical issues impacted student performance.	(b) Identify which interaction/interface issues impacted student performance.	(c) Identify which learning design features impacted student performance.
Data	Results from (S2:a S2b) Whole data set including incomplete entries to help identify technical faults.	Results from (S2:a S3:c)	Results from (S2:a S2:b S3:a)
Method	Identify students who performed extremely poorly, and look for correlating technical-related problems with the data.	Identify students who performed extremely poorly, and look for patterns in the interaction data.	Identify students who performed poorly, and look for correlating education design related problems with the data.

(Qn) Quantitative numerical data (seconds or minutes) - (Ql) Qualitative numerical data (ratings from 0-5 of overall satisfaction) - (Qlx) Qualitative non-numerical data (verbal and written feedback/responses)

Table 4.2: Research Questions and Experiments

Each research sub-question below will expand on descriptions from Table 4.2, and refer to data collected from that summary table using the same method as the table, for example *(S2:b)*. Each sub-question will describe how the data will be analysed and any considerations that are accounted for in answering the question.

What steps are required to design an appropriate learning simulation? *(S1)*

The critical factors will be ascertained by examining the common themes based on information from key stakeholders *(S1:a)* and by cross-examining these themes with the main learning objectives outlined in the First2Act manual and the education techniques used in simulations. An analysis of similar simulation design processes will check for any common issues in relation to learning and user experience *(S1:b)*. Through investigating the current development methods and the ideal outcomes for this particular project, it should become evident which pathway to follow in order to achieve the intended outcomes *(S1:c)*. Comparisons of the pathways against the resources available should outline the most fitting simulation features *(S1:d)*. A set of guidelines can outline a basic framework to follow for the analysis and development process, plus direct decisions on which features are effective for certain learning outcomes and resource combinations. This reference material can then be used to help with the development of future online simulations. Finally, mapping of key learning objectives and project priorities will occur. Two factors will rate each objective: the necessity concerning the objectives *(S1:c)*, and the resources available. The achievability of objectives will be determined from these two factors.

How do students' interactions with the system relate to improvements in their performance? *(S2)*

To identify the key factors of student improvement, the students who show improvement in certain areas of knowledge can be compared with the interaction data from the simulation *(S2:a)*. Utilising the pre-MCQ and post-MCQ results will separate the learning for each specific area of knowledge. A relationship between the interactions that pertain to that area of knowledge, and improvements in understanding that same area, will be established as a result of this link.

The data collected on the click choices will reflect and build on the existing research. The click logs should demonstrate a decreased number of explorative clicks as students become more familiar with the interface. A result like this would reflect and replicate existing research into this area, but also demonstrate that the interface design can impact the users learning capacity, and will likely reduce dramatically after the first scenario. Using three scenarios, rather than one, will reduce the impact of learning the interface on the overall results (Aldrich, 2005; Gibson & Baek, 2009; Peters, 2013).

Investigating the interactions related to each area of knowledge should provide insight into which interactions were effective. Cross-examining all interactions where students did poorly might expose differences. A comparative study of pre-MCQ and post-MCQ results and click-log may reveal patterns where the interface had an impact on the students' learning, either positive or negative. Utilising pre-MCQ and post-MCQ will highlight areas of concern or interest for a more focused review of the click logs *(S2:a)*. For example, if an interaction centres on teaching AVPU (a sequence of assessing alertness of the patient) and the related MCQ question shows improvement, then that particular method of interaction will be deemed effective. When that pattern is cross-examined with the interaction pattern from students who did not change or did poorly on the same question, then evidence should show the patterns to be different. Interaction patterns that are the same for improvement, no change and worsened results, would suggest that the simulation has little or no impact on education for that content area.

The broad scope of MCQ scores cannot gauge all positive learning outcomes. MCQ scores will advise of a net gain in students theoretical knowledge related to those specific questions. Further review of students' feedback is required to gain a better understanding of the impact the learning simulation (on students) and where additional improvements might be found. A thematic analysis of open comments and Likert-styled questions *(S2:b)* may help to consolidate results about the students' experiences that contribute to their performance. When common themes are found, further investigation can occur in the click-log data related to that area. Deeper analysis will either reinforce the interaction patterns found, or provide alternate means of how the scenarios may have impacted student performance.

What characteristics of the simulation align with improvements in the students' perceptions of their confidence with the subject matter? *(S3)*

Improvements in student confidence can have a lasting impact on the students' study and career futures (Bambini et al., 2009). Therefore, students will answer questions concerning how confident and enjoyable they found using the simulation. These questions collect qualitative data, through a Likert rating of 1-5. Questions include students perceived confidence, students perceived competence, as well as asking how well they felt they could execute certain learning objectives in a real-life situation *(S3:a)*. Open comments will be analysed and placed into thematic groups to ascertain whether the scenarios as a mode of delivery appealed to students. The data should gauge the user experience, and the likely acceptance and usefulness of the simulation technology *(S3:a)*.

Pre-MCQ and post-MCQ data will also be used to seek out any anomalies in feedback. For example, the data may suggest some students did not enjoy the experience, but those same students scored extremely low in MCQs *(S3:b)*. Further relationships could then be found by mapping the results of student confidence improvements against student performance improvements attained from sub-question 2 *(S2:a,b)*. This comparison may reveal insights into which simulation interactions and features improve confidence.

What characteristics of the simulation align with decreases in students' perceptions of their confidence with the subject matter? *(S4)*

Results from S3 will be reassessed for negative results *(S4:a),* looking for patterns in the data that suggest issues with the scenarios interactive features that are having a damaging effect on student confidence. The analysis should expose patterns of interaction that cause students to perform worse, or reduce their confidence. Examination of sub-questions S3 and S4 may reveal that no correlation exists between student performance and confidence.

What was the student reaction to the simulation experience? *(S5)*

The student reaction to the simulation (the experience the student has) can influence the ability to learn (Aldrich, 2005; Carini et al., 2006). Open comments provided by the students *(S2:b)*, as well as Likert responses about students' experiences *(S2:b)*, can provide strong evidence about the student perception. Establishing themes for both negative and positive comments will show which parts of the simulation influenced students' experiences. A scale could be used stating the impact each feature is likely to have on the student experience. The scale would range from strong positive impact to strong negative impact.

What features of the simulation need to be improved? *(S6)*

Once previous sub-questions are answered, a definitive list can be created suggesting changes that should be made to improve the simulation as a learning tool. The areas of improvement may be divided into three categories.

1. ***Instructional (learning) design***; where the focus is on what order students receive the information and in what format.
2. ***Interaction and interface design***; mostly usability and graphic user interface issues.
3. Lastly, ***technical issues***: largely programming, asset delivery via the Internet, and general technical failures.

Each area is approached differently. Instructional design improvements will likely be derived from MCQ scores, interaction data, and open comments. Problematic areas will most likely show patterns that may highlight how the problem occurs and, as a result, show possible ways to solve it.

Interface and interaction issues would be identified in previous experiments *(S2:a,b, S3:a)*. A list of recommended changes may be derived from a combination of student comments/suggestions and actual interaction with the system. Evidence of redundancy in the interface is most likely revealed in click-data. For example, redundant clicking of buttons that have already been actioned - a widely recognised common issue with interaction design (Shneiderman, 1998; Tidwell, 2010; Tognazzini, 2003). Themes can be established from the open comments for education design. Any students who performed poorly could be investigated to identify patterns of interaction that are linked to how the student moved through the information.

To identify technical issues, examining the data for incomplete entries will offer clues as to where technology has failed. General testing and attempts to replicate these technical failures should reveal the causes and, therefore, the solutions to these issues. A review of comments for remarks related to technical issues may also reveal themes around common problems students faced while using the system *(S2:b)*.

Ideally, a priority and impact rated list of changes would be sufficient to begin improvements on any future versions of this simulation software. It will foreseeably provide a list of common issues faced with the development of online simulations in general, highlighting areas to avoid in future projects.

4.5 Controls and Considerations

A population sample of 489 final year university and TAFE college students received email invitations to participate. Three universities, Monash University, Deakin University and University of Queensland, and two TAFES, Chisholm Institute and Central Gippsland Institute, were involved in the recruiting process. Academic staff co-ordinated all classroom sessions on their specific campuses, staff were present during the time that students accessed the website and while they worked through the online program. Small numbers of students attempted the online program from home or other off-campus location. There was no data collected to distinguish between students who accessed the program on campus or off campus. University students were completing a registered nursing qualification while TAFE students were completing an enrolled nursing qualification. 409 students attempted the program at various sites, with recruitment rates of 37% to 100% across the five cohorts, averaging 87%. Of this group, 367 students (91%) completed all eight steps of the program with 330 students from university and 37 from TAFE. Most of the participants were female (88.5%), the median age being 23 years, with a range of 18-60 years. There were minimal differences in demographic profiles across university and TAFE cohorts.

Collection of demographics *(Appendix A),* freeform comments *(Appendix E)* and signs of technical failures in the data should ensure that any anomalies in the data are accounted for in the following analysis. The demographics collected typical statistics such as age, but also collected information about previous experience in the field. Questions noting any previous medical emergency experience will be matched to data collected to investigate any possible discrepancies between students with previous experience and without. The student's level of education or experience may also impact their ability to identify the simulated medical experiences. Patterns may emerge with connections to specific demographics that affect student performance, placing results well above or below the average. The outliers could be identified as fitting a certain theme, allowing for better explanations of results.

Instructional screens will guide users of the scenario through the interface and minimise its impact on learning outcomes. Demographics collected details about students' native language, which may impact their ability to comprehend the learning materials and 'how to' instructions.

4.6 Ethics

Email invitations *(Appendix K)* were sent to participants to take part in the First2Act program online. Academic staff at the involved institutions selected the students, with the majority coming from Monash 3rd or 4th year nursing. Participation was voluntary, and students could exit at any point during the program without penalty. Students were either signed up manually by the webmaster or, when this option was not possible due to time constraints, were given a direct website link to the program where they could sign themselves up to the online program. Both methods resulted in an invitation email being sent. The email invitations *(Appendix K)* contained a student's username and an automatically generated password, and were sent directly to the email address of that student. No mediator in the program had access to these details. Personal details collected were private, and only minimal details were required of students to sign up. Email addresses were the only identifying information collected, as students could define their own usernames as a pseudonym.

Details about the program were given on the website as part of accepting terms during the sign-up process, so that participants had informed consent before attempting any part of the online program. The academic staff involved at each specific institution controlled the selection of participants. However, the students typically were selected by year level and course, for example, all 4th year nursing students. Students were required to use only official institution forms of communication, such as student email addresses. The program only allowed access to students with specific email addresses, such as @student.monash.edu, limiting access to only institution participants. The website was not advertised outside of the participating institutions. It is unlikely that students from non-nursing backgrounds would participate in the program as there was no real external motivator for doing so, and the program was likely to take 1½ to 2 hours to complete.

The data collected in all instances uses an anonymous numeric identification value. This value is created when signup occurs and links all the data for that participant together. Personal details of students that are able to be associated with other data, such as personal information, will be stripped before collating data from the website database. When analysing the data, no student information, beyond the information given in the demographics as well as open comments, can be linked to the specific student. Unless the student was to give away their identity by including indentifying information in the open comments, or if they were to be singled out due to defining demographical information (such as, for example, the only student of 39 years of age), it is highly unlikely that a student would be identifiable by the data. If these rare cases occur, this data will not be included in any publication in a way that could identify them. As an example, open comments would be stripped off the identifying details, or, not included at all.

4.8 Experimental Treatment

The research instrument is located at www.first2actweb.com and uses Wordpress; a website template and content management system. Wordpress also allows for a number of plug-ins that can add extra features to the website, such as a custom login screen. The website login and student profile is managed Cimy Extra Fields plug-ins to allow for additional fields to collect information on the students university and campus (cohort and location) (e.g. 'Monash Clayton' or 'Gippsland TAFE'). Demographics, pre-MCQs and post-MCQs use the Wato Pro plug-in providing the functionality in the website to create multiple-choice quizzes and survey style questions. The final evaluation questionnaire uses the WPSQT plug-in to create the Likert style questionnaire. Data collected from Wordpress and all the plug-ins is stored in a MySQL database, which includes login information and all answers to questions.

The development of the scenarios uses Adobe Flash, a tool used to create interactive programs. Video assets are imported into the file during use, but all other interactive features of the scenarios are built inside the Adobe Flash development environment. On completing a scenario, the data from the recorded clicks and the final scores are sent to the MySQL database to be stored with other information collected by Wordpress. Hopmans manages the data, including downloading data sets from the database and intermittent back-ups of the database in SQL format. All First2Act website technical issues are monitored by Hopmans. Participants can contact the project leader, Cooper, or Hopmans via email if they experience issues with the program.

An initial pilot including 24 participants identified technical issues. Cooper, Porter and Hopmans ran the pilot session and took notes on issues as they occurred. Participants were manually enrolled to the program and attended a classroom session at Monash University Clayton Campus. Students were given verbal instructions in class on how to use the program. Feedback collected from the pilot was assessed, and changes made to the program before becoming available to the larger cohort.

4.9 Summary

This research has used Design Science as the methodology, largely due to its alignment with the creation of the simulation (artefact), a core component of Design Science. Design Science stipulates that research results in improvements in the understanding of the development process and the design of a system. This research aims to improve both the process and design of educational simulations.

While the creation of the simulation is central to the program’s success, careful design of the surveys and quizzes was required to collect meaningful data from the simulation. Collection of a range of data allows for an in-depth analysis of the simulation’s features. Analysis will include cross-examining demographics with theory knowledge and actual scenario interactions, and should yield some interesting results. The following chapter explores the results of the experiment. Each research sub-question is reviewed, and related data analysed, with a discussion of the findings thereafter.

Chapter 5: Experimental Results and Analysis

5.1 Introduction

This chapter discusses the data, analysis and results produced by the experiments described in Chapter 4 'Methodology'. This chapter revisits each data set briefly, and a discussion of preliminary findings are summarised. These initial findings are intended to help the reader have a holistic view of the research data as each sub-question relies on multiple data sets to thoroughly address the question. Each sub-question is discussed at length, and conclusions are drawn before moving to the next question. A brief discussion of the conclusions regarding the primary research question ends the chapter, but a lengthier conclusion forms part of Chapter 6.

5.2 Data Results

The data listed below was collected from a sample population of 483 final year nursing students, studying to become registered nurses at three universities and two TAFE institutions. From the invitations sent to the students, 409 students started the program and 367 (91%) students completed all parts of the simulation. Data was collated from the website's database, and any incomplete entries were flagged. Issues for not completing the program varied, but most were due to technical issues on the website where video failed to play, or when a student had inadequate Internet access. The following section will briefly describe preliminary findings. The preliminary findings will help scaffold the analysis of the research questions.

5.2.1 Stakeholder Input

The stakeholder input includes discussion between team members and has been used to create learning and project goals. Discussions at various stages of development helped to establish the learning objectives, and main project goals. Criteria were then drawn up to determine what a successful project execution would be, assessing both progress and completion of the project. This information was gathered and collated into a table of key criteria. There were three main stakeholders to this process, the first being the project leader who worked with other academic or professional advisors who were specialists in areas of critical care specific to the three scenarios covered (cardiac, respiratory and shock). Any information gathered through face-to-face meetings, video-chat, email and phone calls, was summarised and then forwarded to all involved for further comment. The process occurred over a period of several months. Comments from stakeholders include:

> *"Need for authentic, engaging learning experiences that motivate students: e.g., create an enhanced method for moving students to action in completing written tasks requiring high-level cognitive processing of complex, integrated, professional problems. Such challenges will inevitably require students to draw on multiple information sources in a scenario that requires professional judgment."*

> *"Do the questions need altering – was the information available in the slide show and scenarios to help them get the right answers – (answers may be in manual, but they may not have read this)?"*

A close examination of the manual, followed by advice from the project leader, guided the creation of the key learning outcomes. The First2Act simulation trials (face-to-face trials with actors and assessors) identified key issues in the process, and the key learning objectives were arrived at and aligned with learning gaps recognised by face-to-face trial *(Table 5.1)*.

Table 5.1: Key learning objectives identified by stakeholders		
Issue	**Example**	**Learning Objective**
Students focus on singular intervention	Students often focused on taking blood pressure, while ignoring other vital signs	Students should be encouraged to check all vitals
Students need to systematically treat patient	Students worked haphazardly through interventions	Student should be encouraged to work systematically through taking vitals and other interventions
Students need to recognise a deteriorating patient	Students often missed the signs that indicated the condition of a deteriorating patient	By taking vitals readings regularly, key indicators become evident to the student
Students need to manage patient in the correct order	An established methodical approach to treatment is not widely accepted, however the First2Act manual has a suggested best course of action	Students should practice patient management until it is second nature
Students need experience in the pressure associated with patient deterioration	Most students are not exposed to this situation often enough, or even at all before hospital placements	Students are exposed to the conditions similar to that of the real life situation (e.g. only 8 minutes to intervene)
Students don't have all key knowledge for specific treatment of patient deterioration	Students often don't have key knowledge committed to memory for easy recall	Demonstrate and explain key knowledge and allow students to put it into practice

Table 5.1: Key learning objectives identified by stakeholders

The project utilised many recommended methods of multimedia simulation systems design, including Aldrich's (2005) methodologies of interaction design for education (Benyon, P. Turner, & S. Turner, 2005; Gibson & Baek, 2009; Hoekman, 2008; Hoekman & Spool, 2009; Shneiderman, 1998; Tognazzini, 2003). The following table highlights the key development goals for determining the success of an interactive simulation *(Table 5.2)*.

Table 5.2: Interactive simulation development success criteria		
Goal	**Area of activity**	**Success**
Learning outcomes drive selection of technology	Education, technology	Effective use of technology to deliver content
Technology used adds value to teaching and learning	Education, technology	Better learning outcomes with the use of technology than using traditional methods of teaching the same content
Technology assists in delivery of content and assessment	Education, technology	Content is delivered better than non-technological delivery and technology assists with assessment in an automatic, or more efficient way
Adequate IT support is supplied to insure efficient construction, running and maintenance of the project	Education, technology, finance	Technology is developed in a timely fashion, within budget and has appropriate methods of design to allow for efficient management over the life time of the project
Clear and consistent communication between educational and technology professionals	Education, technology, management	Communication is open and regular between parties involved. Clear goals are defined and adhered to.
Clear outline of resources available matched against project goals	Education, technology, finance, management	Clear milestones are set. Resources are estimated and allocated according to their ability to achieve project goals.

Table 5.2: Interactive simulation development success criteria

Some stakeholders mandated certain goals to monitor the success of the project. These stakeholders were the Office for Learning and Teaching (OLT formerly Australia Learning and Teaching Council), Monash University School of Nursing, Queensland University School of Nursing. Monash University spearheaded the project, setting the main educational targets; other academic professionals were also involved in an advisory capacity. The main mandated goals are outlined in the table below *(Table 5.3)*.

Table 5.3: Project success criteria from stakeholder requirements		
Goal	**Stakeholders**	**Success**
Produce an evidence-based, sustainable online learning package to enhance nursing students' management of deteriorating patients	Monash University, OLT	A self-sustaining web-based simulation training website, accessible to all Australians
Website and content accessible for five years	OLT	Website to be maintained for five years (lifetime of the project) to be included as part of the funding
Excellence in teaching	Monash University	Maintain a high standard of teaching that matches the models currently used at Monash University
To supplement education resources as a part of nursing higher education	Monash University, Queensland University, Other educational institutions	Students practice the management until it is second nature
Report outlining the results of the program	OLT, Monash University	A report outlining the projects successes, failures and justifying funding.
Analysis of students results and interaction (data) with the program	Monash University, Queensland University	Ongoing collection of data to enable effective analysis for, research, reporting, papers and further development of the program and other programs

Table 5.3: Project success criteria from stakeholder requirements

Each of the goals outlined here form the project success criteria, and is assessed in the analysis section of this chapter. The above criteria create the structure used for development of the simulation, and guides design decisions for cognitive psychological, instructional system design and simulation design.

5.2.2 Demographics Questionnaire

The demographics questionnaire collected general details about the participants, such as age, gender and education level. However, some questions also asked for experiential details. Information about prior industry experience, such as previous hospital placement including whether this experience was similar to that of the simulation, was also included in the questionnaire. The majority of participants were female (88.5%) with an age range of 18-60 years of age, the most common age (mode) was 21 years old ($n = 71$). Most students were domestic students (91.5%) with the rest being international, 220 students were in 3rd year, with 63 and 34 being in 2nd year and 4th year respectively. In the cohort, 51% of the students had no prior industry experience. University groups and TAFE groups shared the same demographic profile. Chi-square testing on students with previous patient deterioration experience, when compared to students without that experience, revealed no correlation between pre-MCQ scores ($p=0.61$) and limited correlation with scores attained in the first scenario ($p=0.06$) *(Appendix I).* If prior experience gave those students an advantage, the expected results from the pre-MCQ scores should be, on average, higher for those students. The same is also true for the experienced students and their performance in the first scenario, however, in both pre-MCQ scores and the first scenario scores, correlations were not significant.

5.2.3 Pre Multiple-Choice Quiz

Students answered eleven multiple-choice questions *(Appendix B)* based on the First2Act manual. Each question had four possible answers with only one correct answer per question. Students did not receive any training or information specifically related to the First2Act program before the quiz. The average total score was 7.63 out of a possible 11, with a standard deviation of ±1.52. Question 1, "A patient who is in hypovolaemic shock will have … ", achieved the best result with 98% of students correctly answering. The question that was least correctly answered was question 7, "When assessing a patient's breathing … ", with only 30% of students answering this correctly *(Table 5.4)*.

Table 5.4: Pre and post multiple-choice quiz results			
No.	**Question**	**Mean results (SD) Pre-test**	**Mean results (SD) Post-test**
1	A patient who is in hypovolaemic shock will have …	0.98 (0.13)	0.98 (0.13)
2	A patient with hypoxia is likely to be …	0.96 (0.19)	0.96 (0.19)
3	Slow capillary refill is a sign of …	0.93 (0.26)	0.96 (0.20)
4	The pulse can be palpated …	0.44 (0.50)	0.60 (0.49)
5	A normal heart rate for an adult at rest is …	0.77 (0.42)	0.90 (0.30)
6	Pulse oximeters may be unreliable when …	0.77 (0.42)	0.84 (0.37)
7	When assessing a patient's breathing …	0.30 (0.46)	0.40 (0.50)
8	*A 14-16 gauge needle is most likely to be used for …**	0.75 (0.43)	0.75 (0.43)
9	Which of the following is NEVER compatible with a cardiac output: …	0.55 (0.50)	0.64 (0.48)
10	A.V.P.U. stands for …	0.79 (0.41)	0.88 (0.32)
11	When using a non-rebreather mask …	0.37 (0.49)	0.75 (0.43)
	Totals	**7.63 (1.52)**	**8.68 (1.5)**
** No change in results*			

Table 5.4: Pre and post multiple-choice quiz results

5.2.4 Post Multiple-Choice

The post multiple-choice quiz was a replica of the pre-MCQ test *(Appendix B)*, with all questions being identical, and presented in the same order. Students undertook the quiz in the final stages of the program, but before the evaluation and certificate stages. During the time between the pre-MCQ and post-MCQ, students were presented with an audio-video presentation of the First2Act manual. They worked through all three scenarios, receiving feedback and a score after each scenario. The average overall score showed an increase in student performance compared with the pre-MCQ results. The mean result of the post-MCQ was 8.68 (SD±1.50) with a significance of $p < 0.000$ when compared with pre-MCQ results. All questions scoring <95% correct in pre-MCQ test showed improvement, with the exception of question 8 (14-16 gauge needle) where no change occurred *(Table 5.4)*. The largest improvements in scores occurred for question 11. There was no control group for the pre-MCQ and post-MCQ, so changes in scores cannot be benchmarked against changes that may have occurred naturally in a control group. Whenever investigating relationships connected with MCQ score increases, the lack of a control group is taken into account in the findings.

5.2.5 Scenario Scores

The scenarios recorded each interaction (including the time in seconds) that students made during the eight-minute scenario. Each action was allocated a point value between -1 and +3 *(Appendix C)*. Most scores were independent of time and were given the same score irrespective of when they occurred. In cases where choices could be changed multiple times, such as the bed position, only the last choice counted in the scoring, with previous choices being ignored. Other scores were time dependent, such as emergency receiving the highest score between 2-6 minutes. Some actions were allocated negative scores, as they would be detrimental to the patient's condition. Separating the three scenarios, the mean score was 18.60 out of 30 (SD±3.44) for the first scenario, 21.48 out of 28 (SD±3.49) for the second scenario and 20.24 out of 30 (SD±4.09). No students achieved a maximum score for the first scenario, while 7 students did for scenario 2 and 1 achieved the maximum score for the third scenario.

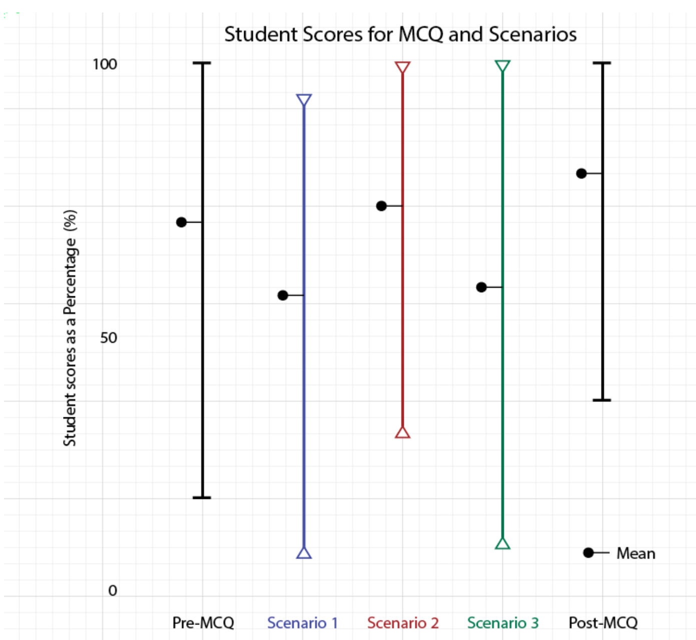


Figure 5.1 Student scores for pre-MCQ and post-MCQ and scenarios, including mean and range of all scores.

There was no clear consistency between the scenarios and the specific actions students took. For example, students did not consistently check all vitals twice, as recommended, in any of the scenarios. However, in the first scenario nearly all students (n = 363/367) performed an ECG on the patient, a key procedure for the Cardiac scenario. In the second scenario, large numbers of students (>90%) performed four key procedures, and for the final scenario, at least two key procedures were conducted by 90% of students. This finding is in line with the mean scores for scenario 2 and 3, as the performance of more of the correct procedures would result in a higher score.

5.2.5 Scenario Click-Logs

Secondary tracking of the students' interactions utilises a log of all the click interventions taken *(Appendix L)*. Separate from the scoring system, the logging tracks each click and at what time the click occurred in lapsed seconds during the eight-minute period. This log record includes the number of clicks in total, as well as the order and timing of clicks. Tracking clicks provides an opportunity to observe students who change their minds about choices, and highlights changes that would not be evident in looking at the scores alone. For example, if a student changed the bed position numerous times, each change is recorded in the click-log, whereas only the last bed position is used in calculating the score. The extra data allows for deeper analysis of interaction, such as superfluous clicks that might indicate an indecisive student. Each scenario has a minimum number of clicks required to action all the interventions required *(Fig. 5.2)*.

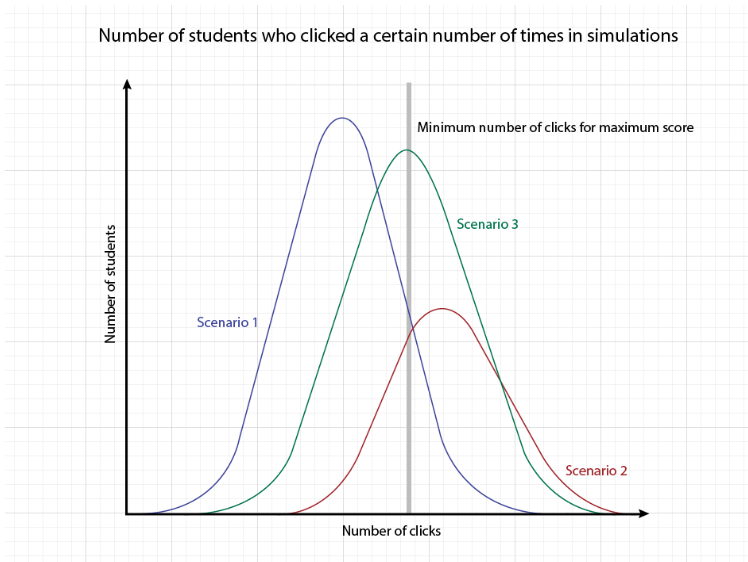


Figure 5.2: The number of students who clicked a certain number of times, bell curves normalised on the minimum number of clicks needed for each scenario to score a maximum score.

The minimum number of clicks is different for the first and third scenarios (n=27) compared with the second scenario (n=24). The majority of students clicked less than the minimum required times (n=27) in the first scenario with a mean of 22.05 clicks (SD±4.19). For the second scenario the majority of students clicked more than the minimum required (n=24) 26.78 (SD±4.72). Finally, the greatest number of students clicked almost the minimum required times (n=27) in the third scenario 26.97 (SD±4.64). However, the expectation is that students would click more than the minimum to achieve a top score. The score results show this to be the case, with scenario 2 having the highest average score.

5.2.6 Final Questionnaire: Feedback and Evaluation

The final questionnaire *(Appendix E)* invited the students to give feedback on their perceived performance, understanding of concepts, and confidence in performing. Using a Likert rating, students gave a rating of one to five (one being the lowest and five the highest). Of the 367 students who gave the ratings to all the questions, 163 responded to open comments, giving freeform feedback. The first seven questions revolved around the relevance and educational qualities of the program with a mean of 4.56 (SD±0.70) out of 5 for the combined results of the seven questions. The second set of questions involved the student rating their confidence, competence and overall ability before and after the online activities. The students measured their previous perceived ability with a mean of 3.34 (SD±0.86), the combined results of the three questions (recognise a deteriorating patient, manage emergency priorities, perform emergency tasks). The perceived abilities questions showed an increase in the 'after the online program' section to a mean of 4.20 (SD±0.67) for the combined totals of those three questions. Student-confidence level ratings increased from 2.94 (SD±0.84), before the activities, to a mean of 3.99 (SD±0.65). Competence levels increased less so, with means from 3.14 (SD±0.79) to 3.98 (SD±0.66) *(Table 5.5)*.

Table 5.5: Evaluation Questionnaire Results (Likert 1-5)		
Evaluation question	**Mean**	**SD**
The FIRST2ACT Web program …		
Was relevant to my needs	4.62	0.66
Was appropriate to my level of training	4.62	0.65
Provided effective feedback	4.43	0.83
Was challenging without being threatening	4.44	0.71
Enabled me to integrate theory into practice	4.58	0.68
Stimulated my interest in the topic	4.61	0.65
Encouraged me to think through a clinical problem	4.65	0.66
Before the online activities my perceived ability to:		
Recognise a deteriorating patient	3.53	0.81
Manage emergency priorities	3.21	0.85
Perform emergency tasks	3.29	0.89
After the online activities my perceived ability to:		
Recognise a deteriorating patient	4.37	0.58
Manage emergency priorities	4.14	0.66
Perform emergency tasks	4.10	0.74
Before the online activities overall:		
Confidence level	2.94	0.84
Competence level	3.14	0.79
After the online activities overall:		
Confidence level	3.99	0.65
Competence level	3.98	0.66

Table 5.5: Evaluation questionnaire results

Using thematic reviewing techniques outlined by Ryan and Bernard (2003), the free form feedback *(Appendix E)* was scrutinised to highlight key themes or terms. The research identified broad positive and negative feedback terms, like “fantastic”, “good”, “excellent” and “needs improvement”, “confusing” and “didn’t like”. The example below shows positive terms highlighted green and suggested improvements in yellow.

> *The program was fantastic at giving me a chance to manage a deteriorating patient in a non-threatening environment. I feel that I have learned a lot just from the 3 scenarios presented and definitely feel more confident about managing a patient[sic] like these. One improvement could be having access to ongoing SaO2 and BP monitoring in a separate[sic] window so I can just glance at them while managing the patient, as I would if I was on the ward.*

From this overview of the feedback, categories were then created to link the themes found in the research questions. Each category looked at terms that would define a positive or negative reaction to the First2Act program. The categories were used to group comments or parts of comments to establish commonly discussed issues and features. This grouping helped recognise the most popular aspects of the program that worked, and the issues that needed attention for future development of the program.

Table 5.6 describes the categories and the key words for both positive and negative comments. All key words are examined in the context of the entire phrase, as words like “great” could be used in different categories. For example, “It was great”, “I felt great afterward” or “The video was not great quality”. The table lists some of the keywords used. These words were used as a guide for the initial search, and each comment or part of the comment was assessed on its own merits as fitting in one or many categories. Each comment or part-comment was assigned (through highlighting) to one of the categories outlined below, and then flagged as positive or negative. *(Table 5.6)*

Table 5.6: Open comments thematic review		
Category	**Flagged**	**Keywords**
General description	Positive	*Great, fantastic, excellent*
	Negative	*Bad, horrible, terrible*
General experience	Positive	*Enjoyed*
	Negative	*Did not enjoy, annoying*
Learning experience	Positive	*I learnt, my knowledge improved, helpful, relevant, educational*
	Negative	*Not helpful in my learning, confused, felt I was doing it wrong*
Ability and confidence	Positive	*I feel more confident*
	Negative	*I feel less confident*
Experience/Sim was real	Positive	*It felt real, I was stressed, sense of urgency, confronting*
	Negative	*Did not reflect, not real, in real life we wouldn't*
Evidence of learning	Correct	*You need to check vitals regularly*
	Incorrect	*There was no need to check patient history*
Technical Experience	Positive	*Video played well, the interface was easy to use*
	Negative	*The interface was confusing, stopped working*
Suggestions		Suggestions given by students for changes or improvements

Table 5.6: Evaluation open comments thematic review

The majority of the 167 comments were positive or very positive. Most students who found fault with the program would in turn suggest ways to improve it. Many comments mentioned how relevant the program was to their education, and requested that more scenarios are created. Comments provided an insightful view of how the qualitative learning objectives, such as ‘feeling pressure’, were experienced by students.

5.3 Analysis

The previous section contained some of the preliminary findings from the data collected. The First2Act program showed improvements in understanding based on pre-MCQ and post-MCQ scores. The use of the scenarios also improved, although students performed worse in the third scenario when compared to the second. Evaluations from the students suggested they both liked the program and found the program relevant, with confidence and competence levels rising as a result. A more in depth analysis of the results will follow, as each research sub-question is reviewed. A summary at the end of the chapter will review the results and answer the main research question. Chapter 6; ‘Conclusions and Further Research’, draws important conclusions in relation to this research.

5.3.1 What steps are required to design an appropriate learning simulation? *(S1)*

The steps required to design an appropriate learning simulation come from a mixture of design principles. Success of a simulation is determined by how well it achieves the set criteria. On reflection of the success criteria for the First2Act project outlined by the key learning objectives *(Table 3.1)* and project and development success criteria *(Table 3.2, 3.3)*, the project can be deemed largely a success. By utilising the chart that aligns project goals with both their necessity and resources available, it is obvious that many of the objectives were achievable.

The following diagram *(Fig 5.3)* highlights the objectives of the project mapped to necessity and the resources available. Of the objectives shown to be successful, partially successful or unsuccessful, only one of the objectives from the funding body was not met. The program was to remain available for five years using the original funding, however, further funding needed to be sought to continue the maintenance of the site for the project’s five-year lifetime. All other areas achieved success based on the results, and two areas achieved partial success.

While students indicated in open comments that they experienced required time and performance pressure, it is difficult to ascertain to what degree this was successful beyond self-reported comments. There was little quantitative data recorded to examine and support its effects. Finally, the technology selection was chosen without consideration towards key learning objectives, and while there was some flexibility, many decisions were locked in place due to time and budgetary constraints.

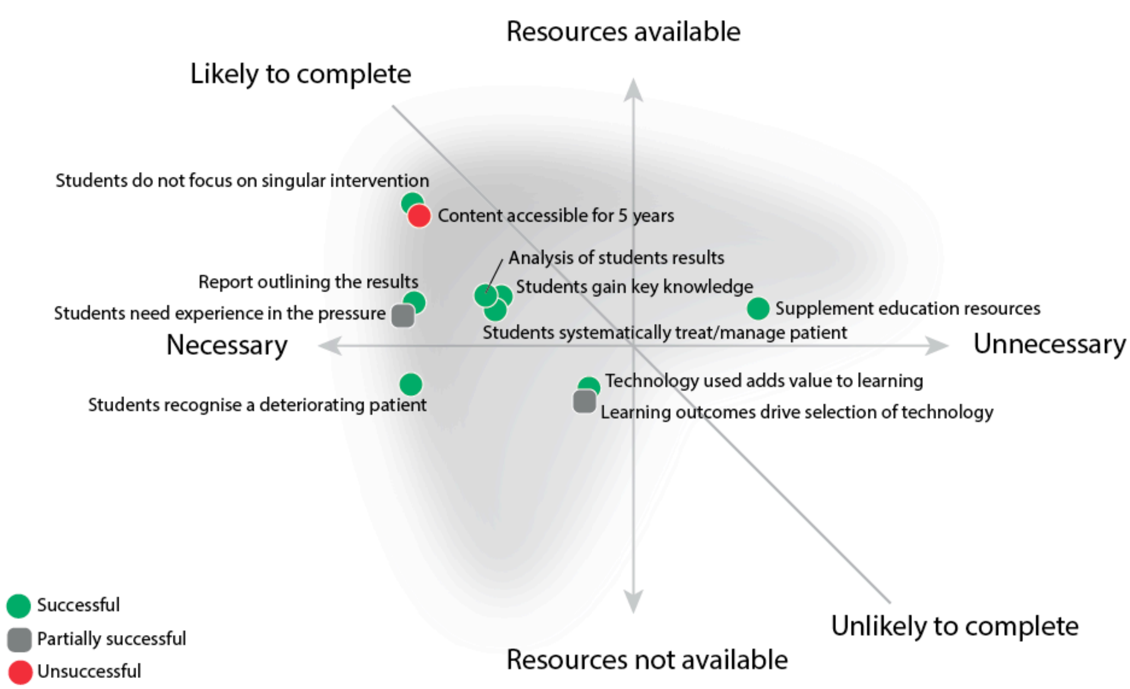


Figure 5.3: Successful or unsuccessful project objectives mapped on scale of necessity and resources.

The most successful areas were predominantly learning outcomes. Some design decisions made at the early stages of development impacted the project in later stages, for example, the failure to set aside adequate funding to maintain the website for five years. Sometimes unpredictable factors, such as programmers quitting, also played a part, but contingency for these events needs to be included in project planning. Rating each of the goals for their likely success helps to alert developers of potential problem areas. Tables 5.7, 5.8 and 5.9 describe the techniques used that lead to success or failure of each of the minor objectives. The minor objectives are taken from table 3.1, 3.2 and 3.3 in Chapter 3, but have been reworded slightly to reflect a successful outcome. Each description of how the objectives were achieved helps to elaborate on the steps that might be considered during development of other simulations.

Table 5.7: Key Learning Objectives for the First2Act Program: Successful techniques		
Minor objectives	**Major objectives**	**Techniques used**
Students do not focus on a single intervention	Produce an evidence based online learning package to enhance nursing students' management of deteriorating patients Provide excellence in teaching	Students were encouraged through feedback to check vitals regularly. The menus showed all interventions available so students could see all choices rather than focusing on a single intervention.
Students systematically treat/manage patient		The observations chart (OBS chart), used to record vital signs of a patient was presented as a list, encouraging a systematic approach to taking vitals, checking them one after the other. The menu also presented all options available so students could work through the menu step by step. Feedback outlined the steps required of them to manage the patient.
Students gain key knowledge for specific treatment of patient deterioration		Students received feedback about how to treat each patient's specific condition. They were able to apply some feedback in future scenarios. Unfortunately, they were not able to retry the previous scenario with the new information.
Students need to recognise a deteriorating patient		The First2Act presentation informed students about how to recognise a deteriorating patient. Applying this information in the scenarios and seeing the results of observations helped to establish knowledge.
Students need experience in the pressure associated with patient deterioration		The videos showed a patient in constant decline, and the added pressure of a timed simulation gave students a sense of pressure involved in treating deteriorating patients. How accurately this translated was hard to measure quantitatively.

Table 5.7: Key Learning Objectives for the First2Act Program: Successful techniques

Table 5.8: Project Success Criteria for the First2Act Program: Successful techniques		
Minor objectives	**Major objectives**	**Techniques used**
Project Success Criteria		
Website and content accessible for 5 years in a sustainable way	Complete OLT grant conditions	Due to delays in IT development and having to restart some aspects of programming, the budget allocated for development was over-run, and no funding remained to dedicate to maintenance.
To supplement education resources as a part of nursing higher education		The use of online version of the simulation successfully provided an alternative to face-to-face simulations with a real patient. Students felt the experience was valuable to their learning and there were minimal issues raised with the use of technology. Accessibility does cause concern as the program relies on adequate internet access and the use of certain browsers only.
Report outlining the results of the program		The requested report was submitted to funding body by the deadline.
Analysis of students results and interaction (data) with the program	To improve the resource and provide Monash University and Queensland University with an education and research asset	There was sufficient data collected for analysis, resulting in numerous papers being published and a better understanding of the ways students learn through simulations, highlighting inadequacies in teaching, and in turn, the areas of improvement for the First2Act program.

Table 5.8: Project Success Criteria for the First2Act Program: Successful techniques

Table 5.9: Development Success Criteria for the First2Act Program: Successful techniques		
Minor objectives	**Major objectives**	**Techniques used**
Project Development Success Criteria		
Learning outcomes drive selection of technology	Provide the best learning outcome through appropriate selection of technology	Video content created and previous development, both of which occurred before a detailed investigation of IT possibilities, influenced selection in a negative way. Delays forced the project towards a less desirable technology choice in an effort to hasten deployment and meet deadlines.
Technology used adds value to teaching and learning		The technology used added value to the teaching by providing a highly interactive, accessible and stable learning environment. Students found the simulations a valuable addition to their learning experience. It is difficult to gauge if alternatives would have been more or less successful than the current choices, but feedback from students helps to support this model of learning.

Table 5.9: Development Success Criteria for the First2Act Program: Successful techniques

The tables above show the techniques used to achieve the minor objectives in the project by utilising the three areas outlined by *Fig 2.2*, cognitive psychology, instructional system design, and simulation design. Considering how these three elements can affect each specific objective is consistent with better design choices. The weighting of the three areas from *Fig 2.2* can vary depending on the objective. Reflecting on the first minor objective, “Students do not focus on a single intervention”, design factors considered what might be discouraging the narrow focus students had for any one intervention. How the three areas affected the interaction design is described below:

1. *Cognitive psychology:* Instruction was given on how to use the interface to reduce the cognitive burden of learning the interface. Buttons on the observations chart (OBS chart) were highly visible and labelled ‘check’, to indicate at the kind of action that would occur when the button was clicked.
2. *Instructional system design:* The video presentation included instructions that explicitly told students to take regular vital readings and to take baseline (initial)

readings to measure variations. On completion, feedback explained which vital measurements were essential.

3. *Simulation design:* The interface provided all options available in the one space. Students could see all vitals at the same time, encouraging a systematic approach to taking readings, as if working down a checklist.

By taking a systematic approach that investigates each of the three areas, a plan of how each of the project's objectives is being addressed and measured can be created. Without clearly identified goals and the corresponding solutions, it is far more difficult to ensure the success of the project. This technique forms a basis for the initial stages of simulation development and draws attention to any critical objectives. Any objectives that are rated necessary for success can then be examined in more detail, checking if resources are adequate for completion. Highlighting potential issues at the design stage avoids problems during the development stage, which can often add considerable costs to the project, and in some cases, are impossible to correct.

5.3.2 How do students' interactions with the system relate to improvements in their performance? *(S2)*

The interaction with the simulation has the potential to impact the students' ability to understand the key learning objectives. It is important to understand which interactions have a positive impact on learning. While a simulation typically improves learning, key learning objectives may be impacted by interactions in different ways. However, an initial indicator of improvement in understanding results from changes in the pre-MCQ and post-MCQ scores. When looking at the overall results, an improvement is evident, with a mean increase from the pre-MCQ score of 7.63 (SD±1.52) to the post-MCQ score of 8.68 (SD±1.50), and a significance of $p < 0.000$ *(Fig. 5.4)*. It is important to note that in this study there was no control group for the MCQs, so changes cannot be benchmarked against changes that may have occurred in a control group or by using other teaching methods, such as live demonstrations. In this research the participants only interacted with the presentation and the simulation between the pre-MCQ and post-MCQ. Any learning that occurred can be attributed to information garnered from the presentation and simulation.

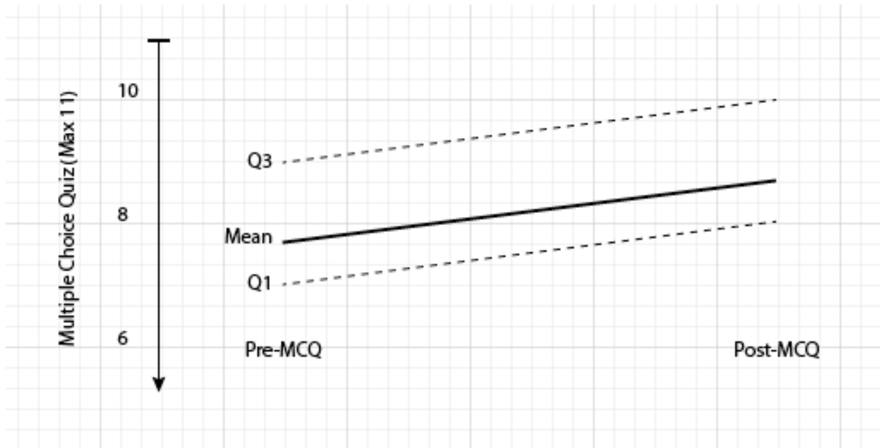


Figure 5.4: Mean and upper and lower quartiles of results for all students on pre and post multiple-choice quiz scores (maximum score 11).

The overall improvement in the results is not representative of all questions equally, and the findings show that high pre-scoring questions show little to no improvement. In the first two questions, over 95% of students correctly answered in the pre-MCQ phase, with most students (99%) answering the same in both pre and post MCQ phases. The first question had 357 of 361 students answer correctly to both pre-MCQ and post-MCQ, and the second question 350 of 353 - suggesting the majority of students had previous knowledge of these questions before starting the program. The simulation did not have a negative effect on any MCQ questions. All other questions, except question 8, showed improvement. The last question about oxygen therapy received the greatest improvement. The table below *(Table 5.10)* maps the questions from pre-MCQ and post-MCQ results against scenario content for that particular question. The presentation is the video/slideshow of the First2Act manual that students viewed before doing the scenarios (Step 3/8) and after the pre-MCQ. The presentation contained instructions about how to diagnose and manage a deteriorating patient. If information about that question is present, it is marked with a ✓. In the scenarios, information for each question could take a number of forms. It might be presented as video of the patient demonstrating the condition related to that question, or it could be feedback given after performing a vitals assessment. Not all scenarios contained the same content, so individual scenarios are identified if they contained specific information about that question. Feedback given to the students upon completion of each scenario gave advice about what the patient condition was and what actions to take in that situation *(Appendix D)*. Feedback ranged from highly specific, such as

"… should be given oxygen via a non-rebreather mask" or less specific, such as "… all vital signs should be recorded at frequent intervals, including respiratory rate, capillary refill time and temperature". The latter description does not describe all possible vital signs, or the fact that vitals should be taken at least twice. Any highly ambiguous feedback was not included in this section so that a clear connection between the information given and information retained/gained could be maintained.

Table 5.10: Comparison of MCQ results and where information is conveyed in the program

Question	Pre-MCQ Mean (SD)	Post-MCQ Mean (SD)	Presentation	Scenarios	Feedback
1) A patient who is in hypovolaemic shock will have …	0.98 (0.13)	0.98 (0.13)	✓	③	③
2) A patient with hypoxia is likely to be …	0.96 (0.19)	0.96 (0.19)	✓	②	②③
3) Slow capillary refill is a sign of …	0.93 (0.26)	0.96 (0.20)	✓	①②③	②③
4) The pulse can be palpated …	0.44 (0.50)	0.60 (0.49)	✓	①②③	
5) A normal heart rate for an adult at rest is …	0.77 (0.42)	0.90 (0.30)	✓	①②③	
6) Pulse oximeters may be unreliable when …	0.77 (0.42)	0.84 (0.37)	✓		
7) When assessing a patient's breathing …	0.30 (0.46)	0.40 (0.50)	✓	①②③	①②
*8) A 14-16 gauge needle is most likely to be used for …**	0.75 (0.43)	0.75 (0.43)		①②③*	
9) Which of the following is NEVER compatible with a cardiac output:	0.55 (0.50)	0.64 (0.48)	✓	①	①
10) A.V.P.U. stands for?	0.79 (0.41)	0.88 (0.32)	✓	①②③	
11) When using a non-rebreather mask …	0.37 (0.49)	0.75 (0.43)	✓	①②③	①②③
Totals	**7.63 (1.52)**	**8.68 (1.5)**			

Numbers represent each scenario: ① Cardiac, ② Respiratory, ③ Shock.

** This (14-16 gauge) needle was used in the scenarios and nursing students were highly likely to recognise the gauge size from the video, however it was not included in the presentation or scenario feedback*

Table 5.10: Comparison of MCQ results and where information is conveyed in the program.

The questions showing the greatest improvement include a combination of at least two of the three sections, presentation, scenario and feedback. Most notable is the "non-rebreather mask" question (11), where information for the student was strong in all sections. In the presentation, it was a specific step in the treatment process. Students also needed to apply that therapy to the patient as an interaction in all the scenarios. Students are given repeated and specific instruction in the feedback about using this treatment in all scenarios, namely *"delivered initially by a non-rebreather mask at a high flow rate (15 L/minute)"*. The reinforcement of this treatment is very explicit in that it mentions text from both the question *"non-rebreather"* and the answer *"15 L/minute"* of the MCQ. Student numbers for those who answered question 11 correctly in the pre-MCQ (n=139), increased by 97% (n=275). Few students had a negative impact due to the experience, as only 10 students of 139 answered correctly for pre-MCQ, then answered incorrectly in the post-MCQ. While most questions show increases in understanding, further investigation is needed to understand knowledge gained for the areas that were covered by MCQs.

An examination of the improvement in scores for the MCQ tests should also indicate improvement in the three scenarios over time. Indeed a strong correlation between MCQ results and scenario scores does exist, with a $p<0.01$ for both MCQ tests and each of the scenario scores (*Appendix H*). Evidence would normally be expected to show that scores increase with all students improving over time. Certainly, scores are higher in scenarios 2 and 3, when compared to scenario 1. However, average scores drop for scenario 3 when compared with scenario 2. A closer examination of interactions is needed to understand why this may have occurred.

Examining the number of clicks taken for each scenario does reveal an increase in the number of clicks as students' improved their understanding of the interface after the first scenario. Figure 5.2 shows the numbers of students (n=367) who clicked a certain number of times for each scenario *(Fig 5.2)*. A general shift in click numbers was well below the minimum number of clicks required to score 100%. The minimum clicks required, and the mean number of clicks students actually performed for each scenario is: (minimum=27, mean=22) for scenario 1, (minimum=24, mean=26) for scenario 2 and (minimum=27, mean=26) for scenario 3. The number of clicks ideally should be higher than the minimum required, as there are likely to be superfluous clicks. It is unlikely that students choose interventions with perfect precision; therefore, more clicks are needed to allow for some redundant interventions. For example, although not all vitals required checking, many students would often check all vitals twice as is recommended in the general feedback. Time constraints would have prevented excessive clicking, however, this is more likely to have occurred in the first scenario as students may have spent more time investigating the interface and videos. Scores for the scenarios are highest for the second scenario, which also had a larger number of students clicking more than the minimum required. This result aligns with the scoring system that relies on correct clicks to tally the score — the more clicks that occur the more likely some of them will be correct. As scenario 2 required fewer clicks than scenario 3, students had more time per click to reach the minimum.

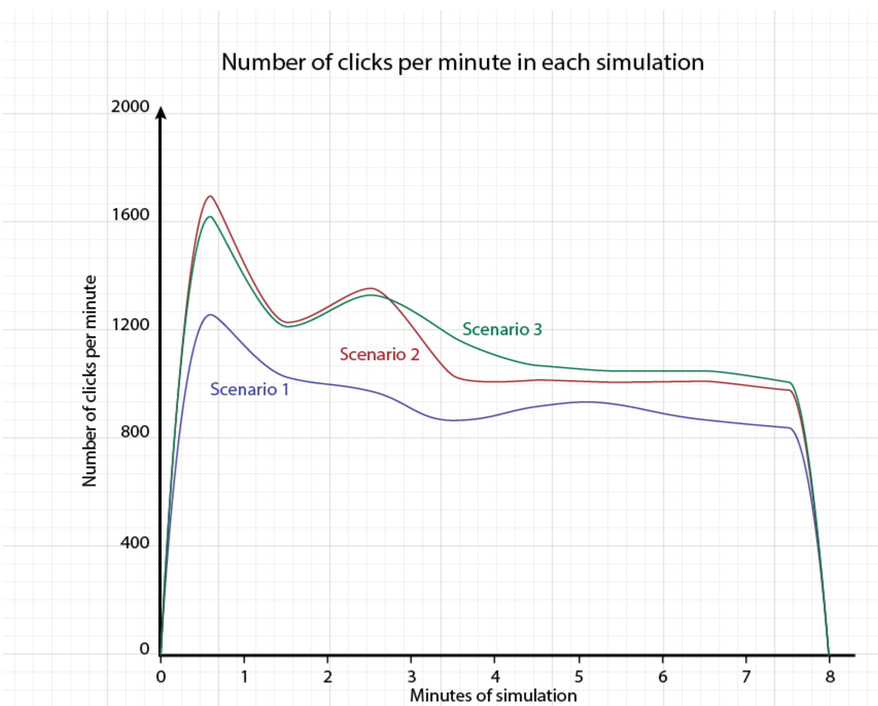


Figure 5.5: Total number of clicks per minute over all students for each scenario.

Figure 5.5 shows the difference in number of clicks per minute for scenario 1 when compared with the other scenarios. This graph shows the collective number of clicks of all students (n=367) per minute in each scenario. It is possible that students might have clicked excessively as they explored the interface in the first scenario. However, the opposite is true, as there are clearly fewer clicks than the other scenarios. It is important to add that clicks were only recorded when an intervention was actioned, and not when a menu was opened. Students may have spent more time viewing menu options without actioning any treatments. Students perhaps took more time to understand the scenario, reading the text and investigating the navigation, rather than clicking experimentally on actions. A number of factors could cause this hesitation to explore actions in the scenario. For example, because each action takes time, students are cautious about wasting that time in an effort to get a good score. Alternatively, medical students might be cautious in nature, not wanting to test actions at the risk of the patient's life. Further investigation is needed to understand more thoroughly, the motivations in these early stages. However, it is clear that scenarios in this research elicited a cautious response in the first scenario. While the patterns in the click data show improvement, increased performance may be revealed in other data forms.

Reviewing open comments may offer a deeper understanding of student performance. Below are examples of comments that specifically reference learning objectives, indicating that students have understood these concepts. The first comment identifies an ordered approach to intervention, and the second specifically explains that they learnt how to recognise a deteriorating patient, and how to prioritise interventions.

> *"The key things I took away from this program is how to create an ordered intervention approach to a deteriorating patient."*

> *"The main points I attain from this program is a further understanding of how to recognize [sic] a deterioration of the patient and how to prioritize [sic] the nursing intervention in terms of looking after deteriorating patient."*

The comments from students and improvements in MCQ results indicate improvements in student understanding. And, although students were cautious in the first scenario, later attempts show a marked improvement in scenario scores and interactions. The students' responses, using number of clicks as a measure, is higher in their subsequent scenario attempts

(Fig. 5.5). Increases in scenario scores and higher click rates demonstrate more confidence with using the scenarios with repetition. This, in combination with the feedback given after the first and subsequent scenarios, resulted in a better performance in the post-MCQ, and is backed by comments from student evaluations.

5.3.3 What characteristics of the simulation align with improvements in the students' perceptions of their confidence with the subject matter? *(S3)*

It is clear that students improved in theoretical knowledge through answering more MCQ questions correctly after the simulation experience than before. However, a deeper understanding of how students' knowledge improved or worsened would be beneficial. Student confidence links to a better grasp of the learning material and their ability to apply that knowledge outside of the learning environment (Aldrich, 2005, Bambini et al., 2009). Students who have a richer understanding of the theory are also more likely to feel confident executing actions in the scenarios.

Student confidence was self-reported using a Likert scale, having before and after confidence ratings, to balance the variations in the initial confidence levels of individual students. The evaluation questionnaire used a five-point Likert rating to gauge student confidence for different simulation experiences. The results show that the simulation improved overall confidence in students from a mean of 2.94 before the online activities, to 3.99, and an increase in competence from 3.14 to 3.98 *(Table 5.11)*.

Table 5.11: Confidence and competence ratings before and after simulation

	Before the online activities		After the online activities	
	1-5 rating (mean)	**SD**	**1-5 rating (mean)**	**SD**
Recognise a deteriorating patient	3.53	0.81	4.37	0.58
Manage emergency priorities	3.21	0.85	4.14	0.66
Perform emergency tasks	3.29	0.89	4.10	0.74
Confidence level	2.94	0.84	3.99	0.65
Competence level	3.14	0.79	3.98	0.66

Table 5.11: Confidence and competence ratings before and after simulation.

For other key learning objectives, students found recognising patient deterioration, management of priorities and their perceived ability to perform an emergency task as improved. The students' experience of the simulation clearly empowers them. While confidence and competence overall increased, there may be characteristics of the simulation that have differing affects on these increases.

Using pre-MCQ scores as an indicator of students' confidence, derived from a better understanding of the content — students can be separated into two groups; those that scored in the top half of the multiple-choice (more confident), and those that did not (less confident). By comparing interactions of the upper and lower groups, some patterns may emerge revealing differences in the way students used the scenarios. Students that score well are more likely to understand the material and should in turn be more confident with their knowledge. While some students may have chosen correct MCQ answers by chance, the overall number of students participating should reduce the impact that outliers have on any results. The groups were split using the mean value score of 7.63 *(Table 5.10)* from the pre-MCQ. All students who received an eight or higher on their pre-MCQ form the upper half (n=194) and the other students the lower half (n=173).

A sign of their understanding, and also confidence, could be highlighted by the number of clicks performed in the scenarios. The students who click more often are considered more confident as they will be less likely to hesitate when choosing interventions. This is especially true of the first scenario where the additional pressure of understanding the system can reduce confidence further, as seen by the lower click pattern in *Figure 5.5* when compared with click patterns of scenarios 2 and 3. Figure 5.6 separated the students into two groups, using the pre-MCQ score mean as the divider. The average range (1 standard deviation) of clicks in the first scenario for the two groups show the upper half of students averaging a click range of 18.7 to 26.5 clicks, where the lower half averaged 17-25.8 clicks *(Fig 5.6)*. Students who were more confident clicked more readily. While there may be other possible causes for this, further examination is required and is beyond the scope of this research.

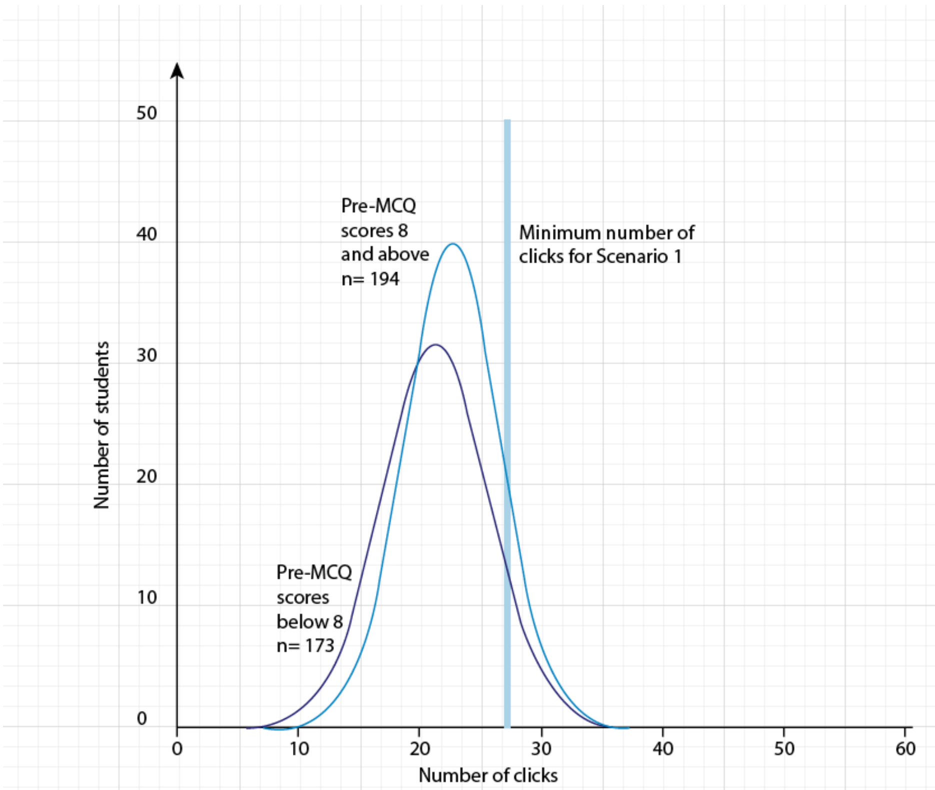


Figure 5.6: Distribution of the average number of clicks for Scenario 1, grouped by lower and upper halves of student performance in the pre-MCQ.

Improvements in confidence are linked to improvements in learning. The greatest improvements for a specific learning area was oxygen therapy, question 11 in the MCQ. The content for question 11 was presented the most frequently, and in all three areas; presentation, scenarios and scenario feedback. Information presented regarding question 11 was also very explicit. As a result, this question has strong connections with the scenario content, and will likely reveal a relationship.

If scenario features can improve the understanding of applying oxygen therapy, then more students will select this option as each scenario is completed. The graph only shows an increase between oxygen related choices in the first scenario to the second *(Fig 5.7)*. While scenario two has more correct actions than three, it is important to remember that scenario two also has a higher average score (76%) than scenario three (67%), and required fewer clicks to reach the maximum score. This suggests that scenario three might be more difficult than scenario two for students to comprehend,diagnose and interact with. This disparity was further compounded by the fact that scenario two was about a respiratory condition with a patient struggling to breath, and so required a real need for the highest level of oxygen treatment.

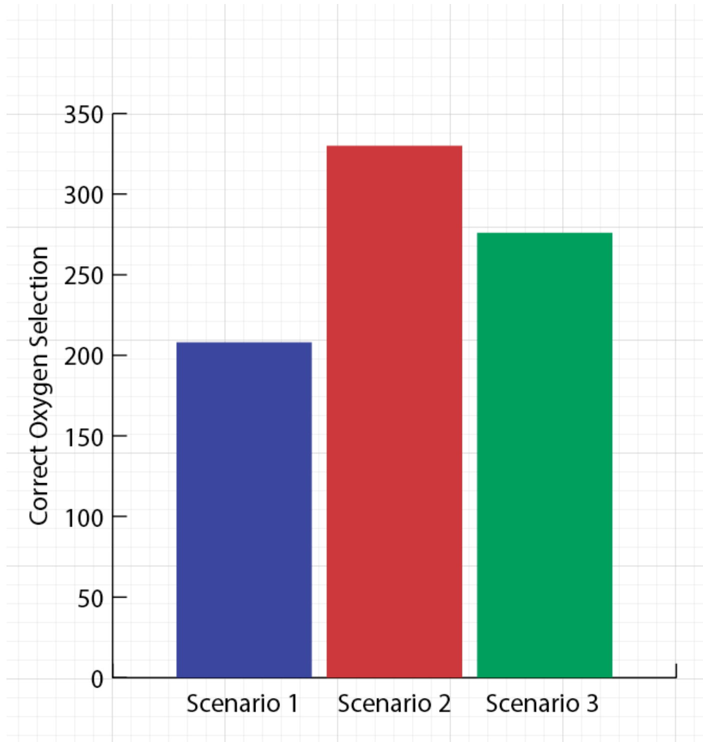


Figure 5.7: Correct oxygen selections in each scenario.

The line graphs in figures 5.8, 5.9 and 5.10 show the number of oxygen choices for each scenario by their place in click order — the student's first click to their last click. The correct choice in each scenario is *non-rebreather* and this is stated specifically in the feedback at the end of every scenario *"...oxygen therapy delivered by a non-rebreather mask at 15 L/minute"*. When looking at the three scenarios, it is important to remember that the second scenario is a respiratory condition. The patient is struggling to breath, highlighting to the students that oxygen therapy is an urgent intervention, and non-rebreather is the highest level of oxygen treatment available.

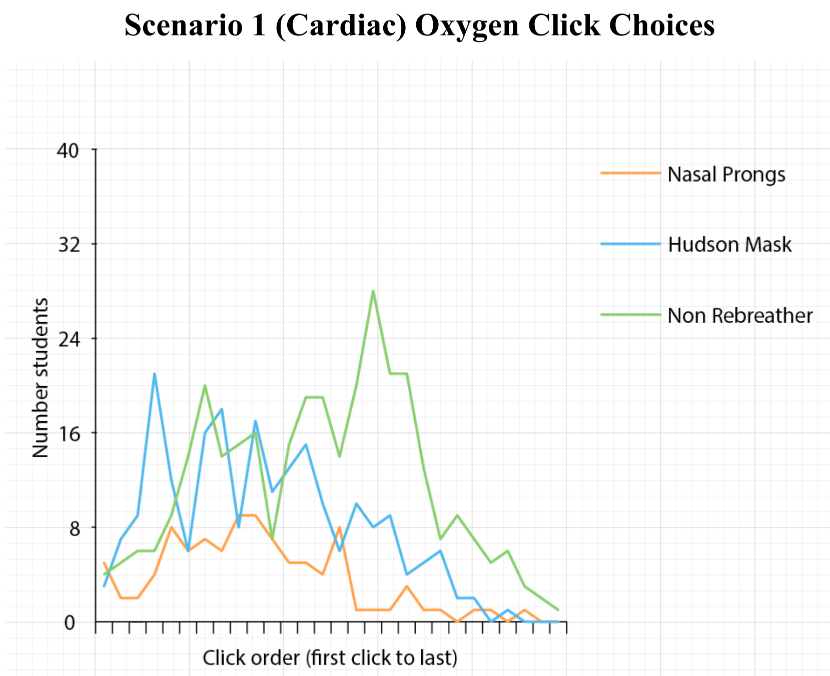


Figure 5.8: Oxygen therapy choices by click order (first click to last) scenario 1

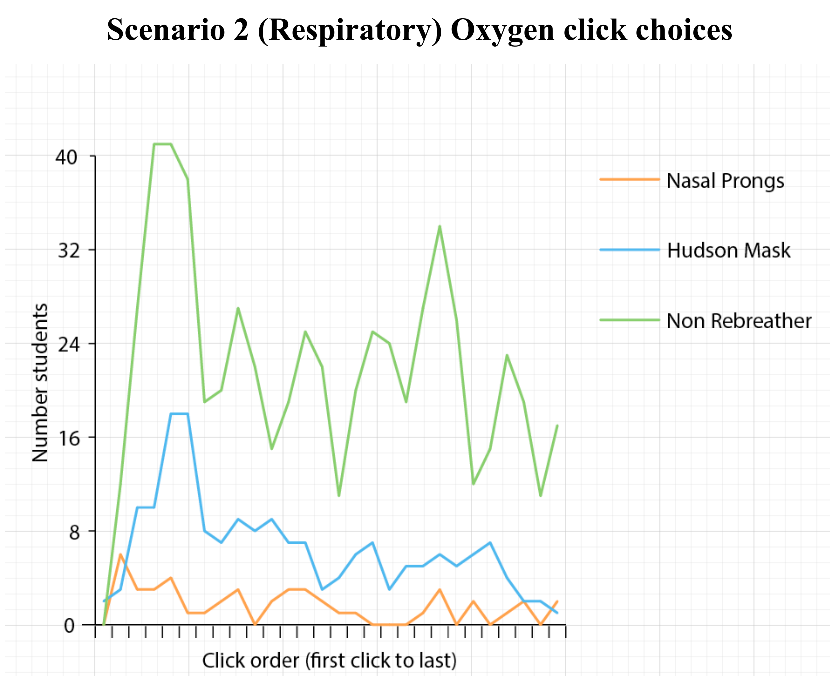


Figure 5.9: Oxygen therapy choices by click order (first click to last) scenario 2

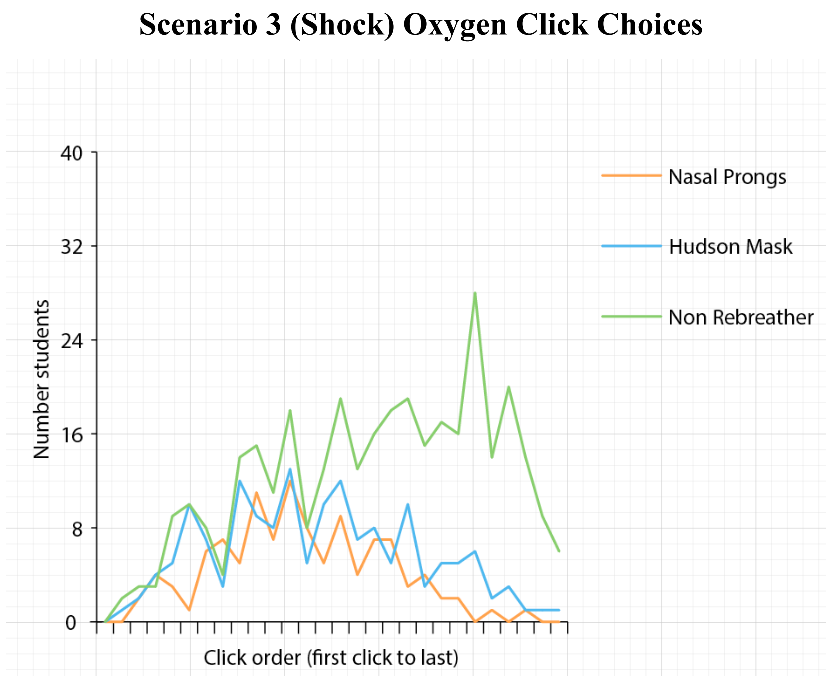


Figure 5.10: Oxygen therapy choices by click order (first click to last) scenario 3

Each scenario shows a different pattern of the time the correct oxygen was administered. If we look at the results, there is a clear use of the correct oxygen early in the second scenario where the third scenario shows correct oxygen use later in the process. This likely demonstrates that other interventions were administered prior to oxygen therapy in scenario 3. The distribution of clicks over time is similar for both scenario 2 and 3 *(Fig. 5.5)*. This pattern indicates that the number of interventions over time is similar, but that oxygen therapy occurs later for scenario 3. The correct oxygen interventions as a percentage of overall oxygen related interventions are 56.7% (scenario 1), 89.9% (second scenario) and 75.2% (scenario 3). A total of 255 students (69.5%) correctly applied oxygen therapy in both scenario 2 and 3. The expectation would therefore be that students, who correctly chose *non-rebreather* for scenario 2 and 3, would also correctly answer the related question in the post-MCQ.

Investigation of the students who incorrectly answered question 11 in the pre-MCQ using Chi-square does not show a relationship between performing the intervention and answering question 11 in the post-MCQ correctly *(Table 5.12)*. This result was similar for question 5 and question 8 *(Appendix J)*. These two questions were selected because one excluded any scenario feedback (Q5) the other included only minimal scenario feedback and no presentation content (Q8). The 3 questions cover the spectrum of content shown to students, such as no feedback and no presentation content, but all include interventions related to those questions. This result suggests that there may be limited connection between individual scenario interventions and related post-MCQ question results.

Table 5.12: Comparison of question 11 & correct oxygen interventions for scenario 2 & 3 for students who answered pre-MCQ question incorrectly

Post-MCQ Question 11	Correct intervention scenario 2 or 3	Incorrect intervention scenario 2+3	Total
Correct answer	145	3	148
Incorrect answer	76	4	80
Totals	221	7	228
Chi-square = 1.5423, P = 0.21			

Table 5.12: Comparison of question 11 (Post-MCQ) and correct oxygen interventions for scenario 2 and 3

Closer examination of the students answering question in the post-MCQ does reveal an interesting observation. Thirty four percent of the students who performed correct interventions answered question 11 incorrectly. Interestingly, 64 (84%) of those students chose the "Ensure 100% Oxygen Delivery" as an answer to question 11. Ambiguity in the answers may be the reason for this discrepancy between students who would normally be expected to answer correctly in the post-MCQ. While at no point in any education material is "100% Oxygen Delivery mentioned", there are many references to >93% and students may have confused this to refer to anything above 93%. Of the four possible answers there was only one answer that included a percentage amount over 93%. Students may have opted for this because of the confusion. Relationships between the interventions and the results in the MCQ are inconclusive; the act of the intervention may still be a measure of student understanding and requires further investigation.

When looking at the interventions related to oxygen, the first scenario had few students apply correct oxygen therapy. The low number of students suggests that the presentation alone did not greatly improve the students' understanding of the required oxygen related intervention, despite clearly stating "…if the patient is acutely ill give high-flow oxygen at 15L/min…"

However, after specific feedback from scenario 1, in combination with a patient with breathing difficulties in scenario 2, students greatly improved their oxygen therapy choices in the second scenario. Finally, the last scenario, where oxygen therapy was not inherently required, as the patient did not show signs of breathing issues, the majority of students still chose correct interventions.

Using oxygen therapy as an example, the findings that suggest the greatest impact from the scenarios are from the specific feedback given at the end of each scenario, resulting in an increase in correct intervention in later scenarios, and an increase in correct MCQ responses. Situational feedback, such as the patient clearly showing signs of difficulty breathing, resulted in a spike in the number of students making correct oxygen intervention choices. Situational influences should be a consideration when assessing the educational impact. As a result of feedback and situational learning, the majority of students did apply oxygen therapy correctly in the final scenario despite no obvious patient symptoms requiring it. Student confidence improves performance as we can see in the better click patterns from scenario 1 *(Fig 5.6)*. Clear information helps student comprehension, and this improves their perceptions of their confidence, which improves their performance further. Characteristics such as clear instruction, using learned information in new settings and feedback, are effective in improving confidence where the ability to repeat these activities reinforces the knowledge and improves confidence further.

5.3.4 What characteristics of the simulation align with decreases in students' perceptions of their confidence with the subject matter? *(S4)*

When looking at the sections where student confidence with subject matter decreased, there is no one area within the MCQs that showed negative results. This is understandable when the objective is to educate, and the aim is to leave students with more knowledge. If no change occurs in understanding, it may be due to ineffective education, such as an absence of content. While three questions, 1, 2 and 8, experienced little to no change, only question 8 (needle gauge) started at a low enough point for improvement. Most students knew the answers to questions 1 and 2 before starting the program, leaving little room for improvement in those areas. Question 8, however, started with 75% of students giving correct responses and did not change between the pre-MCQ and post-MCQ. This suggests that students did not learn anything from the presentation and scenarios to change their understanding.

There are a few factors to consider as to why this might have occurred. Firstly, the presentation video did not include any information about needles, and second, it was not explicitly part of the feedback in any scenario. Of the 275 students who got the question right for the pre-MCQ, 260 of those students answered correctly on the second attempt. Of the 92 students who answered incorrectly in the pre-MCQ, 76 answered incorrectly again in the post-MCQ, and 59 of that group gave the same incorrect answer. This suggests no change in their thinking and reduces the likelihood that they were guessing. It is important to remember that students were not told any results until after both quizzes had been attempted, so they would not know they had answered any questions incorrectly, and would therefore have no reason to answer differently in the post-MCQ. The pre-MCQ quiz questions were answered using only the knowledge students brought to the program, as no First2Act information was given before commencing the pre-MCQ. The number of students who answered the same way for both pre-MCQ and post-MCQ reinforces that no new knowledge was exchanged, as students received no feedback and limited information about needle gauge during the simulation, or the presentation. This result suggests that explicitly presenting content in multiple ways is best and designers can not assume content shown in the background, such as the needle gauge in the *IV cannula* video, will be learned effectively.

The limited content provided during the simulation did provide an easily recognised needle gauge in the video, however it did not have a lasting affect on student knowledge. There was also nothing in the presentation that covered needle gauge information. Students' answers to question 8 in the post-MCQ are tallied in Table 5.13, against those who saw the needle gauge video. These are the results of a Chi-square test *(Appendix J)* on the entire cohort (n=367), for each individual scenario intervention. Testing in this way offers an alternate perspective on potential relationships between interventions and MCQ results, in that it isolates the specific scenario situations (Cardiac, Respiratory and Shock) and compares them. The difficulty of the scenario, or the time between the scenario and post-MCQ, may play a part in the students' ability to assimilate the knowledge.

Table 5.13: Total number of students answering question 8 and viewing related content in scenarios				
Question 8/Viewed content	**Scenario 1**	**Scenario 2**	**Scenario 3**	**All scenarios**
Correct/Yes	205	182	112	69
Correct/No	71	94	164	32
Incorrect/Yes	50	48	43	16
Incorrect/No	41	43	48	15
Total Students	367	367	367	132
P	0.0005	0.0240	0.2637	0.0893

Table 5.13: Total number of students answering question 8 and viewing related content in scenarios.

Students who did not administer IV intervention did not see the video containing the needle, which is the only content related to the question. In scenario 1, 205 students saw the video and also answered this question correctly in the post-MCQ. This association was strong for scenario 1 $p<0.01$. However, the association weakened in scenario 2 ($p<0.05$) and was not present for scenario 3. The connection between seeing the video and question 8 could suggest this knowledge had already been established by the second scenario and perhaps, the third scenario caused confusion in some way. Scenario 3 was more difficult than scenario 2, and students may have thought inserting an *IV cannula* was less of a priority in that patient's case.

Interestingly, there were also fewer students viewing the needle gauge video in each additional scenario, despite every scenario's final feedback recommending the insertion of IV. There may be a disconnect between the correct answer and the example scenarios. Question 8 has a correct answer of 'trauma and burns', yet no patients experienced these conditions. Strangely, only 3% (n=12) of students chose 'elderly patients' as an answer to question 8, despite all patients being elderly. It is, therefore, unlikely that patient characteristics affected student responses to question 8.

The less successful characteristics of the scenarios clearly indicate that subtle information is easily missed, where relevant and explicit content has a much broader reach in education terms. The result is hardly surprising, but becomes an important consideration in regards to creating complex educational material. It is worth remembering that motivation for students can come from the challenge of learning the material (Ames & Archer, 1988). A careful balance between presenting content and engaging students in a thought-provoking way is far more likely to have a greater and long lasting impact on the students' education.

A secondary consideration to content development is that the video of IV is not mandatory, so students can miss the video entirely. Providing flexibility in learning is important, but the chosen assessments criteria require careful attention, guaranteeing that students are exposed to the appropriate material to have access to the new knowledge. It is possible not to see the video, so students could easily miss key information related to the corresponding question.

The characteristics that decrease student confidence are difficult to specify given that the MCQs did not show any questions where results decreased. However, it is still possible to highlight characteristics that were ineffective for learning. Unclear, or out of context information, did not help students improve their responses to question eight. Information needs to be framed in a way where students can ascertain meaning from it, and be able to apply it and receive feedback on performance, in order to perceive greater confidence. Making students confused leaves the student in doubt of their knowledge, reducing their confidence.

5.3.5 What was the student reaction to the simulation experience? *(S5)*

The evaluation questionnaire from students can improve the understanding of the overall experience, including their confidence with the material, as well as their enjoyment and understanding. The qualitative data can be helpful to measure the effectiveness of the tool for learning. The review of the First2Act program used an evaluation questionnaire *(Appendix E)* with a Likert scale of 1-5, 1 being "not at all" and 5 being "to a large extent". The majority of students rated the program highly. Of all questions discussing the program's relevance and efficacy as a learning tool, the lowest mean rate was 4.43 (SD=0.83) and the highest 4.65 (SD=0.66). Students rated all questions positively at 88% or higher, suggesting a very high satisfaction rate with the program. It is worth considering that students bore no costs to the learning experience apart from their time. It is entirely likely that students may expect more from the online program if the costs to the students were higher, for example, if they had to pay a subscription to the service.

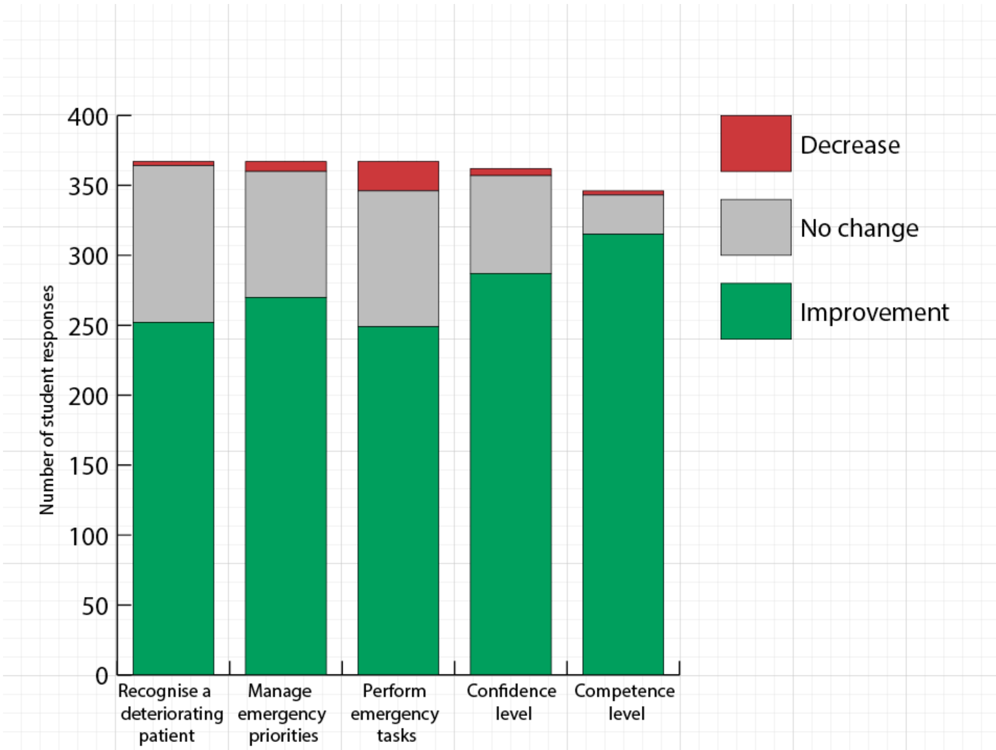
The second and third sections of the evaluation involved self-assessment of the students' abilities - their confidence and competence. Again, using the same Likert scale as for the previous section, the students rated their perceived improvement before and after the simulation. The following table shows the number of students who gave a higher rating for 'after' (showing improvement), the same rating (no change) or a negative rating (a decrease) *(Table 5.14, Fig. 5.11)*.

Table 5.14: Total number of students whose ratings changed in perceived abilities after the simulation

	Improvement	**No change**	**Decrease**
Recognise a deteriorating patient	252	112	3
Manage emergency priorities	270	90	7
Perform emergency tasks	249	97	21
Confidence level	287	70	5
Competence level	315	28	3

Table 5.14 Total number of students rating their change in perceived abilities after the simulation.

Note*: there were some errors in the data for confidence level (n=5) and competence level (n=21), so no measure was taken for those specific entries. Those results do not add up to n=367.*



Note*: there were some errors in the data for confidence level (n=5) and competence level (n=21), so no measure was taken for those specific entries. Those results do not add up to n=367.*

Figure 5.11 Total number of students rating their change in perceived abilities after the simulation.

There is a clear improvement in all areas as stated by the students' responses. However, there are a number of students who felt there was no change in their abilities. This suggests there are areas where improvements could be made. The open text comments from students included several suggestions for improvement. In the final section of the evaluation questionnaire, students were asked to give open text responses to the question:

> *Please add any other comments or suggestions:*
> *(For example - what were the key things you learnt from this program? or How could the program be improved?)*

Using thematic analysis on the feedback (Ryan & Bernard, 2003), the overwhelming majority of comments were positive. There was an emphasis on requests for more scenarios. Overall, 165 students (45%) commented in the open text question. Students gave a range of responses about how much they enjoyed the program; how they felt they had learned from the experience and highlighted features they liked. In general, the feedback was overwhelmingly positive, and a large number of students found the experience both interesting and useful, with comments like:

> *"Great program! Really relevant and stimulating way to learn…"*

Common negative themes typically focused on technical issues students had faced, or limitations of technical features. Other negative themes discussed the program not meeting student expectations. However, these comments were often coupled with suggested improvements. The comment below discusses the issues with realism and a limitation of the current software design.

> *"In reality help would arrive and we would not have to make all these decisions in isolation. I was often clicking options while the time was running down as the program did not allow me to stop (the stop button didn't seem to be working)"*

This student would like the emergency team to come and help. This assistance removes some of the pressure the student might have to face in a real situation (even though this isolation could occur in reality). It was difficult to come up with a feasible solution as to how this might be implemented effectively without reducing the educational impact of the simulation, as an emergency team would largely take over the patient care.

In many case students who wrote more positive comments wrote a simple statement of satisfaction with at least one defining factor, such as "*stimulating way to learn*". The general description and experience for the students was complimentary, with the majority of students using strong supportive keywords such as "*great*" and "*fantastic*", rather than "*good*" and "*satisfactory*". While there were a few negative comments about the general experience, most could be attributed to the technical issues they faced, or in some cases, a misunderstanding of what was expected.

As with general feedback, a similar positive outcome occurred for the learning experience, with the majority of comments being positive, and many students using phrases like "*It has* *helped my understanding*". The consensus here suggests that the students who took the time to comment found the learning experience enjoyable and rewarding.

To a lesser extent, students made fewer comments on their confidence and ability. While only a small number of students commented, all were positive, with no students finding that their confidence had decreased. Some comments connected well with Moreno-Ger et al. (2008), who state that simulations provide an opportunity of transferring theoretical knowledge to better prepare students for real life experiences, as highlighted by this student's comment (p. 289).

> *"...I have not been able to experience any such situations on placement yet and this is my final year therefore I have been very anxious on how to manage such situations next year, but after this program my confidence has increased and I feel more capable…"*

The comment above demonstrates this student has limited practical experience but feels more confident about any future experience with a reduced level of anxiety. Learning through a simulation can provide students with a safe, non-threatening environment to practice in, and a reduction in anxiety towards exercising skills in a real environment.

Despite some research suggesting that comparisons of simulations with the real world has limited impact on learning (Norman et al., 2012), students made comments about the realness of the simulation. Student comments were mixed when relating to the experience of the simulation, with regards to its effectiveness as a representation of reality. While no students declared it as an exact replication (which is expected given the nature of video as a medium), some students found the limitations harder to accept.

> *"I felt as though some of the actions took longer in the program than in real life - make it more real life like (for example, rarely would you put an O2 stats on every time you took their O2, same with heart rate etc. But once I understood what was happening it was much easier to use. Also, I struggled to make*

> *assumptions/diagnoses of the patient with the little amount of information from the patient."*
>
> *"What I didn't feel was fully simulated was that the patient's condition didn't seem to be improving very much when certain interventions were carried out - even though this might be so in the real situation."*

The above responses were typical of this kind of commentary; students' expectations were misconstrued from reality. In both these cases, the reality is represented correctly in the simulation. In fact, in the case of the interventions/actions, the videos were edited down shorter than real-time. The likely origins of the point can be attributed to altered time perception within high-stress situations (Stetson, Fiesta, & Eagleman, 2007). When performing under pressure, our perception of time passing is slower than reality, making the video of the interaction seem to take a long time. It can seem even slower when watching the same video repeated several times as the pressure to take action increases.

The second comment also included a misunderstanding, as the student mentioned that the condition did not change, however in most cases, despite treatment, a deteriorating patient's condition may not start improving until after the 8 minute episode (Buykx et al., 2011). This comment could potentially stem from the common expectation of feedback loops from systems, such as computer games, mobile apps and other interactive systems. While it is easy to dismiss these students' comments, it is important to remember that this perceived error in the simulation is the experience they have, misguided or not. Rather than just try to correct the student, it may be better to work with the expectations, trying to find a balance between accuracy and an enjoyable or rewarding experience. If the students find the simulation more engaging, then they are more likely to learn from it (Aldrich, 2005, Ames & Archer, 1988).

The final group of comments contained only a few students discussing issues they faced. While overall these comments were limited in number, the majority were related the technical issues.

> *"There was a lot of technical issues during the activities. The videos would freeze [stop playing] on the last 4 minutes."*

It is important to remember that open comments were in the last step in the program, and could only be accessed after completing all other steps. Students who had technical issues preventing progress to the last evaluation step would not have been able to comment about this issue.

The majority of the technical issues focused on the video freezing; a known technical problem with Internet Explorer that was unable to be resolved before trials began. It is also unlikely that responses would have contained any reference to technical issues if there were none, as it is unlikely they would feel the need to comment that they experienced no technical problems (Ryan & Bernard, 2003). There were also no direct questions in the evaluation that solicited students to discuss either successes or failures with regards to technical performance.

In the open text comments, many students found the experience real enough to convey the sense of urgency required to save the patient, helping students gain an appreciation of the pressures they may face in the real situation. Many students also learned that interventions can take longer than they expect. Given the short timeframe for patient deterioration situations, students found that they do not have much time to do all tasks required. Open comments highlight the key learning objectives achieved by the simulations, such as experiencing time pressure, something that may be harder to learn from more passive teaching approaches.

Students also suggested ways to improve the program. The majority mentioned improved feedback, to help them understand what they were doing wrong so they could further improve on future scenarios. The feedback in each scenario was a paragraph of information related to that scenario, and was the same for each student. During the development, no solution was found to make the feedback dynamic for each student's specific experience. High fidelity feedback is something that can be easily achieved by a teacher giving feedback on performance. However, it was not possible to achieve this for the project, due to resource constraints. Dynamic feedback is possible to include, as interactions are tracked and this data could be used to generate the feedback.

In summary, the students' responses to the simulations were overwhelmingly positive, with a large number of students asking for more simulations. The open comments highlighted some issues, mainly inadequate feedback; something that can be addressed in future versions. The rated responses show that the majority of students found the program enhanced and improved their knowledge, confidence and competence in patient deterioration.

5.3.6 What features of the simulation need to be improved? *(S6)*

When looking at the areas of the simulation that need to be improved, there are a number of factors that should be considered. Creation of a complex simulation takes a considerable amount of time and resources. There are many parts of the design process that require people from different industries to come together and find solutions to problems. It is important that the team works well together and that communication remain clear. Team members often use different language to describe the design process, so time is required to make sure that everyone has a well-defined sense of the project before any major decisions are made. Other resource limitations can also play a role in achieving outcomes, and in the case of this project, there were a number of issues at play.

The project was extensively delayed, and much of the content had been created ahead of any real planning of the simulations' technical development. This resulted in retrofitting of the simulation to the content, and not the other way around, or in unison. Ideally, content should be created for one test scenario in order to develop a methodology to follow, so that future simulations and their content can be created efficiently. This method of development was applied to the programming components, despite the content being created, and the first scenario was developed to completion before the second and third.

The development process was evolutionary for the education components, and while questions were devised before development, the connections between some multiple-choice questions and the content was weaker than it ought to be. Mapping out questions to content would have revealed the weak links between the question on needle gauge and the presentation and simulation content. A closer connection between the key learning objectives, the questions and the presentation/simulation, would more effectively reach the learning objectives. Careful planning before and during development means that some of these issues could have been avoided.

The last evaluation questionnaire *(Appendix E)* provided an opportunity to discover similar issues with the education material. Students were aware of what they answered incorrectly in the post-MCQ, and yet no students mentioned the lack of information about the needle gauge. Many students did discuss the lack of detailed feedback. Students felt the feedback was limited and did not highlight areas of improvement when working through the scenarios. Students were curious as to how to improve their performance. Feedback was general, and did not give specific information about how scores were calculated. As a result, students were unable to determine with accuracy what they did wrong, and therefore, could not avoid mistakes in future attempts. The table below shows the number of students who intervened incorrectly, either selecting the wrong choice or failing to take action. In most interventions, mistakes decreased in each new scenario and all scenario performances were better than scenario 1.

Table 5.15: Total number of intervention errors for each simulation			
Intervention type	**Scenario 1**	**Scenario 2**	**Scenario 3**
respiratory rate	33	6	15
iv cannula	112	137	212
pain score	32	59	8
social	316	181	227
emergency call	71	65	62
increase fluids*	n/a	n/a	122
oxygen therapy	60	6	46
temperature	176	84	38
heart rate	29	27	16
blood pressure	9	15	5
oxygen saturation	16	2	3
presenting complaint	67	26	46
capillary refill time	197	136	128
ECG*	4	n/a	n/a
medical	167	66	98
medications	14	60	98
chest auscultation*	96	12	n/a
conscious state	223	205	137
take blood	173	161	113
bowel sounds*	n/a	n/a	126
bed position	102	9	163
** These interventions were either not available for all scenarios or had no score applied*			

Table 5.15: Total number of intervention errors for each simulation.

The graph below shows the number of students whose interventions were wrong or absent for each scenario, scoring 0 or less. In most cases, incorrect responses decreased with each scenario *(figures extracted from the Table 5.15)*. Consideration can be made for interventions that do not show this pattern. For example, *bed position* for scenario 2 was more likely to be changed to the correct answer, as explicit instruction in the presentation explained that breathless patients should be positioned *upright* or *orthopneic*. However, immediately after this, the presentation went on to discuss how hypotensive (shock) patients should be in the *legs elevated* position. The number of students who incorrectly changed the *bed position* in scenario 3 (shock) was extremely high. A link between the lower average score for the final scenario may suggest gaps in student knowledge in terms of identifying shock patients. Students struggled to make the connection between presentation information and scenario 3.

IV cannula error rates also increased. Time constraints in the scenarios may have made this less of a priority for students. In scenario 3 the patient already has an *IV cannula* inserted, however a second cannula is required. This may not have been apparent to students who may have thought a single *IV cannula* enough, and explains the high jump in erros from scenario 2.

Medications on the other hand encompassed a combination of interventions, rather than a single choice, as was the case with bed position. As a result, this may have impacted the number of students getting this incorrect more often in the final scenarios. Under the medications menu, there were six possible choices. There were four possible correct choices in the first scenario, and then only two in each of the following scenarios. Students had a greater chance of getting at least one medication correct in the first scenario. This, combined with a reduced number of negative scoring medications, made it more likely to get a correct response for medications in the first scenario. Medications were also mutually exclusive, and each scenario required a completely new combination of medications for the different symptoms of the patient. This provides no opportunity to accumulate and build on knowledge learned from previous scenarios *(Fig. 5.12)*.

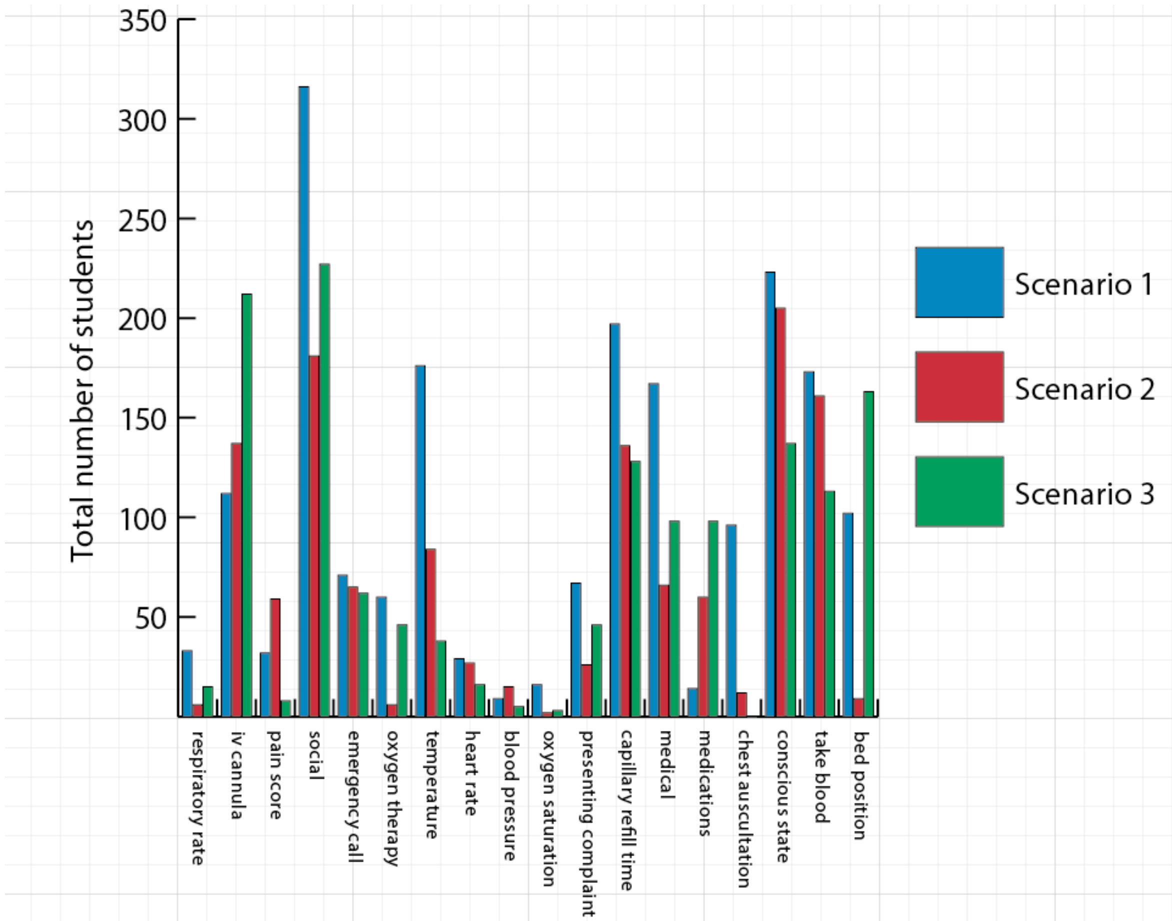


Figure 5.12: Total number of intervention errors for each simulation.

The *consulting patient* interventions (labelled *social* and *medical*) seem to resist the pattern. The different kinds of conditions the patients were showing (some more obvious than others) may have impacted the students' choices. Perhaps they skipped these steps to save time due to building urgency. A deeper investigation of students who did not change their approach to *consulting patients* despite explicit feedback might highlight areas where students were not learning. The graph below shows the total number of students who incorrectly responded to a range of intervention types for every scenario. An incorrect response is also the same as no response (scoring a 0 or less). Participants have incorrectly responded to that intervention for all scenarios. Colours highlight whether the students' numbers are below 10% of the total numbers (n=367), between 10-20% or above 20%. Red bars represent student numbers above 20% with the highest number of 155 students (42.2%) for *social* (consulting the patient about social history). *Bowel sounds* intervention was only available for the final scenario; this number represents students who did not check for *bowel sounds* in the final scenario only.

Increase fluids was available for all scenarios, but only scored points in the final scenario. Results for *increased fluids* represent only students who were incorrect for the final scenario at which point students had been exposed to the most content *(Fig. 5.13)*.

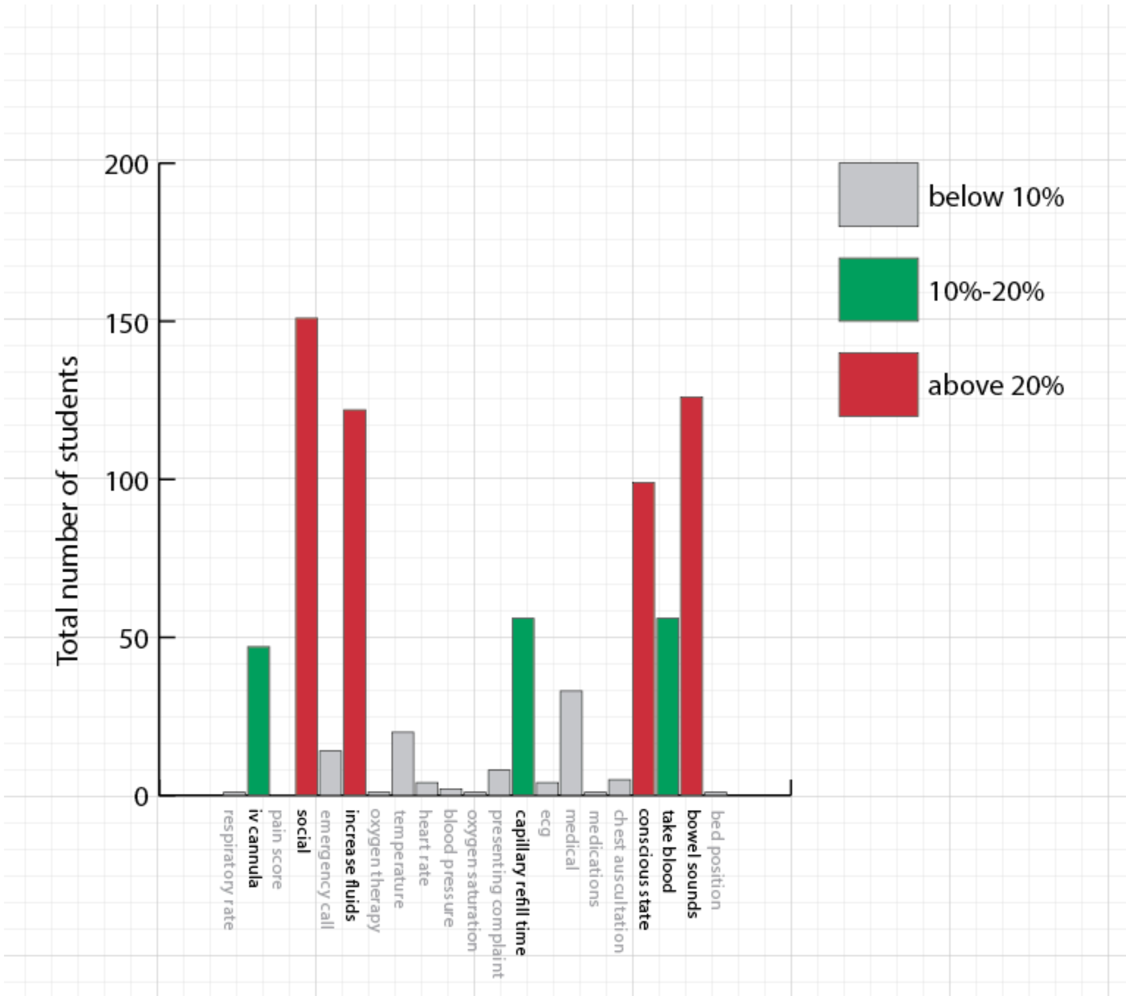


Figure 5.13: Total number of students who made repeated intervention errors in every simulation.

To fit within the scope of this research only the top five incorrect interventions were investigated. Patterns do emerge from the top five most incorrect interventions (excluding *bowel sounds* and *increase fluids*). The graph *(Fig 5.14)* highlights the top five interventions and how many students were incorrect with interventions in each scenario. Of the five interventions, three (*capillary refill time, conscious state* and *taking blood*) show improvement in correct interventions from one scenario to the next — an expected pattern that demonstrates students' knowledge improving over time.

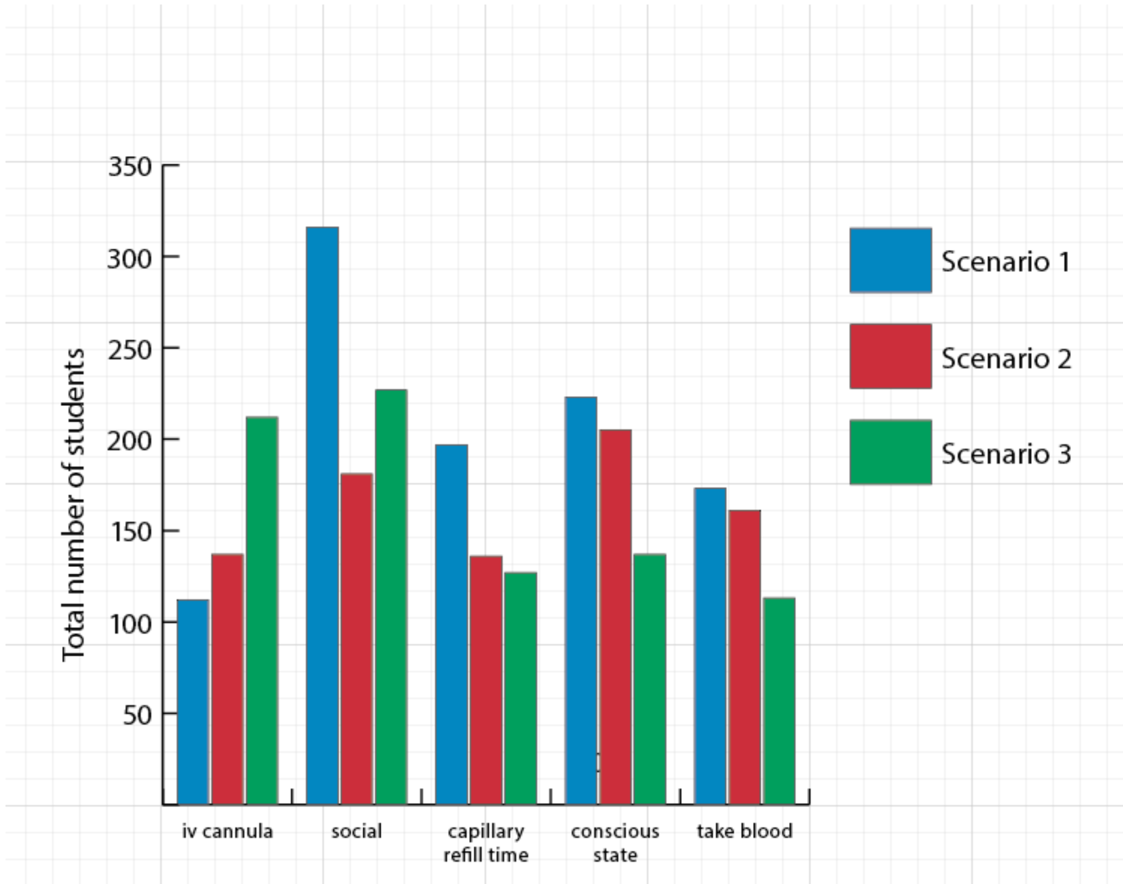


Figure 5.14: Total number of students who made intervention errors for each simulation.

The high number of students who chose not to consult the patient about their *social history* may suggest that students found this intervention of little value. Strangely, there was no cost to the students to perform this intervention as the timer paused during that intervention. Some students mentioned in feedback that some videos seemed longer than they would ordinarily take, suggesting that some students may not have played the video again after the first attempt because of the length.

> *"I felt that when undertaking the scenarios that when taking observations it took too long because in an emergency situation you would undertake observations at the same time as talking to the patient and asking the patient for history. You would also have the patient on continuous oximeter observations so that should be documented quickly as well. Other then that the program was very helpful and aided in my learning."*

The comment above displays a misunderstanding of the system, as the student was not aware that consulting the patient did not reduce their time (the timer being paused). This pausing was included to represent the exact situation that the student is describing, where nurses would make observations while they conversed with the patient. It is unlikely many students misunderstood the pausing of the timer, therefore, the high numbers might suggest that students saw less value in learning about a patient's *social history* in subsequent scenarios. Perhaps students thought the value of their real-world time was higher than witnessing the video for the sake of the simulation. It is important to remember that students were not aware of how the scoring worked, so they never knew that watching the video would add to their score. While these factors could contribute, the cost in real-time may be amplified by the fact that the patient was not a real patient. Perhaps when nurses deal with a live patient, there may be social pressure for them to ask patients about their *social history*.

IV cannula was the second intervention that actually increased in incorrect responses over time. The length of the video for this intervention was the third longest intervention video (32 seconds), excluding the *consulting patient* videos. There were 48 students (13%) who never actioned the *IV cannula* intervention again after the first scenario. It is also possible that students felt that the need to use *IV cannula* was more necessary for the first scenario. In the final scenario an *IV cannula* had already been applied, as described during the handover video. However, a second *IV cannula* is required. Students may have thought it unnecessary to add a second. Further research is required to understand the medical theory that might influence students' decisions here. However, it is beyond the scope of this research to analyse this in further detail.

There are a number of areas for improvement that have been highlighted. A careful examination of the key learning objectives and assessment criteria can assure that all learning material is adequately covered, especially in areas like feedback. Open text comments suggest that better feedback may help poor intervention responses. The final section of the evaluation explicitly asked for suggested improvements. While there was some variation, three main themes emerged; more comprehensive feedback, more scenarios, and the ability to do a practice run on one of the scenarios. The comment below highlights some of these points.

> *"Would be great to see a midwifery one as well. Ones that have scenarios with pediatrics [sic] and adults would be good, as these ones focused on the elderly. A practice one that goes for 2 minutes to get you used to the feel, without the pressure of possibly "killing" someone while learning to navigate the program. Several levels (of ability) and scenarios that could be passed and completed over several days/weeks."*

This comment specifically discusses possible suggestions for future scenarios. Other suggestions included the ability to assess what the condition was, rather than explaining it in feedback, or improvements in the practicalities of treating the patient. Also, the practicalities, such as leaving the blood pressure monitor on rather than attaching a new one every time (most nurses would do this to save time). Increases in the number of interventions (treatments) available were also suggested, and lastly, the ability to repeat scenarios to help improve performance.

Content in the simulations needs to represent reality in a way that seems fair. For example, if a video is too long or includes repeated steps that a nurse would typically not take, then the students feel cheated out of time — a precious resource in a timed simulation. These factors are similar to how game design uses 'balance' to be both challenging and fair on a player (Koster, 2013). In some cases, the reality of the simulation is accurate, but the students' perception is that the simulation has treated them unfairly. It is exceptionally important that the simulation design does not create false impressions on nurses about the reality of these situations. However, with clever design, simulations might be able to bridge both the presentation of realism and the impression of fairness on the user.

5.4 Summary

Results from the experiments that tested the effectiveness of the simulation in nurse training, as well as examining the method of developing a simulation, show there are some areas that must be improved. The methods currently used are adequate, however, areas of concern are around deep understanding of the material, in combination with good communication between stakeholders and developers. Careful planning of the education material is paramount, and can avoid many problems down the track. A good testing environment allows for an iterative design approach, and is extremely useful for designing novel and untested simulations. Student reaction to the simulation was overwhelming positive from both an experiential and educational standpoint. The majority of comments asked for more simulations. The empirical data that shows improvements in knowledge and understanding occurred in most areas. A smaller impact on learning occurred in well-understood areas of knowledge, and on areas where there was limited content. In the following chapter, there will be a more detailed explanation of the conclusions derived from this research. This will include possible directions that this research can take in the future.

Chapter 6: Conclusions and Further Research

6.1 Introduction

This chapter is divided into three sections. Section 6.2 explains the results from the experiments in terms of the research questions, and how this work contributes to knowledge. Section 6.3 discusses how to improve the First2Act system. The final section (Sections 6.4-6.6) discusses limitations of this research, future research, and finishes with a summary of the findings and their application to designing simulations for education in the future.

6.2 Addressing the Research Questions

This section reviews each research question, explaining the key findings of the research, the potential impact, and contributions to knowledge. Each sub-question is briefly revisited before elaboration on early findings.

What steps are required to design an appropriate learning simulation? *(S1)*

The steps required to design an appropriate learning simulation come from aligning project goals with both their necessity and resources available. Design decisions made at the early stages of design process impact the project in later stages. Rating each of the goals by their likely success helps to alert developers of potential problem areas. Considering how the three elements illustrated in *Fig 2.2*, cognitive psychology, instructional system design, and simulation design, can affect each specific objective is consistent with better design choices. The weighting of the three areas from *Fig 2.2* can vary depending on the objective. By taking a systematic approach that investigates each of the three areas, a plan of how each of the project's objectives is being addressed and measured can be created. Without clearly identified goals and the corresponding solutions, it is far more difficult to ensure the success of an educational simulation project.

How do students' interactions with the system relate to improvements in their performance? *(S2)*

Students' interactions with the system led to improvements in their performance in a variety of ways. Using the pre-MCQ and post-MCQ scores as a measure of performance, the data shows an improvement. Scores from the pre-MCQ 7.63 (SD±1.52) to the post-MCQ 8.68 (SD±1.50) and a significance of p <0.000 *(Fig. 6.1)*.

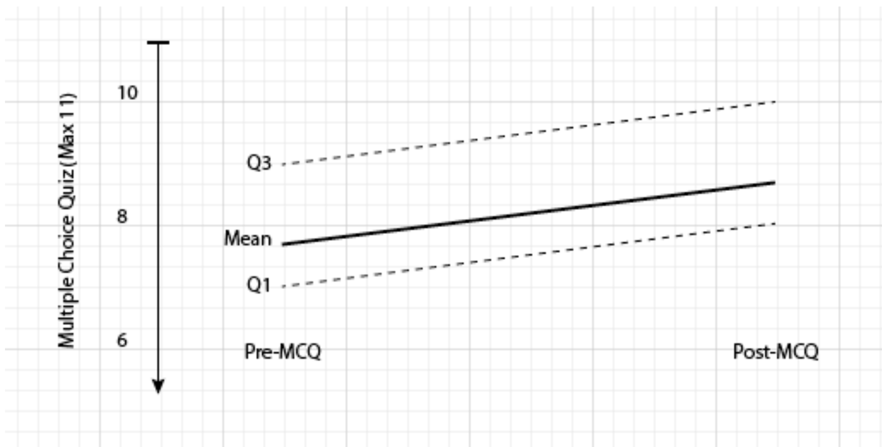


Figure 6.1 Mean and upper and lower quartiles of results for all students on pre and post multiple-choice quizzes

Individual questions showed a variation in how students improved. Questions with high initial correct responses (Q1 and Q2) showed little or no change. Questions with correct answers below 95% showed varying amounts of improvement. Question 8 maintained a steady 75% correct response rate between pre-MCQ and post-MCQ, showing no change. Closer examination revealed the limited information pertaining to the question in the scenarios, with only one visual reference tied to a specific intervention. When this is compared with questions that showed greater improvements, the relationship between content presented to the student and better understanding is strong. Not surprisingly, the more explicit the information, the better the improvements in the pre-MCQ and post-MCQ results. Wilson's (1996) strategies for developing problem-based learning are very much in line with the relationship between the simulation content and learning improvement.

Providing opportunities for the student to receive instruction and then applying that knowledge in both a direct actionable way and in the larger context, proved a favourable way for students to learn. Once the scenario was completed, specific feedback about those actions further enhanced the learning. Students were then given an opportunity to apply this learning again, but in a slightly altered setting, which was followed by more feedback. Finally, testing that knowledge can help students reflect on their learning.

Multiple-choice questions that showed the greatest improvements followed this process closely, using the presentation video, simulation actions and feedback, to instruct students. The key aspects identified in simulation design in relation to learning improvement are:

- Clear instruction towards new knowledge in an engaging and interesting way.
- Application of that knowledge in a practical and actionable way (simulations), using framing that allows students to picture application outside of the simulated environment (relevance).
- Feedback that is explicit and insightful, allowing students to reflect on their application and correct mistakes.
- Allow students to apply knowledge again (repeat simulation) with the insights from feedback, preferably in a slightly different setting to assist with application in the real world, and to maintain student interest.
- Final feedback may assist with further reflection and help with student satisfaction by confirming their improvement after completing the course.

The key steps can be arranged in a multitude of ways, but having all of these steps will greatly increase the effectiveness of the learning environment. These steps align well with scenario-based learning design (Aldrich, 2005, Herrington et al., 2010, Holzinger et al., 2009), but are not always incorporated throughout the whole development process. The five points above should guide each step in the design process.

What characteristics of the simulation align with improvements in the students' perceptions of their confidence with the subject matter? *(S3)*

The characteristics of the simulation that aligned with student improvements in confidence with the subject matter varied. The key learning outcomes required a number of interaction types to achieve all of them. An evaluation at the end of the simulation captured the overall student confidence data. Students rated their confidence before and after using a Likert scale from 1-5. The rating showed an improvement from 2.94 (SD ±0.84) before the program to 3.99 (SD ±0.65) after. The evaluation suggests students' confidence and competence improved in each of the broader areas, recognition of deterioration, management of the patient and performance during these difficult situations.

While nearly all multiple-choice content areas showed improvements, the research focused on question 11, which demonstrated the greatest improvements, making the potential reasons for this improvement more visible in the data. These improvements are most evident with the scenario feedback related to question 11. Although information was provided at every point in the program, the feedback explicitly described using the 'non-rebreather mask at 15L', (the answer to question 11). After receiving the feedback on completion of the first simulation, most students applied oxygen correctly in the second and third scenario. The second scenario was respiratory issue, so students were more likely to apply oxygen therapy early, which they did. In the third scenario the patient showed no visible signs of breathing issues. Students applied the correct oxygen, but much later in the eight-minute period. The correct response for all three scenarios is early application of oxygen. This highlights the impact that the simulation situation can have on the student's decisions. Considerations of how students might react to situational feedback (the patient showing signs of difficulty breathing) needs consideration when providing instructions and feedback outside of the simulation.

Further investigation of the oxygen question revealed a third of students who correctly applied oxygen in simulations, incorrectly answered the related post-MCQ question. Although very little of the content was ambiguous, the majority of these students chose the incorrect answer of 100% oxygen. The presentation content may have confused some students when it stipulated that patient oxygen levels should not be below 93%. Students may have chosen this answer as it was the only choice that contained a percentage value over 93%. While it may be hard to avoid such information overlaps, careful attention to question wording is very important to avoid confusion.

The characteristics that align well with student confidence are: scenario contexts that align well with the learning objectives (a respiratory patient teaching oxygen management), assessments (i.e. questions) that are carefully designed to avoid confusion and align with learning objectives, which are reinforced with scenario activities, and feedback that is clear and further reinforces learning objectives and helps students understand where they have made mistakes. During the design process, mapping learning objectives with interactions within the simulation (be it assessments, scenario content or feedback) should be done early and reviewed throughout the design and development process.

What characteristics of the simulation align with decreases in students' perceptions of their confidence with the subject matter? *(S4)*

Characteristics that reduced student confidence with the subject matter were minimal. There were no areas of the simulation that had a negative effect on the student's learning. There was one question in particular that seemed to show, at the very least, a neutral result. Question 8 described the needle gauge required for particular patients and many students showed no improvement in their understanding.

The content related to this question was only presented to students in the form of video (*IV cannula*), and was only seen if the students chose this intervention during the simulation. Interestingly, the students who saw the *IV cannula* video in the first scenario had the strongest correlation with answering correctly ($p<0.01$), with fewer and fewer students intervening with the *IV cannula* in future scenarios. Students were encouraged to see the video as each scenario feedback included the recommendation to insert *IV cannula* for the patient. Strangely, the number of *IV cannulas* inserted dropped with each scenario.

The correct answer for question 8 was patients with 'trauma and burns', something which students did not experience. Students were unable to make a connection with the correct answer and the needle gauge. Interestingly, only 3% of students chose the one answer they did experience in the simulation; the 'elderly patients', indicating that most knew this was not the correct answer. The majority of students answered the same for both pre-MCQs and post-

MCQs, which would suggest that the scenarios in this case had little to no impact on learning. When reviewing the presented content related to question 8, a number of areas were not addressed:

- There was no instruction in the presentation related to question 8.
- Students could therefore not apply the theory in the first scenario. The framing was not inherent to the answer for question 8, as the needle was not used on a burns victim, so there may have been difficulty picturing its application outside of the simulation environment.
- Feedback was included, but not explicit or insightful, without initial instruction. Students may have found it difficult to reflect on their application and correct mistakes.
- Students could apply knowledge again, in the next two simulations, but this did not occur. Perhaps feedback was difficult to put in context. Simulations might teach better if the simulation settings were similar, such as the burns victim, as this would assist with being more relevant to the student.
- Final feedback did reveal the correct answer to allow students to reflect on mistakes. Students may have felt dissatisfaction, as they were unlikely to know the correct answer given the limitations of the content shown to them. Students were unable to repeat scenarios, so information at this point could not help with learning via the simulation.

An important aspect of designing content is to carefully examine the questions and answers, in order to see that they are a good fit with the content. The adjustments must be made to either the content or the question to make sure they align constructively (Biggs & Tang, 2011). Better learning outcomes rely on students having the necessary access to information, so they can be instructed, and have the ability to apply the knowledge and reflect on the feedback given to them afterwards.

While student performance did not decrease for any questions, the characteristics that align with decreases in student confidence can be surmised from the student's experience with question 8. Decreases in confidence are likely to occur when: information given to the student is unclear or out of context with the scenarios, the scenario activity is misaligned with the assessment (i.e. the assessment, *needle gauge,* is contained within an unrelated activity, *IV cannula* video), students are confused or misled by the information, and whether feedback from assessments or scenario activity is confusing or unclear. Mapping the learning objectives to the activities in the simulation during the design process would help to avoid the issues that cause decreases in student confidence.

What was the student reaction to the simulation experience? *(S5)*

The students' reactions to the simulation experience were overwhelmingly positive, with a large number of students asking for more simulations. The majority of the comments represented experiences that were both enriching and positive. The open comments did, however, highlight some issues, mainly inadequate feedback, inaccuracies with the simulation, and some technical issues. Many students suggested changes to some of the interventions, saying they were too long, or that they would have left certain devices attached to patients. Alterations to the interventions, and the way the simulation handles them, can be easily implemented in future versions, making it both more realistic, and seem fairer to the student.

The Likert rated responses show that the majority of students found that the program enhanced and improved their knowledge, confidence and competence in patient deterioration. Nearly three quarters of students rated themselves as improving after the experience across all five areas; the highest increases being their confidence (79%) and competence (91%). Very few students showed a decrease in their rating, less than 2% for all, but 'perform emergency tasks' was 6% of students, and while still low, may have been higher due to students feeling their learning would not easily translate into real world performance. The ability to repeat the scenarios multiple times would help build a more automatic/systematic response to real world situations, making students feel this kind of practice would transfer better to the real world. The open text comments and Likert ratings are a valuable indicator for the areas where the simulation can improve, and essential in the development of future versions of the program.

The current simulation clearly provides a satisfactory experience for students. However, some improvements (as suggested in the open comments) could make this experience even better. A review of the types of engagements that appeal to students would improve the design process. This could be done prior to developing the simulation, but would be worth building into the design process to allow for changes to the system after students had used the simulation. Planning for changes after a simulation's creation would allow for a more dynamic development lifecycle, and improve the experience for students long term.

What features of the simulation need to be improved? ***(S6)***

There were a number of features of the simulation that need to be improved. Students provided suggestions in open comments that could be utilised to design a future version of the program. The comments also highlighted design flaws in the current methods. MCQ results show problem areas in the education capacity of the simulation, advocating for better instructional system design. Content creation also affected some educational aspects of the simulations down the development pipeline. The questions and answers from the multiple-choice needed to link with the content of the initial presentation and the simulation experience. If this relationship is not clear, students struggle to implement the new knowledge when applying and reflecting on that knowledge. Feedback received when completing a scenario should be explicit and help students to improve by providing feedback that students can associate with, and apply in future attempts. An example of this is to provide a more detailed feedback that highlights the errors made by the students, and how to correctly apply the content or techniques in question. This feedback would be dynamic and adjust with each attempt at the scenario. This feedback can help students improve their personal performance at a much faster rate by correcting only mistakes they made, and not overloading them with superfluous information. It also moves feedback closer to the fidelity of feedback received by the face-to-face First2Act program. Students mentioned that simulation feedback could be improved, but not one student mentioned that information was inadequate to answer the multiple-choice questions.

Other negative results varied between each scenario, such as medications, which showed a worsening of treatment with each scenario. Bed position improved from scenario 1 to scenario 2, but then worsened in scenario 3. Perhaps students may have been overloaded with information by the third scenario, or found it difficult to diagnose the shock condition from that scenario. Better feedback at the end of each scenario may offer a solution. If the feedback included information that might help the student to reiterate what they have learnt, it will help the student more accurately identify the correct course of action. Utilising the data captured regarding the order and time of the student's actions could make the feedback even more dynamic. Adequate analytical data-capturing is a requirement to make this level of dynamism work.

The numbers of students who incorrectly intervened in every simulation define the final area that could be improved. *Patient consultation*, specifically the *social history* of the patient, was a poor performing area with 41% of students never consulting a patient about their *social history* in any scenario. There are some factors that could have impacted this, but considering that this cost students no time it is interesting that students did not complete this. A few reasons may have caused this problem, and they outline some key flaws in the simulation design. First, students did not know that consulting the patient would add to their score, however, making this apparent to them may defeat the purpose as students may then do this just to improve their score. Second, although it cost students nothing to consult the patient, as the timer would pause, not all students may have realised this. Clearer instruction may have reduced misunderstandings. Despite this being more apparent with each scenario, the number of students who performed this intervention actually fell between the second and third scenarios. Students may not have considered it worthwhile for their 'real world' time when compared to the information they might gather from it. Lastly, students may not have thought it worthwhile to interact socially as it was not a real patient, and therefore the impact of being social was not as useful as it would be with a real patient. Although it is hard to say with certainty, all these points can play a part in the success or failure of learning non-critical treatments. These treatments need to be considered important by the student, and this can be done through making them more relevant. If the content of the *social history* reveals certain useful pieces of information, it may help students understand the importance of that task. Extra information was included in the social interventions, although feedback did not explicitly explain that a patients' *social history* was important. Perhaps students overlooked the benefit of this intervention. The final concern is that students should feel a connection to the patient. The more emotionally invested they are, the better chance you may have of transferring these non-critical treatments. If this can be achieved in a simulation then students might perform these tasks better with a real patient.

There are a number of areas for improvement that have been highlighted. A careful mapping of the key learning objectives and assessment criteria against content and feedback can assure that all learning material is adequately covered. Clearer feedback, which is also more dynamic to the student's needs, will help facilitate learning that is more effective. Finally, measurement methods, such as the multiple-choice questions, need to be mapped against the content in the presentation and scenarios, to make sure that they appropriately cover student learning objectives.

6.3 Revised Design Principles Based on Critical Aspects of Designing an Online Learning Simulation that Assists Nursing Students in Patient Diagnosis and Management

The design principles for simulation design for medical students act mostly as guidelines and considerations. While the project was largely successful, a few areas could be improved. The reasons for these oversights are described in the following paragraphs.

Project management failures occurred largely due to certain situations of miscommunication, and, in some cases, unexpected problems. However, communication was relatively good between the different fields of the team, which included nursing academics, technology developers and video production. This was mainly due to the close nature of the team. In this project, the team all worked for the same institution and they all worked in education. This made communication far less of an issue on the project, as they typically shared similar terminologies. However, some oversights did occur. The required five-year maintenance period was not achieved because of cost overruns, and it was not specified early on in development. Timeframes were tight due to earlier issues with the first developer who left the project, leaving less room for testing and experimenting with different technical solutions. The development difficulties were compounded by the content being created, well before a discussion of technical delivery had occurred. With any new project, it is difficult to predict problems in advance. Having a unified team with good support and the flexibility to adjust to changes helped the project overcome most issues.

Design failures were problematic, and a deeper understanding and alignment of learning objectives, content and simulation design would have avoided some of the problems. A clear and concisely mapped chart of how the learning objectives were to be addressed may have raised the team's awareness to some of the issues later made by students. More sophisticated feedback would have improved student learning, but was not built into the simulation. This was not resolved due to a combination of poor planning and lack of resources. The ability to repeat the scenarios was also requested by students, and would have greatly helped with student learning. Repetition was not considered as part of the learning design, and time did not allow for this added feature. Being able to repeat the simulations will no doubt be included in future versions for the First2Act program. Carefully looking at the learning objectives and cross-checking this with best practice for instructional system design would have helped identify these issues.

Some design decisions in regards to learning material lead to poor performance in multiple-choice questions. Creating content that utilises a constructionist approach to education will help to make sure that content included in the simulation aligns well with the specific goals of the learning objectives, namely the knowledge that students will be tested for. Question 8 lacked the supporting instruction to help students answer the question. While the multiple-choice quiz is not the main purpose of the First2Act program, it highlights the importance of being vigilant with learning tasks and supplying sufficient content to meet the needs of students.

A design model included here shows a combination of principles earlier discussed. The flow chart below shows the design process for a medical simulation. Not included in this process are the external factors, such as funding, and any variable initial steps that occur before a project can begin. This would likely impact criteria for success, including such things as learning objectives and the team selection *(Fig 6.2)*.

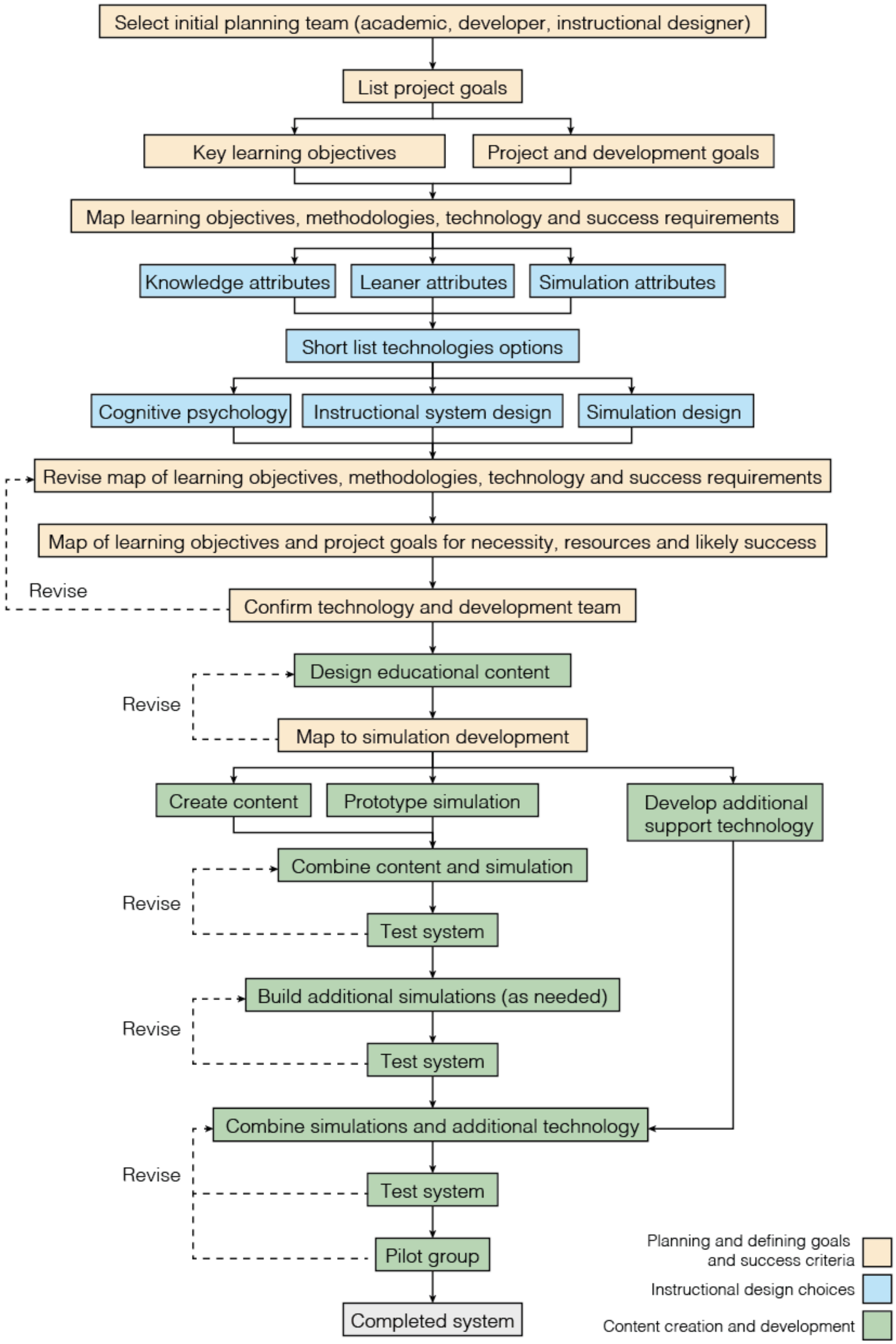


Figure 6.2 Development lifecycle for simulation development for educational purposes.

The development lifecycle defines the key steps involved with the creation of an educational simulation. The definition of key learning objectives and project and development goals is essential to achieving good results for the project. Choosing an appropriate learning structure and technology to match will improve the learning potential of the system. Revising the project as new issues arise, for management or in the testing phases, is critical to completion. When developing these systems it is difficult to factor all possibilities, however a clear vision for all team members improves the chance of success when problems arise.

The critical aspects of designing online learning simulations require instructional and simulation design to focus on the learning objectives. These objectives can be mapped to the assessment tasks, scenarios, and feedback, to help scaffold the information given to the students. Ideally it should be an authentic experience for the students, to be engaging and to help build student confidence in their abilities to practice what they have learned. Current methods of instructional design and online simulation development do not work together to achieve learning objectives, and the resulting learning simulation is often less effective than it otherwise might be. Combining the design processes will likely produce a simulation that is more focused and returns better learning outcomes for students.

6.4 Limitations

There were a number of technical limitations to this research design. Some of the content was created before the design of the artefact, limiting the scope of design choices and interactivity when choosing the delivery technology. The use of Adobe Flash limited the program to certain browsers and reasonably fast computers, as well the need for a reliable Internet connection. Many students worked through university computers to make sure the program would be accessible, and technical issues with Microsoft Internet Explorer could not be overcome.

Despite these technical limitations, a great deal of data was collected. Unfortunately, to analyse all aspects of the multiple-choice questions and related content was beyond the scope of this research. Many questions showed improvements, with varying types of content used and different kinds of interactions. It would be helpful to review all MCQs in an effort to find more connections between content and interactions and learning.

Other forms of data were difficult to extrapolate into a form that could be analysed. Click sequences were recorded from each student, and it was difficult to compare the sequences between students. Some analysis did occur for oxygen and medicine, however, analysis of other interventions may reveal much more about the way students use this particular system. A more thorough comparison of interaction patterns between top-performing students and lower-performing students was also beyond the scope of this research, and this could yield interesting results about different aspects of the simulation.

Unfortunately, it was also impossible to gain access to the face-to-face trial results data, which would have been helpful in establishing how the simulation performed by comparison. First2Act face-to-face would have assisted as a benchmark, in lieu of a control group, something that was also not possible for this research.

As a result of the limitations, analysis was restricted investigating the pre-MCQ and post-MCQ questions, which showed the most potential to reveal patterns. This moved the analysis to the investigation of other areas, such as *oxygen therapy* and *IV cannula* interventions. Error rates in the scenario results brought attention to *consulting patients*, *medications* and *IV cannula* interventions. As there were 32 different interventions, there is a great deal more this data could reveal.

6.5 Future Research

There are number of areas where this research could be furthered. Data collection was quite extensive and a deeper understanding of the interactions that affect learning would be an asset to future interaction designers. There are a number of guidelines available for good design of learning simulations, but few are evidence based with a specific focus on learning outcomes. A more subtle understanding of how students use different arrangements of an interface and how that influences learning would be beneficial. Design methods, such as arranging buttons vertically or horizontally, could change students potential to learn, or even their decision-making. It would be worth investigating how much of a difference this would actually make to ascertain the importance of such precise design decisions.

In future studies it would be interesting to examine how much of the learning achieved by the simulations was retained. Experiential learning is regarded as a memorable way to learn. However, a comparison between the predicted curve of knowledge retention and how simulations differ would be an interesting measure of success. Running a number of students through the program a second time, months later, could reveal some evidence of how effective the program performs over the long-term. Many students commented that they would like to be able to repeat the program as practice for exams.

Finally, the simulation clearly shows evidence of students learning. However, to be able to investigate the impact once those students enter the workforce would be an excellent demonstration of the cost/benefit of such systems in industry. While this is well beyond the scope of this research, the true benefit to this type of education would be truly felt, if it translated to better care of patients.

6.6 Summary

The critical features in developing an educational simulation for the medical context can be defined by the features that achieve highest educational outcomes, are most satisfying and engaging for students, and are integral to the success of projects goals and its completion.

The study revealed that the key features that improved student learning consisted of elements where students were presented with comprehensible information, and were asked to apply that learning in the simulation, and reinforced the learning by providing the student with reflective feedback. The best learning outcomes occurred when the information was closely related to the content of the simulation, whether it was relevant across all simulations, and whether it was reiterated through feedback. When the message was clear it reached more students. Conversely, information that was not as clear or relevant in the simulations, or not reinforced by feedback, showed little to no impact on learning outcomes. In First2Act there were no adverse educational impacts, but it is likely that if the information was wrong or ill conceived, simulations could mislead students. In medical education great care is taken to prevent misinforming students, however, designers of other industries should endeavour to avoid these kinds of problems.

Although these factors returned the best learning results, they did not necessarily achieve high user satisfaction. Content created in an engaging way was educational, but in a more qualitative way. Students rated the experience of treating the patient in the simulation environment as most rewarding. The actors' skills in appearing realistically sick, combined with the patient's worsening condition, and the timer pressing students to act quickly, helped students appreciate the urgency of these situations. Many students were grateful for the chance to test their skills under pressure. Building engaging content is what hooks students in and draws them into a believable, "more real" experience. A more engaging experience is both more satisfying, and can improve teaching capacity of simulations. Factors that were educational and achieved high user satisfaction combined both comprehensive information, and high-level engagement.

Interestingly, students gave little feedback on the educational value of the multiple-choice quizzes or presentation, and while it is important to structure these correctly, the scenarios were the most influential parts of the program. However, a correctly designed quiz or presentation could also be quite engaging, and should be designed in such a way where appropriate.

Educational simulation projects often achieve good results; however creating them requires abundant resources. Both student engagement, as well as education, needs to be considered to develop educational simulations as effectively as possible. Carefully outlining the intended learning objectives and project goals is essential to making sure that the development is on track. When designing simulations, cognitive psychology, instructional system design and simulation design should be taken into account. To meet the goals and achieve a successful educational simulation, the educator, developer and instructional designer must work together to choose the appropriate design methodology that delivers an informative, engaging and rewarding experience for students.

Current simulation design methods do not place enough emphasis on meeting learning objectives. Current instructional design methods typically do not include a thorough grasp of the techniques required to make an engaging online simulation. The critical aspects of designing online learning simulations require instructional design and simulation development to occur simultaneously, with the focus on achieving the learning objectives and secondarily the other project success criteria. These objectives and criterion should be clearly defined early on in the process, and be mapped to the assessment tasks, scenarios and feedback. Learning is likely to occur in even moderately well designed simulations, however learning outcomes can be greatly improved by adhering to guidelines outlined in this research. To create a simulation that helps students reach their best learning potential, it should include well-structured learning material, assessments, authentic learning experiences such as scenarios, and feedback that informs the student and can be applied in future attempts of the system. The simulation content must be designed to convey the learning objectives and be clear, concise and remain in context to avoid confusing the student. Using a design process that combines instructional design qualities with the simulation development lifecycle will produce an online learning simulation that can return better learning outcomes for students.

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Appendices

(A) Demographics Questionnaire

<table>
<tr><th colspan="5">Participant demographic form</th></tr>
<tr><td>Your sex? (please tick one)</td><td colspan="4">☐ Female ☐ Male</td></tr>
<tr><td>Your age?</td><td colspan="4">…………………..Years</td></tr>
<tr><td>Your course of university of study? (Please tick one)</td><td colspan="4">☐ Bachelor of Nursing
☐ Bachelor of Nursing/Bachelor of Midwifery
☐ Bachelor of Nursing/Bachelor of Public Health and Health Promotion
☐ Bachelor of Nursing/Bachelor of Applied Science (Psychology)
☐ Bachelor of Nursing/Bachelor of Commerce
☐ Diploma of Nursing
☐ Other (please name): ……………………………………………………….</td></tr>
<tr><td>What year of your course are you currently studying?</td><td>☐ Year 1
☐ Year 2
☐ Year 3
☐ Year 4</td><td colspan="2">In which semester or trimester are you currently enrolled? (please tick one)</td><td>☐ Semester 1
☐ Semester 2
☐ Trimester 1
☐ Trimester 2
☐ Trimester 3</td></tr>
<tr><td>Have you ever worked as an employee in a nursing or healthcare related field (eg., EN, PCA)</td><td colspan="4">☐ No
☐ Yes – <u>If yes</u>, what was your role and how many years did you work in that role?
…………………………………………………………………………
……………………………………………………………………………….</td></tr>
<tr><td rowspan="5">Where have your clinical placements been during your nursing education? (please tick any)</td><td>Aged care</td><td></td><td>General wards</td><td></td></tr>
<tr><td>Community</td><td></td><td>Mental Health</td><td></td></tr>
<tr><td>Critical / intensive care</td><td></td><td>Operating Theatre</td><td></td></tr>
<tr><td>Emergency</td><td></td><td>Rehabilitation</td><td></td></tr>
<tr><td>Other (please specify)</td><td colspan="3"></td></tr>
<tr><td>Have you ever cared for a patient whose condition suddenly deteriorated such that a medical emergency or Medical Emergency Team (MET) was</td><td colspan="4">☐ No
☐ Yes –If yes, what was your role?
☐ Observer ☐ Recorder/scribe
☐ First responder ☐ Calling MET
☐ None
Comments ……………………………………………………………………</td></tr>
</table>

called?	

(B) Multiple-choice Quiz

Patient Deterioration - ANSWERS

1.	A patient who is in hypovolaemic shock will have	
	a.	Normal capillary refill
Correct	b.	Cold clammy skin
	c.	Facial flushing
	d.	Warm dry hands
Feedback: Hypovolaemic shock is characterized by failure of the circulatory system to maintain adequate perfusion of the vital organs. The peripheries shut down in an attempt to maintain circulation to the vital organs.		

2.	A patient with hypoxia is likely to be	
Correct	a.	Confused
	b.	Pink
	c.	Happy
	d.	Hot
Feedback: the brain requires large amounts of oxygen to function. Confusion is likely when the patient is hypoxic.		

3	Slow capillary refill is a sign of	
Correct	a.	Vasoconstriction and poor peripheral perfusion
	b.	Malnutrition and dehydration
	c.	Warm hands and feet
	d.	Reduced concentrations of oxyhaemoglobin
Feedback: vasoconstriction and poor peripheral perfusion tends to occur as a compensatory mechanism in 'shocked' patients with blood concentrated to the central organs.		

4	The pulse can be palpated …	
	a.	Every time the atria contacts.
	b.	When a vein is close to the surface of the skin.
	c.	Every time the left ventricle contacts.
Correct	d.	When an artery is close to the surface of the skin
Feedback: The pulse can be palpated when an artery is close to the surface of the skin. Contraction of the left ventricle may not cause a palpable pulse.		

5	A normal heart rate for an adult at rest is	
	a.	60-80 bpm
Correct	b.	60-100 bpm
	c.	60-90 bpm
	d.	60-110 bpm
Feedback: The average rate is approximately 60-100 bpm but account must be taken of the individual patient's age, health status and medications.		

6	Pulse oximeters may be unreliable when	
		tissue perfusion is poor the patient is wearing nail varnish haemoglobin is 100% saturated measured on the ear lobe the patient has a cold haemoglobin levels are low digits are cold the patient is elderly
Correct	a.	1,2 & 7
	b.	2, 3 & 6
	c.	1, 4 & 8
	d.	2, 5 & 7
Feedback: Pulse oximeters may be unreliable where tissues perfusion is poor, where the patient is wearing nail varnish and where the digits are cold. Other factors such as the patient's age, position of measurement or the level of haemoglobin will not make them unreliable.		

7.	When assessing a patient's breathing	
		1. Assess for 30 seconds 2. look for chest movements 3. use a mirror to check for exhaled air 4. listen for breath sounds 5. feel for exhaled air on your cheek 6. always remove dentures
	a.	1, 2 & 4
	b.	2, 3 & 5
Correct	c.	2, 4 & 5
	d.	1, 4 & 6
Feedback: Look, listen, and feel for normal breathing for no more than 10seconds. Well fitting dentures do not need to be removed and will help maintain the shape of the mouth.		

8	A 14-16 gauge needle is most likely to be used for	
	a.	Elderly patients
	b.	Paediatric patients
	c.	Inserting in the back of the hand
Correct	d.	Trauma or burns patients
Feedback: a large bore needle is required to rapidly administer large volumes of fluids to patients who are haemodynamically unstable		

9	Which of the following is NEVER compatible with a cardiac output:	
	a.	Supraventricular tachycardia
	b.	Ventricular tachycardia
	c.	Atrial fibrillation
Correct	d.	Ventricular fibrillation
Feedback: In order to produce a cardiac output, the electrical activity of the heart must cause the ventricles to contract in an orderly manner.		

10	A.V.P.U. stands for?	
	a.	Alert, Visual, Peripheral, Unconscious
	b.	Altered, Verbal, Pain, Unresponsive
	c.	Anxious, Violent, Paranoid Unsettled
Correct	d.	Alert, Voice, Pain, Unresponsive
Feedback: This is a quick way of assessing patients' level of consciousness identifying if they are Alert, responding to Voice, Painful stimuli, or are Unresponsive		

11	When using a non-rebreath mask	
	a.	40% O2 is delivered to the patient
	b.	100% O2 is delivered to the patient
	c.	The reservoir bag should not be inflated prior to placing on the patient's face
Correct	d.	O2 flow rates of approximately 15 litres a minute are required in adults
Feedback: When using a non-rebreath mask oxygen delivery rate is likely to be greater than 90%, but as there is air mixing it can never be 100%. The reservoir bag should be inflated prior to placing on the patients face and the flow rate set to approximately 15l/min		

(C) Grade Weighting for Interactive Scenarios

Weighting of tasks for feedback loop – FINAL

		Cardiac	Respiratory	Shock
Bed position	Upright	2	2	0
	Semi-upright	1	1	0
	Orthopneic	0	2	0
	Flat	0	0	1
	Flat with legs elevated (Trendelenberg)	0	0	2
Maximum score		2	2	2
Oxygen therapy	Non-rebreather @ 14L/min	2	2	2
	Hudson @ 8L/ min	1	1	1
	Nasal prongs @ 4 L / min	0	0	0
Maximum score		2	2	2
Emergency call (only Once)	0-3 minutes	0	0	0
	Between 3-6 minutes	2	2	2
	6-8 minutes	1	1	1
Maximum score		2	2	2
Actions/ investigations (only once)	(ecg) ECG	1	0	0
	(IV) Ask Dr to insert IV cannula	1	1	1
	Ask Dr to take bloods	1	1	1
	Ask Dr to increase fluids	0	0	1
	(stethoscope) Chest auscultation	1	2	0
	Bowel sounds	N/A	N/A	1
Maximum score		4	3	4
Patient history	Medical	1	1	1
	Social	1	1	1
	Presenting complaint	1	1	1
		3	3	3

		Cardiac	Respiratory	Shock
Vital signs	(chart) Heart rate x 1	1	1	1
	Heart rate x 2	2 (maximum score)	2 (maximum score)	2 (maximum score)
	(chart) Respiratory rate x 1	1	1	1
	Respiratory rate x 2	2 (maximum score)	2 (maximum score)	2 (maximum score)
	(chart) Blood pressure x 1	1	1	1
	Blood pressure x 2	2 (maximum score)	2 (maximum score)	2 (maximum score)
	(chart) Oxygen saturation x 1	1	1	1
	Oxygen saturation x 2	2 (maximum score)	2 (maximum score)	2 (maximum score)
	(chart) Capillary refill time (CRT)x 1	1	1	1
	Capillary refill time (CRT) x 2	1 (maximum score)	1 (maximum score)	2 (maximum score)
	(chart) Temperature x 1	1 (maximum score)	1 (maximum score)	1 (maximum score)
	(chart) Pain score x 1	1	1	1
	Pain score x 2	2 (maximum score)	2 (maximum score)	2 (maximum score)
	(chart) Conscious state x 1	1	1	1
	Conscious state x 2	1 (maximum score)	1 (maximum score)	2 (maximum score)
Maximum score		13	14	15
Medications (only once)	Glyceryl Trinitrate 300-600mcg sublingually	1	0	0
	Aspirin 300mg orally	1	0	0
	Morphine 2.5-5mg IV	1	0	1
	Metoclopramide 10mg IV	1	0	1
	Salbutamol 5mg nebulised	0	1	0
	Ipratropium bromide 500mcg nebulised	0	1	0
Maximum score		4	2	2
Maximum total score		30 (27 clicks)	28 (24 clicks)	30 (27 clicks)

(D) Feedback Statements for Interactive Scenarios

CARDIAC SCENARIO Maximum score is 30; Band 1 (fail) 0-9; Band 2 (borderline) 10-19; Band 3 (distinction) 20 or more.

Distinction score (20 or more)

“Congratulations you’ve achieved a score of (20-30)/30 which is a ‘distinction’ in this scenario. This patient is having an AMI and it is important to sit him upright in the bed. In this scenario, oxygen therapy should be delivered initially by a non-rebreather mask at a high flow rate (15 L/minute) to maintain oxygen saturation levels at between 94-98%. Assistance from others is required early and all vital signs should be recorded at frequent intervals whilst observing for trends of deterioration. Ascertaining a full history is important including presenting condition, past and social history. Nurse led investigation/actions should include an ECG, and a respiratory assessment. A doctor will request IV cannulation and blood tests (e.g. cardiac enzymes). Prescribed medications will include Glyceryl Trinitrate 300-600mcg sublingually, Morphine 2.5-5mg IV, Metoclopramide 10mg IV and Aspirin 300mg orally. A useful mnemonic to help you remember some of these treatments for an AMI is MONA (Morphine, Oxygen, Nitrates and Aspirin)”

‘Borderline’ score (10-19)

“Well done but you could improve somewhat as you achieved a score of (10-19)/30 which is ‘borderline’ in this scenario.(repeat above from “This patient”

‘Fail’ score (0-9)

“Your performance was not good in this scenario - you achieved a score of (0-9)/30 which is a ‘fail’. ....(repeat as above)

RESPIRATORY SCENARIO Maximum score is 28; Band 1 (fail) 0-9; Band 2 (borderline) 10-18; Band 3 (distinction) 19 or more.

Distinction score (19 or more)

“Congratulations, your score was (19-28) /28 which is a ‘distinction’ in this scenario. This patient has an acute exacerbation of COPD, brought on by a chest infection. It is important to either sit him upright in the bed or in the orthopneic position. All patients with acute respiratory distress should be given oxygen via a non-rebreather mask at a high flow rate (15 L/minute). If the COPD patient has hypercapnic respiratory failure (i.e. a ‘CO_2 retainer’) and is critically ill, high flow oxygen can be given initially, aiming for a target oxygen saturation of 88-92% and closely monitoring the patient for worsening respiratory failure. Assistance from others is required early and all vital signs should be recorded at frequent intervals, including respiratory rate, capillary refill time and temperature. Ascertain a full patient history. Nurse led investigation/actions should include a respiratory assessment. A doctor may request IV cannulation and blood tests (e.g. arterial blood gases; blood cultures). Prescribed medications will include Salbutamol 5mg and Ipratropium bromide 500mcg via a nebuliser."

Borderline score (10-18)

"Well done, but there is room for improvement. Your score was (10-18) /30 which is 'borderline' in this scenario.......... (repeat as above from "this patient"

'Fail' score (0-9)

"Your performance was not good in this scenario - you achieved a score of (0-9)/30 which is a 'fail'...................(repeat as above)

SHOCK SCENARIO Maximum score is 30; Band 1 (fail) 0-9; Band 2 (borderline) 10-19; Band 3 (distinction) 20 or more.

Distinction score (20 or more)

"Congratulations you've achieved a score of (20-30)/30 which is a 'distinction' in this scenario. This patient is in hypovalaemic shock from a ruptured appendix and it is essential to lay him flat in the bed, elevating his legs if possible. The patient requires high flow oxygen therapy delivered by a non-rebreather mask at 15 L/minute. Call for help early. Monitor all vital signs frequently, including capillary refill time and conscious state, observing for trends that indicate further deterioration. It is important to obtain a full history including presenting condition, past and social history. An abdominal assessment should be performed to assess for pain and bowel sounds. A main focus of treatment is fluid replacement. A doctor will request a second large-bore cannula and an IV fluid bolus, and will order blood tests such as cross-matching and a full blood count. Prescribed medications will include Morphine 2.5-5mg IV and Metoclopramide 10mg IV.

'Borderline' score (10-19)

"Well done but you could improve somewhat as you achieved a score of (10-19)/30 which is a 'borderline' in this scenario........(repeat as above from "This patient is in…..")

'Fail' score (0-9)

"Your performance was not good in this scenario - you achieved a score of (0-9)/30 which is a 'fail'..........(repeat as above)

(E) Evaluation and Open Comments Questionnaire

The FIRST²ACT Web program:	Not at all				To a large extent
Was relevant to my needs	1	2	3	4	5
Was appropriate to my level of training	1	2	3	4	5
Provided effective feedback	1	2	3	4	5
Was challenging without being threatening	1	2	3	4	5
Enabled me to integrate theory into practice	1	2	3	4	5
Stimulated my interest in the topic	1	2	3	4	5
Encouraged me to think through a clinical problem	1	2	3	4	5

FIRST²ACT Evaluation. –

Please tick the most appropriate number:

My perceived ability to:	Before this session					After this session				
	Not at all				To a large extent	Not at all				To a large extent
Recognise a deteriorating patient	1	2	3	4	5	1	2	3	4	5
Manage emergency priorities	1	2	3	4	5	1	2	3	4	5
Perform emergency tasks	1	2	3	4	5	1	2	3	4	5
My overall:	Before this session					After this session				
Confidence level:	1	2	3	4	5	1	2	3	4	5
Competence level:	1	2	3	4	5	1	2	3	4	5

Please add any other comments or suggestions
For example - what were the key things you learnt from this program? How could the program be improved?

(F) Pre and Post Multiple-choice Quiz Results (Grouped Values)

Case Processing Summary

	PRESCORE	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
POSTSCORE	2.00	1	100.0%	0	0.0%	1	100.0%
	3.00	1	100.0%	0	0.0%	1	100.0%
	4.00	6	100.0%	0	0.0%	6	100.0%
	5.00	18	100.0%	0	0.0%	18	100.0%
	6.00	54	100.0%	0	0.0%	54	100.0%
	7.00	93	100.0%	0	0.0%	93	100.0%
	8.00	87	100.0%	0	0.0%	87	100.0%
	9.00	68	100.0%	0	0.0%	68	100.0%
	10.00	31	100.0%	0	0.0%	31	100.0%
	11.00	8	100.0%	0	0.0%	8	100.0%

(G) Definition of Terms

Term	Definition
F2A	First2Act Web Online Program
IT	Information technology
POV	Point Of View: the angle of a video camera that represents looking through the viewers eyes
ECG	Echo Cardiogram: Graph of the heart beat of a person
PHP	A server-side scripting language designed for web development to create dynamic web pages
Wordpress	Website development tool allowing for creation of a website with a content management system, and the ability to install plugins to add to the functionality of the website
MySql	A relational database management system, using structured query language

(H) MCQ Scores, Scenario Scores and Scenario Click Counts

To compare the pre and post MCQ test scores with the simulation scores and click counts correlations between them must be justifiable. The following table notes strong correlations between Pre and Post of (.643) at significance of 0.01. A predictable result given that the pre and post MCQ test questions were identical. More interestingly is the connections between the three scenarios and the pre and post MCQ scores. With significance of 0.01 for all correlations, the first scenario was slightly more correlated with the pre-MCQ than the post with a change from 0.211 to 0.204. The second and third scenario changed from 0.165 to 0.201 and 0.214 to 0.257 for pre and post MCQ respectively. Second and third scenarios had a stronger correlation with the post MCQ test. There is clearly a strong connection between scores obtained between MCQ and the simulation scenarios.

Correlations

		Pre-MCQ score	Post-MCQ score	Scenario 01 score	Scenario 01 clicks	Scenario 02 score	Scenario 02 clicks	Scenario 03 score	Scenario 03 clicks
Pre-MCQ score	Pearson Correlation	1	.643**	.211**	.147**	.165**	.044	.214**	.128*
	Sig. (2-tailed)		.000	.000	.005	.002	.401	.000	.014
	N	367	367	367	367	367	367	367	367
Post-MCQ score	Pearson Correlation	.643**	1	.204**	.096	.201**	.057	.257**	.139**
	Sig. (2-tailed)	.000		.000	.067	.000	.274	.000	.008
	N	367	367	367	367	367	367	367	367
Scenario 01 score	Pearson Correlation	.211**	.204**	1	.502**	.547**	.314**	.469**	.357**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000
	N	367	367	367	367	367	367	367	367
Scenario 01 clicks	Pearson Correlation	.147**	.096	.502**	1	.282**	.480**	.302**	.498**
	Sig. (2-tailed)	.005	.067	.000		.000	.000	.000	.000
	N	367	367	367	367	367	367	367	367
Scenario 02 score	Pearson Correlation	.165**	.201**	.547**	.282**	1	.524**	.572**	.454**
	Sig. (2-tailed)	.002	.000	.000	.000		.000	.000	.000
	N	367	367	367	367	367	367	367	367
Scenario 02 clicks	Pearson Correlation	.044	.057	.314**	.480**	.524**	1	.357**	.627**
	Sig. (2-tailed)	.401	.274	.000	.000	.000		.000	.000
	N	367	367	367	367	367	367	367	367
Scenario 03 score	Pearson Correlation	.214**	.257**	.469**	.302**	.572**	.357**	1	.637**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000
	N	367	367	367	367	367	367	367	367
Scenario 03 clicks	Pearson Correlation	.128*	.139**	.357**	.498**	.454**	.627**	.637**	1
	Sig. (2-tailed)	.014	.008	.000	.000	.000	.000	.000	
	N	367	367	367	367	367	367	367	367

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

(I) Chi-square Tests for Prior Industry Experience of Students Based on Response in Demographics Questionnaire

Prior experience and pre-MCQ test scores

Pre-MCQ score	**Prior industry experience**	**No prior industry experience**		**P**
>7	96	98	194	0.610205264
<=7	81	92	173	
Mean = 7.63	177	190	**367**	

Expected	93.5640327	100.4359673	194
	83.4359673	89.5640327	173
	177	190	**367**

Prior experience and scenario one scores

Scenario one scores	**Prior industry experience**	**No prior industry experience**		**P**
>18.6	103	92	195	0.060879276
<=18.6	74	98	172	
Mean = 18.60	177	190	**367**	

Expected	94.04632153	100.9536785	195
	82.95367847	89.04632153	172
	177	190	**367**

(J) Chi-square Tests for Pre-MCQ Questions and Scenario Interventions and Correctly Answering the Related Post-MCQ

Comparison of question 5 & correct heart rate interventions for scenario 2 & 3 for students who answered pre-MCQ question incorrectly

Post-MCQ Question 5	Correct intervention for Scenario 2 or 3	No scenario intervention		P
Correct answer	49	0	49	0.23
Incorrect answer	33	1	34	
	82	1	**82**	**CHI**
				1.4588
Expected	48.41	0.59	49	
	33.59	0.41	34	
	82	1	**83**	

Comparison of question 8 & correct needle interventions for scenario 2 & 3 for students who answered pre-MCQ question incorrectly

Post-MCQ Question 8	Correct intervention for Scenario 2 or 3	No scenario intervention		P
Correct answer	10	6	16	0.50
Incorrect answer	54	22	76	
	64	28	**92**	
				CHI
Expected	11.13	4.87	16	0.4566
	52.87	23.13	76	
	64	28	**92**	

(K) Invitation email for the First2Act Online Training Program

You have been invited to participate in the First2Act Web program.

This is an eight step program and will require you to answer a number of short questionnaires, watch a short presentation and run through three interactive video scenarios. Once you have completed the program you will receive a certificate of participation.

As you work through each scenario you can choose nursing and medical interventions in order to manage your patient. Each task will take time so choose wisely. However whenever you talk to the patient the clock will freeze, as we know that tasks are done simultaneously in the clinical setting. You will only be able to attempt each scenario once.

When you log in you may be presented with a user-profile page. To move back into the website, click the button in the upper left 'First 2 Act Web', and choose 'visit site'.

Your user name and password are below.

- Username: test-f2a
- Password: 0X7guAVoB0Tb
- Login at: http://first2actweb.com/wp-login.php

If you have any technical difficulties please contact Ruben Hopmans on [redacted] for assistance.

We hope you find the program useful and look forward to your feedback,

With thanks
First2Act Web Team

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100 Clyde Road, Berwick, VIC 3806
[redacted]
P: PO Box 1071, Narre Warren, VIC 3805

(L) Example of Click Log data collected

Start8:05^bed_position~upright~485^patient_history~current_condition~455^emergency_call~emergency_call~448^vitals~respiratory_rate~431^vitals~oxygen_saturation~415^vitals~blood_pressure~400^vitals~heart_rate~362^vitals~temperature~354^vitals~conscious_state~345^vitals~pain_score~342^vitals~capillary_refill_time~322^medications~morphine~289^oxygen_therapy~hudson~270^action_investigations~chest_auscultation~243^action_investigations~ecg~219^bed_position~semi_upright~158^action_investigations~chest_auscultation~141^oxygen_therapy~hudson~82