The Role of Mobile AR in Facilitating Nursing Independent Learning: The Student Experience

by

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Computer Science

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DEDICATION

To whom my heart belongs;

My parents and brothers,

My loving husband Omar Bawahb,

My adorable daughter Rose.

I dedicate this work to you and I believed, it has made you all proud.

DECLARATION

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. I hereby declare that, except where acknowledged, the work in this thesis has been composed by myself and has not been submitted elsewhere for the purpose of obtaining an academic degree.

Ebtehal Quqandi

Signature: ____________________________

Date: _______________________________

PUBLICATIONS

The published conference papers from this PhD thesis as follows:

- Quqandi, E. and Joy, M. (2018). Mobile Augmented Reality In Educational Environments. In: The 4th International AR and VR Conference, MMU Business School, Manchester, UK, 21-22 Jun 2018.

- Quqandi, E. , Joy, M., Rushton, M. and Drumm, I. (2018). Mobile Augmented Reality In Nursing Educational Environments. In: 10th Computer Science and Electronic Engineering Conference (CEEC), Colchester, UK, 19-21 Sep 2018. Published in: 2018 10th Computer Science and Electronic Engineering (CEEC) pp. 266-269. ISBN 9781538672761. doi:10.1109/CEEC.2018.8674182.

- Quqandi, E., Joy, M. and Drumm, I. (2020). Theoretical Framework For Shifting To Self-Regulated Learning Skills In Nursing Education. In: WEI International Academic Conference on Education, Teaching, and Learning, Barcelona, Spain,11-13 Feb 2020.

- Quqandi, E., Joy, M. and Drumm, I. (2020). AR Virtual Patient and Interactive Self-assessment in a Nursing Clinical Lab. In: The 6th International AR and VR Virtual Conference, University institute of Lisbon, Portugal, 19-20 Nov 2020.

ABSTRACT

Augmented Reality (AR) is a new technology that creates virtual extra layers on a physical object. It allows bringing digital information into the real environment by blending those two worlds. Interacting with digital content is a unique AR feature that offers new learning opportunities integrated with mobile applications. Smartphone devices can be utilised as AR tools to support interactive learning. Previous research has reported multiple benefits of using mobile AR as a learning tool, including enhancing content understanding, improving long-term memory retention, and increasing student motivation.

There are several potentials for utilising AR in the context of nursing education, such as promoting independent learning and facilitating a student-centred learning approach. Comparing to traditional education, the increased use of blended learning in healthcare and nursing education requires students to take more responsibility for their learning. Thus students' independent learning skills have become increasingly important. However, there is a lack of studies focusing on AR technology and independent learning. This research addresses this gap, aiming to investigate the feasibility of utilising AR technology to facilitate independent learning of nursing students while acquiring clinical skills.

In this research, a design science research methodology was adopted, consisting of three phases. The first phase – problem identification – reviewed the literature and undertook an exploratory study. The literature revealed that the ability of AR to allow students to be immersed in a realistic experience has attracted educators to use this creative way of learning. Indicating the ability of AR to replace traditional teaching methods, it does this by encouraging self-directed learning between students and supporting student-centred learning (SCL). In SCL, the teacher's role is as a facilitator who will enable students to learn independently and individually, while the learners are more responsible for their education. AR helps students to control their learning at their own pace and location.

Moreover, the exploratory study investigated the current learning approach in terms of supporting independent learning, and 108 nursing students from The University of Salford answered an online questionnaire about their current learning. The results showed that the current learning environment is less supportive of independent learning due to many environmental obstacles, such as lack of feedback, accessibility issues, and lack of realism of manikins in clinical labs.

The second phase – solution design – proposed a novel learning AR platform called Nursing Mobile Augmented Reality (NMAR), and the learning activities were designed based on self-regulated learning theory to overcome the current approach limitations. Learning with NMAR introduces a new learning strategy, aiming to enhance students' independent learning by adding

interactive self-assessment. Utilising NMAR allows students the freedom to discover the solution independently and activate their learning.

Lastly, the third phase – evaluation – included an experimental lab study, where the NMAR learning environment was deployed to create an overall positive user experience which might motivate the students to be independent learners. A novel NMAR platform to support nursing students was used individually by 34 students at The University of Salford, and both quantitative and qualitative data were collected from the students via questionnaires, screen recordings and semi-structured interviews. The quantitative data were looked at the NMAR aspects, while the qualitative data explored the users' thoughts and perceptions about their experiences with NMAR. Evaluating the platform, understanding the users' perception and comparing the current and proposed learning approaches together provide a deeper insight into the comprehensive user experience.

The quantitative findings showed statistically significant differences in perceived usefulness scores between the current and NMAR approaches. The qualitative findings confirmed that the NMAR platform facilitates the self-regulated learning process greater extent than does the current approach.

Accordingly, the findings of this research revealed that the proposed NMAR learning approach positively enhanced the students' learning experience while acquiring clinical skills. The results confirmed that AR has a positive role in facilitating independent learning. Thus the research findings are expected to help nursing educators and policymakers to understand the feasibility of adopting AR technology in facilitating independent learning to support nursing education inside and outside the classroom.

Furthermore, academia can use the proposed NMAR learning approach as relevant groundwork to initiate other related studies, which might help to fill the gap in the AR learning area.

ABBREVIATIONS

AR	Augmented Reality
VR	Virtual Reality
MR	Mixed Reality
MAR	Mobile Augmented Reality
HCI	Human-Computer Interaction
HMD	Head Mounted Display
SRL	Self-Regulated Learning
SDL	Self-Directed Learning
SCL	Student-Centred Learning
TCL	Teacher-Centred Learning
CSL	Clinical Skills Laboratory
PBL	Problem-Based Learning
ECG	Electrocardiogram
IBSE	Inquiry-Based Science Education
NMAR	Nursing Mobile Augmented Reality
DN	Digital Native
VCTRS	Vuforia Cloud Target Recognition System

"If you control the code, you control the world. This is the future that awaits us."

-MARC GOODMAN

CHAPTER 1

1. INTRODUCTION

This chapter identifies the problem that motivates the study and provides a research overview, the research questions and objectives that present the basis for this research and thesis. It also presents a brief outline of the thesis's chapters.

1.1. Background

Nowadays, the world is becoming smarter than before. Smart devices surround us and people depend on them in every aspect of their lives. Smart devices have the primary advantage of providing access to the internet anytime, anywhere, and for any purpose (Kwon et al., 2013). Because of this evolution, brilliant innovations have been created which can be used to change the structure of the established traditional learning methods to an enhanced application of modern technologies.

Where the notion of mobility is not restricted to students being mobile, the educators and learning resources are also not tied to a specific location (Alrasheedi & Capretz, 2015)**.** Due to the massive growth and acceptance of mobile technologies within all levels of society, educators should start adopting mobile learning in their teaching process (Valk et al., 2010). In nursing education, there is evidence that mobile learning has the potential to facilitate a new way of learning allowing, "in-time" learning activities (Willemse et al., 2019).

In terms of technology, **Extended reality (XR)** is an umbrella term that covers Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and everything in between. XR refers to any computer technology that combines physical and virtual worlds to create fully immersive experiences. This research will only cover AR technology, and the term Mobile AR (MAR) refers to AR applications running on handheld devices such as smartphones and tablets.

Augmented Reality (AR) is a new technology that creates extra virtual layers on a physical object. It allows adding digital information into the real environment by blending those two worlds (Lee, 2012). AR is offering new learning opportunities, integrated with mobile applications. Smartphone devices can be utilised as AR tools to support interactive learning. Increasing interactivity specified as an individual AR benefit introduces new ways of interaction between learner and learning tools (Diegmann et al., 2015). Akcayir & Akcayir (2017) stated that the most preferred AR device in education is a handheld device which functions as a content delivery tool. The reasons that mobile devices offer an ideal platform for AR applications include that they are cost-effective and easy to use.

Additionally, the possibility of using AR in learning and training has become more straightforward than before. This is a result of the integration between computer and mobile technologies, information and communication technologies, and network infrastructure and wireless services (Lee, 2012). In the nursing context, most of the nursing students use smartphone devices as a technological tool for information searching while learning (Nguyen et al., 2016).

Researchers have argued that using technology in the educational process itself is not significant if it is not clearly supporting meaningful learning. The portability features of Mobile AR (MAR) applications facilitate meaningful learning by allowing students to "make on-the-spot inquiries" (Zhu et al., 2015). There are multiple benefits of using AR as a learning tool in the education process (Garzón et al., 2019), for example, it enhances content understanding, improves long-term memory retention, increases student motivation, and facilitates students' independent learning (Radu, 2012). In terms of health education, findings from a recent review encouraged adopting AR in teaching concepts of anatomy, due to its ability to visualise the concepts in 3D and allow the learners to interact with them (Chytas et al., 2020). It is expected that MAR may become even more popular in the future.

Additionally, there are several potential use of AR in the context of nursing education, such as promoting independent learning and facilitating a student-centred learning approach. However, there are a lack of studies focusing on AR technology and independent learning.

Even though AR is used in education, and it is generally acknowledged that it has a positive impact on learning outcomes, the value of integrating AR applications into learning environments has not yet been fully investigated (Diegmann et al., 2015). This study considers the integration of AR technology into a nursing clinical skills lab to enhance students' independent learning.

1.2. Motivation

The nursing context was chosen due to the researcher experience; the author had worked as an IT manager for three years at a high-tech nursing college in Saudi Arabia. The author is familiar with the technologies used in the clinical skills lab. Several informal discussions with nursing educators pointed to the importance of technology in teaching. However, a close colleague, who is passionate about technology, had raised a point about the benefits of using mobile learning in the clinical skills lab. The initial idea of having one application, including three sections: anatomy, pathophysiology, and scenario, was her idea. This idea motivated the author to further investigate learning clinical skills process and the potential benefits of adopting mobile learning.

In a clinical skills lab, nursing students use manikins and patient scenarios to study the clinical skills, AR features introduce a new way of interacting with the manikins and allow the students to visualise internal objects such as internal organs, which makes simulations more realistic and immersive. Also, It helps them to perform real-world tasks and facilitate their understanding of complex scenarios independently. Together, those benefits may lead to enhance students' independent learning skills.

1.3. Research problem

This work is interdisciplinary research that integrates technology into education. The technology integration in learning is a complex interplay of three components; content, pedagogy and technology. The chosen technology here is Augmented Reality, which adopts Self-Regulated Learning theory SRL (pedagogy) in nursing education (content).

Figure 1 below presents that all these three components were considered during designing the NMAR learning tool. While, the evaluation looked at the technical perspective and the AR capabilities in terms of supporting acquiring clinical skills independently. It adopted the lens of Human-Computer Interaction HCI methods and focused mainly on creating a positive user experience.

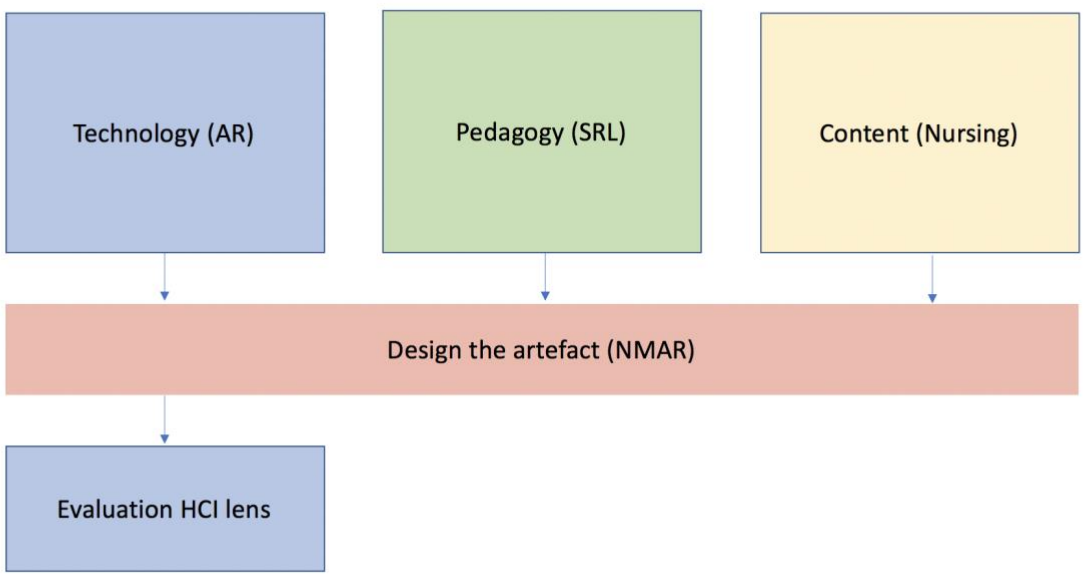


Figure 1: Interdisciplinary research components

Augmented Reality [Technology]

AR can be described as a technology that overlays virtual content onto the real world object. It introduces a novel way of interacting with the digital world by removing the boundary between both worlds (Azuma et al., 2001).

Currently, AR is a popular technology that is attracting researchers. Educators have been attracted to it because of its ability to immerse students in realistic learning activities. When interacting with virtual and real-time applications, learners engage in a natural user experience (Saidin et al., 2015). The increasing numbers of publications in the last few years show that the field of AR in education is growing (Akcayir & Akcayir, 2017).

For instance, recent attention has focused on the positive impacts of AR technology in the educational process, such as increasing content understanding, increasing student motivation and satisfaction, and as a creative way of interacting with materials (Bacca et al., 2014; Barsom et al., 2016; Carmigniani & Furht, 2011; FitzGerald et al., 2013; Radu, 2012). Furthermore, many review findings have indicated that AR has the potential to promote independent learning (Antonioli et al., 2014; Garzón et al., 2019; Koutromanos et al., 2016). Two other studies have reported that AR motivates active learning and encourages self-directed learning in students (Mat-jizat et al., 2017; Vaughn et al., 2016). Diegmann et al. (2015) also, supported this claim by saying that AR technology is supporting independence and individualism.

Self-Regulated Learning [Pedagogy]

From a pedagogical point of view, terms such as self-learning, independent learning, learner control, and self-management can be translated to Self-Regulated Learning (SRL) or Self-Directed Learning (SDL) theories. The main differences between them according to Saks & Leijen (2014) are that SDL is described as adult education which is practised mainly outside the traditional school environment (informal learning), on the other hand, SRL is practised mainly in a school environment, where students are generally enrolled in an educational institution and teachers usually set their learning objectives (formal learning). SRL theory is adopted in this work, because the research is conducted in the nursing department at The University of Salford, which is an educational institution.

In terms of the SRL definition, it can be described as an active, constructive process whereby students set goals for their learning based on past experience and the contextual features of the current environment (Zhao, 2016). The individuals take responsibility, with or without the help of others, in diagnosing their learning needs.

Previous studies have shown that facilitating SRL process in an e-learning environment can be achieved by considering learner characteristics, and useful environmental characteristics (Balapumi, 2015; Liaw & Huang, 2013). Moreover, self-regulated students are more inclined to transfer their knowledge successfully from an e-learning system into real-world situations. Zimmerman (2002) indicated that students with poor self-regulation skills are not as academically successful, whereas successful students are more likely to be self-regulated learners.

Nursing education [Content]

In recent years, there has been an increasing focus on the importance of SRL in nursing and healthcare education to facilitate clinical skills acquisition outside the limited class and practice time (Petty, 2013). Moreover, compared to traditional education, the increased use of blended learning in nursing education requires students to take more responsibility for their learning (Mäenpää et al.,2020). Thus nursing students' SRL skills have become increasingly important.

Literature Gap

Integrating AR technology within the learning process enhances the learning environment rather than completely replacing it. Additionally, AR virtually displays useful information that is not directly detected by the students' senses; for example, students are able to display human organs in 3D in front of them and interact with this 3D model. Those unique features help nursing students to perform real-world tasks and facilitates their understanding of complex scenarios independently. Together, those benefits might lead to improving students' self-regulated skills.

However, there has been a lack of studies determining the relationship between AR technology and students' SRL. As stated in a scoping review of AR in education, a wide variety of pedagogical approaches were not used during the AR learning process. The author explained that the reason could be the lack of guidelines for integrating AR with learning theories (Fatih & Omer, 2017). Additionally, Garzón et al. (2020) reported that most of the previous studies have failed to consider the pedagogical strategies of the AR learning tools. They have focused only on the technical characteristics of the technology.

Research problem

This study addresses the following four gaps related to AR technology, self-regulated learning and nursing education.

- Technology has the potential to be a powerful learning tool for fostering students' will and skill for learning about complex topics. However, the value of integrating AR technology into learning environments has not yet been thoroughly investigated (Diegmann et al., 2015; Kramarski & Gutman, 2006).
- There is a lack of studies determining the relationship between AR technology and students' self-regulated learning.
- The current nursing curriculum relies heavily on teacher-centred approaches to student learning. However, nursing researchers encourage shifting to student-centred learning approaches (Murphy et al., 2011; ZarifSanaiey et al., 2016).
- Despite the importance of SRL in academic success, research indicates that some learners have difficulties with SRL behaviour. Students often do not realise that they should regulate their ideas, and they do not know how to regulate productively (Foerst et al., 2017; Kramarski & Gutman, 2006).

1.4. Research findings

The initial stage in developing any large innovative project in the information system field is proof of concept research. It aims to demonstrate the feasibility of the proposed idea, especially if it is associated with considerable cost. This is a proof-of-concept research that investigates the impact of AR technology on acquiring clinical skills independently.

AR has the potential to enhance the user experience when users interact with the digital world (Han et al., 2018; Olsson et al., 2012). The author believes that if we met the requirement of AR technology, such as the devices and internet connection …etc., and considering the current technical challenges, AR can be an effective tool in the educational field. This belief has led to the motivation to design a nursing MAR as a novel learning platform called Nursing Mobile AR (NMAR) that introduces a new way of interacting with the nursing learning material independently by integrating AR features.

It is hoped that the findings from this research highlights the role of AR technology in facilitating independent learning and demonstrates that the features of AR can have positive effects on independently acquiring clinical skills.

1.5. Research novelty

The novelty of this research lies in producing a new learning strategy using AR technology, including a 3D model of the anatomy, virtual patient, self-assessment mechanism, and instant feedback features. Students will be able to examine the manikin in their clinical skills lab by using a specific marker printed on a piece of paper which interacts with the AR system. Using the same marker, students can transfer and practice the same learning approach at home.

Adopting the theoretical model by (English & Kitsantas, 2013) is another novelty aspect in AR studies. This work replaces the classroom activities in the adopted model, with an interactive AR environment that could encourage the students to become active and self-regulated learners. This study also proposes a theoretical framework that describes how the MAR features fit within the cycle of SLR. The heart anatomy and diseases are the example case used when developing the NMAR. Using the NMAR allows students the freedom to discover the solution independently and activate their learning.

The third novelty aspect in this research is automating three processes of the self-regulation cycle; they are goal setting, self-evaluation, and feedback. The students will play an active role in monitoring their learning progress – while having less cognitive load – and can then activate their SRL strategies (Panadero et al., 2017a).

The focus of this research is mainly on proving the concept that utilising the AR technology has a positive impact on learning clinical skills independently. It measures the user experience from the student's perception. Also, it proposes a software framework of the AR platform for facilitating self-regulated learning in a clinical lab, which can be used by future AR practitioners or developers.

1.6. Research contribution

This research investigates the positive impact of utilising the AR technology in acquiring clinical skills needed in nursing education. Also, it helps to shift from conventional teacher-centred learning into student-centred learning.

Bearing in mind the advances of using technology in the educational process and the mobility features of MAR, they could play a positive role in providing a better user experience for enhancing a student's individual learning. Moreover, MAR produces many advantages in supporting independent learning; it facilitates access to the material and mobilises the learning environment via widely accepted devices. Additionally, the interactive learning environment may motivate passive students to become active learners. Utilising an AR learning platform that facilitates SRL processes could develop students' self-regulated skills gradually.

Accordingly, this research contributes to the information systems field, specifically AR in education. It bridges the gap between the AR technology and the pedagogical approach by proposing an initial theoretical framework for integrating AR in nursing education by following an SRL strategy.

Moreover, as a result of the explosion and rapid development of technologies that could assist learning, there is increasing interest in self-regulation and self-regulated learning research. This development introduces new and accessible learning activities and creates an opportunity to develop a sophisticated technology-enhanced learning environment.

In order to facilitate nursing clinical skills acquisition outside the lab, there is a need for directed learning away from the limited class and practice time. An effective technology-enhanced environment can play a part of achieving that (Petty, 2013). In addition, the structure of the technology-enhanced learning environment influences the students' readiness to study (Mäenpää et al., 2020). This study introduces a structural change to the nursing learning environment by introducing a technology that enhances the learning environment allowing flexibility of learning anytime, anywhere.

Finally, the research findings are expected to help nursing educators and policymakers to understand the feasibility of adopting AR technology in facilitating SRL to support nursing education.

1.7. Hypothesis and research questions

Given the positive impacts of AR technology in the educational process discussed above, the research hypothesis is:

H: AR has a positive role in facilitating the SRL process for nursing students?

Accordingly, this research is built on a hypothesis statement and six research questions. The questions and objectives relevant to each research question as follows:

⇒ **RQ1: How can AR features be integrated with SRL theory?**

OB1: Explore the benefits of using AR in education and its limitations.

OB2: Propose a theoretical framework that integrates AR features with the SRL process.

⇒ **RQ2: To what extent is independently acquiring clinical nursing skills supported in the current approach?**

OB3: Conduct an investigative study, aiming to explore how nursing students acquire clinical skills.

OB4: Identify any limitations of the current approach in terms of supporting independent learning from the students' perspective.

⇒ **RQ3: To what extent do nursing students intend to foster their independent learning?**

OB5: Identify if the students need a new learning platform that supports their independent learning.

OB6: Identify the characteristics of the platform supporting independent learning from the students perspective.

⇒ **RQ4: Is the developed nursing mobile AR platform simple to use?**

OB7: Propose a MAR software framework which introduces a new learning strategy.

OB8: Design and develop the nursing MAR platform (NMAR).

OB9: Evaluate the proposed framework.

⇒ **RQ5: To what extent does the NMAR self-assessment mechanism affect students' interactions with the platform?**

OB10: Evaluate students' behaviour with the NMAR learning approach.

⇒ **RQ6: To what extent does the NMAR approach facilitate independent learning in comparison to the current learning approach?**

OB11: Evaluate students' perceived usefulness in both approaches with AR and without AR, in terms of facilitating acquiring clinical skills independently.

OB12: Perform a comparison between NMAR and current learning approaches in terms of facilitating SRL processes from students' perspectives.

1.8. Design science research paradigm DSRP

DSR is the chosen research paradigm throughout this research. It is a paradigm that focuses on creating and evaluating an innovative IT artefact to solve a specific problem by following a rigorous process. It is used to formulate the problem statement and direct the research design, while the evaluation measurement adopts the lens of HCI methods and focuses mainly on creating a positive user experience.

The term "design science research (DSR)" has recently become an umbrella term to describe any scientific research that includes design activities (Deng & Ji, 2018). Hevner & Chatterjee, (2010) defines DSR as "*a research paradigm in which a designer answers questions relevant to human problems via the creation of innovation artefacts, thereby contributing new knowledge to the body of scientific evidence. The designed artefacts are both useful and fundamental in understanding that problem*". It is a paradigm with potential to bridging the gap between practical relevance and scientific rigour in information systems (IS) research (Baskerville et al., 2018).

DSR is a problem-solving paradigm that involves two essential processes: developing and evaluating a new artefact. The artefact is designed to solve identified organizational problem (Peffers et al., 2007, Deng & Ji, 2018). It can be models, constructs, approaches, or techniques. At the same time, the evaluation determines the utility of this artefact (Goes, 2014; Hevner et al., 2004; Peffers et al., 2007; Weber, 2010). Hevner and Chatterjee (2010) stated that considering the research rigour is based on the researcher's skills in selecting the appropriate methods for developing and evaluating the artefact.

1.9. Design science research process

This research follows (Offermann et al., 2009) process shown in Figure 2 for the following reasons:

- It is a detailed defined process which is straightforward, flexible and easy to follow;
- The process has been developed on top of existing processes and ensured research quality;
- The process is not a research method on its own, but it combines quantitative and qualitative and references to well-known research methods used in IS studies, that guides the overall research process;
- It includes publication possibilities and recommendations.
- It provides the individual work packages during the stages.

The essential requirements for DSR are rigour and relevance. Offerman's process strives to fulfil those requirements; it is structured into three main phases "problem identification", "solution

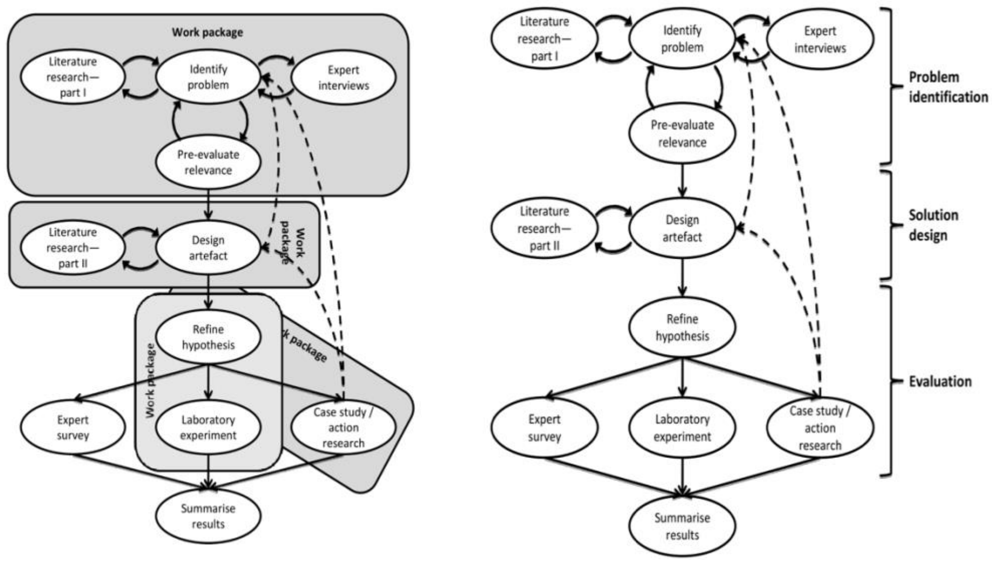


Figure 2: Offerman's outline of the DSR process

design" and "evaluation". Each stage has steps that can interact with each other within the research process. The arrows show the transmission from one step to another, and dotted lines show less transmission. The steps do not require to be executed sequentially; they frequently refer back to each other. The fulfilment of this process produces DSR findings.

1.9.1. Problem identification phase

According to Offerman, this phase aims to identify the problem, and ensures that it has practical relevance. The research question could rise from the opportunities prompted by new technology. Analysing state of the art in the research area offers a reliable and essential foundation for the next phase.

In our case, the new technology is AR, where the nursing context is of practical relevance. As well, learning context is an essential element of developing any Technology-Enhanced learning artefact.

Nursing education is the chosen context due to the collaboration of the nursing department from The University of Salford. The nature of this work demands close collaboration between the developer (researcher) and the educators in order to design the learning artefact. So, it is a collaborative project between The University of Warwick and The University of Salford. The researcher has been granted easy access to materials, educators, students and ethical approvals.

After identifying the gap in the literature, the first step to implement AR in the nursing context is understanding the current learning process. We are focusing mainly on one subject, which is the skills lab. In this phase, we identify the problem by conducting an investigative study to explore in-depth the current learning limitations and how the current approach supports independent learning.

1.9.2. Solution design phase

According to Offerman, the second phase is finding a solution to the identified problem. The solution has to be developed in the form of artefacts, which can be constructs, models, methods, or implemented and prototype systems. During this phase, the research rigours have to be maintained by using related work available.

In our case, the solution is designed for the identified problem from the literature gap and the investigative study. In order to implement any pedagogic technology innovation, it is vital to understand its potential value and possible limitations. So, the literature supports designing the solution and may be re-visited at any stage during the development. The solution is designed by implementing AR features that aim to overcome the limitations in the current learning approaches within nursing students at The University of Salford with the aid of SRL theory.

Because ineffective design of the AR platform may lead to distractions and affect the overall learning effectiveness of the learners, the artefact is developed concerning the usability consideration.

1.9.3. Evaluation phase

Offerman stated that, once the solution has attained a sufficient state, the evaluation can be achieved through a case study, action research, broad expert survey, laboratory experiment, or simulation. It is possible to iterate back to any previous phases whenever is necessary. In the laboratory experiment, the newly designed artefact can be compared to the existing system. Also, to ensure the rigour, the analysis can be achieved by using well-known quantitative research methods.

In our case, AR technology is still in its developing phase, and the limitations of the AR influence the evaluation phase of this work. For instance, as a result of the expensive cost and long period required to develop the AR platform, only one type of nursing scenario has been used while developing the NMAR, which is insufficient to measure SRL skills or any educational factors. Accordingly, the evaluation focuses mainly on the technical perspective rather than an educational perspective.

On the other hand, three review papers have reported that the most technical challenge in AR is usability, and it is “difficult for students to use” (Akcayir & Akcayir, 2017; Fatih & Omer, 2017;

Palmarini et al., 2018). Basically, AR offers many novel ways of interacting with digital objects, which are unfamiliar with the user. This communication may lead to "difficult to use" result. However, usability is an essential technical factor that affects the effectiveness of the educational platform. The usability perspective, focusing on the interaction between the devices and the human users; which is known as Human-Computer Interaction.

Accordingly, the evaluation measurement adopts the lens of HCI methods and focuses on evaluating the overall user experience, which is the broader level of usability. Thus the laboratory experiment is chosen because it is commonly an evaluation method used in HCI studies, more details in chapter 5.

In light of the above discussion, six processes have been deployed to achieve the overall research objectives. A brief overview of each process is presented in Table 1 below, and more details are in the corresponding chapter.

Table 1: Research process and methods

process	*Study*	*Aim*	*Data collection*	*Data analysis*	*Ch*
1	Literature review RQ1	To find the study gap, strength, challenging for future research, and synthesise the state of knowledge	Narrative review	Summarising and synthesising	2
2	Investigative Study RQ 2,3	To formulate the research problem	Online Questionnaire	Descriptive statistics	3
3	Development	Design the artefact with the purpose to solve the research problem	Waterfall		4
4	Validation	To validate the artefact in terms of the educational content or	Expert interviews with Educators,	User experience analysis from three perspectives.	

		early detection of technical issues.	students, and technical.		
5	Evaluation RQ4,5,6	To create an overall positive user experience	Lab experiment	Overall user experience	5,6
			Video recording (Objective)	Descriptive user's behaviour analysis	
			Questionnaire Usability (Subjective)	Descriptive statistics	
			Pre-post usefulness	Comparison of Statistical analysis	
			Interviews	Thematic analysis	7
6	Summaries result				8

1.10. Thesis outline

CHAPTER TWO: LITERATURE REVIEW

This chapter presents a literature review covering the state-of-art of AR technology in general and in education in particular. Moreover, it explores the advantages of adopting AR in health education and identifies the gaps observed in the literature. Also, it covers the pedagogical aspect of the research.

CHAPTER THREE: INVESTIGATIVE PHASE

This chapter examines the current learning approach and determines the challenges that have been faced by students when they are acquiring clinical skills independently. Additionally, it identifies the perspective of the students regarding AR technology for facilitating their independent learning.

CHAPTER FOUR: DEVELOPMENT PHASE

This chapter describes the process of developing the NMAR platform; it illustrates the components, features, and interaction style together with AR functions as the vehicles for data collection. It validates the platform from educational and technical perspectives. Finally, it proposes a software framework.

CHAPTER FIVE: METHODOLOGY OF THE EVALUATION

This chapter presents in detail the data collection methods concerning the study’s validity and reliability. Additionally, it describes the evaluation approach of students’ experiences with the AR platform, including sampling, sample size, recruiting participants, and evaluation measuring.

CHAPTER SIX: QUANTITATIVE ANALYSIS

This chapter illustrates the quantitative usability results and discusses the self-assessment mechanism's impact on students' behaviours with the NMAR platform. It also statistically compares the NMAR learning approach and the current learning approach, then explaining the study's significance.

CHAPTER SEVEN: QUALITATIVE ANALYSIS

This chapter discusses the post-interviews as a qualitative data collection method, including the interview process and analysis. It presents the thematic analysis of the findings by classifying the main themes into learning environmental characteristics and user characteristics, bringing together both findings in a general discussion.

CHAPTER EIGHT: CONCLUSIONS AND FUTURE WORK

This chapter provides the final, conclusive findings for this work. It presents the research contribution, challenges, limitations, as well as pointing to further research directions.

CHAPTER 2

2. LITERATURE REVIEW

Reviewing the literature is the initial step in the problem identification phase. AR technology is still in the development phase. Compared to other more mature technologies in education, AR seems to be in the early stages. The traditional or narrative literature review has been performed in this section to overview the strengths and challenges of AR by reviewing any study that could be relevant to the topic (Snyder, 2019). The aim of critically reviewing the existing literature is to summarise and synthesise the state of knowledge and seek to understand any potential research. However, this work is interdisciplinary; the topic of interest is AR in education in general and nursing education in particular. Hence, the reviewed literature focuses on two main areas: the technology itself and learning by using AR technology. In order to organise the literature effectively, the chapter starts with the technology, including AR definitions, AR hardware and software, and is followed by a comprehensive review of AR in education, including the benefits of using AR in learning, and the potential to use AR in healthcare and nursing education. The reviewed literature reveals some limitations of AR that draw the research boundaries. This chapter also discusses the limitations of AR as well as works related to AR healthcare education. The chapter ends by discussing the pedagogical component as a theoretical background. Given that it formulates the gap in the literature and proposed solution, the output of this chapter achieves the **OB1** and **OB2** of the research.

2.1. [Technology] Augmented Reality

This section discusses the AR technology including definitions, AR hardware and software.

2.1.1. Definitions

In 1994, Milgram introduced the Reality-Virtuality (RV) continuum, aiming to address the concept of mixed reality, which means "*real world and virtual world objects are presented together within a single display*". The continuum embraces Augmented Reality (AR) and Augmented Virtuality (AV) in between, where AV is closer to the virtual world and AR is closer to the real world (Figure 3) (Milgram et al., 1995).

The most common definition of AR is a mixed environment that integrates digital information with physical objects in a meaningful way (K. Wu et al., 2013). However, El Sayed et al. (2011) favoured another definition of AR, and emphasised that "*AR enables the addition of missing information in real life by adding virtual objects to real scenes*". Another definition is "*AR allows for interactions with 2D or 3D virtual objects integrated into a real-world environment*" (Bacca et al., 2014). Diegmann et al. (2015) defined AR as "*a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information*". According to Azuma et al. (2001), instead of replacing reality, AR supplements it. All of these definitions are based on AR features, which allow virtual information to be supplied, such as 2D and 3D images, text, videos, or audio, on top of the real object, along with interacting with them.

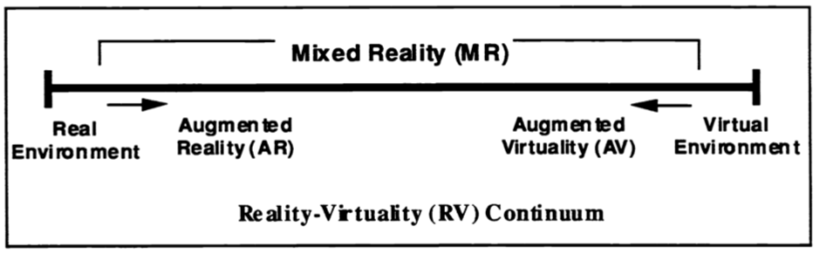


Figure 3: Milgram's continuum (Milgram et al., 1995)

2.1.2. AR hardware

Azuma (1997) stated that AR systems have three main characteristics: (1) AR combines the real and the virtual; (2) it has real-time interactivity; and (3) it should be registered in 3D. In order to achieve those characteristics, there are three essential components of any AR system: display devices, input and tracking devices and computer.

Display devices

There are two categories of AR displays; AR wearable displays and AR handheld displays.

1- **AR wearable display**

In AR technology, the augmented content can be generated at various points along the optical path between the eyes and the physical object. For the smart glasses, the image is created on a wearable Head Mounted Displays (HMDs) (Serubugo et al., 2017). The users wear see-through HMDs to see 3D computer-generated items superimposed on the real-world scene to enhance their view of the real world. This see-through capability can be achieved using either an optical or a see-through video HMD.

According to L. Chen et al., (2017) "a video-see-through HMD captures video via a mono- or stereo-camera, and then overlays computer-generated content onto the real world video". While with optical-see-through HMD, the real world is seen directly combining the virtual objects through a transparent lens. Users will receive light from the real environment and the transparent lens, resulting in a composite view of real and virtual objects (L. Chen et al., 2017).

Several companies have been developed and commercialised AR wearable headsets such as Microsoft HoloLens, Magic leap, Google glass, the expected Apple glasses and others. Circuitstream website summarised the unique strengths and weaknesses of different types of headset in the market as below table.

Table 2:The unique strengths and weaknesses of each headset, (Source: https://circuitstream.com/blog/guide-to-mixed-reality/)

HEADSETS	STRENGTHS	WEAKNESSES
HoloLens 2	1. It's more comfortable than its predecessor 2. It offers a broaer field of view (FOV) 3. It has intuitive ey and hand-tracking	It's expensive
Magic Leap	1. It uses Light Field technology 2. It comes with a tethered Lightpack (mini PC) to power the device 3. It's comfortable	1. It only caters to shortsighted users. 2. The non-click touchpad can be confusing sometimes.
Acer WMR	1. It's easy to set up 2. It's affordable	1. Tracking doesn't work sometimes 2. Haptic feedback is weak 3. It uses AA batteries
HP MR	1. It has a removable tether cable and moisture-proof cushions 2. It doesn't require any external sensors 3. It's comfortable	1. The visor's weight is too much for the plastic hinge 2. It doesn't have built-in headphones
Samsung	1. It has great visuals 2. It's lightweight and comfortable 3. It has built-in audio and is easy to set up	It's not cheap
Varjo XR-1	1. It has <20ms latency 2. It's fast	It's expensive

2- Handheld display

The handheld display uses portable digital equipment with a display screen held in the users' hands, such as smartphones and tablets. The handheld displays use a technique called video-mixing to combine the virtual and real worlds. When a live video stream of the real world is combined with the rendered augmented objects, and they are displayed on the screen (Serubugo et al., 2017).

3- Comparing wearable and handheld AR devices

The rapid development of handheld devices with high quality cameras are providing new opportunities for affordable AR experiences. In comparison to the wearable devices, handhelds are widely accessible because most people own a smartphone, whereas wearable devices are hands-free (Serubugo et al., 2017).

Although wearable AR devices are a promising technology, the current available smart glasses have a limited field of view (FOV) which is not sufficient to visualize all the necessary information (L. Chen et al., 2017; Kim et al., 2019).

The cost of the headsets and technology limitations ;such as blurry image quality, hard to use or heavy and they cause visual fatigue; have been inhibiting factors to the widespread adoption of smart glasses (L. Chen et al., 2017; Ditzel & Collins, 2021).

From a practical point of view handheld devices seem to be more suitable platform for AR experience due to its easy to use and availability, however, the AR headsets required more technological advances to make them more comfortable to use (Serubugo et al., 2017). Regardlessly smart glasses technology continuous growth and value potential in the enterprise and industrial sectors, wearable glasses still face challenges that delay them from reaching market usage (Surti & Mhatre, 2021).

4- A spatial display

An alternative solution to create AR experience without the need to carry or wear any additional display devices by using spatial display. It extracts most of the technology from the users and combines it with their surroundings. It uses tracking technology to display graphical information directly on top of physical objects, such as optical elements, holograms and radio frequency tags.

Input and tracking devices

Input and tracking devices are other crucial components of the AR system. Users often use gloves, wireless wristbands and smart devices as input devices. Carmigniani & Furht (2011) stated that the chosen input devices depend significantly on the type of activities that are being developed in the system. For example, if the system utilises a smartphone, the touch screen will be the input device. However, if the system requires the user to be hands-free, the chosen input device will be wearable devices. However, in the AR desktop, the screen is the display device that covers only part of the surrounding environment, and the interaction happens with regular input devices such as a mouse or keyboard (Maiti et al., 2016). In terms of tracking the user, the tracking devices consist of digital cameras or other optical sensors, GPS, accelerometers, solid-state compasses or wireless sensors. Each of these technologies has a different level of accuracy and depends on the activities of the type of AR system (Carmigniani & Furht, 2011).

Computer

AR systems need a powerful CPU and a significant amount of RAM to process camera data; with the improvements in mobile technology, a configuration deploying a laptop in a backpack for mobility has been replaced by lighter and more sophisticated mobile systems (Carmigniani & Furht, 2011).

The researchers divided the AR systems into image (or visual or vision)-based and location-based AR systems. Wojciechowski & Cellary (2013) described the image-based system as a system that is focused on image recognition methods to assess the location of physical objects in the real world in order to accurately locate the virtual content associated with these objects. This type of AR system can be divided into two categories: marker-based and marker-less AR tracking. The marker-based AR needs unique labels to place the location of 3D objects in the real world, such as the Quick Response Code (QRC), while, in the marker-less AR system, any section of the real environment can be used as a tracked target in order to place the virtual content (Koutromanos et al., 2016). In contrast with image-based AR, location-based AR applies GPS technology to identify the user's real location and display any relevant virtual data from their nearby location (Migliore, 2016;Fatih & Omer, 2017).

Koutromanos et al. (2016) claimed that AR systems are not limited to a particular device, but the integration of technologies and devices. Moreover, the researchers seek to either develop new devices and technologies to combine tracking, displaying and interacting with virtual data in a real-world or develop applications utilising those technologies (Yuen et al., 2011). In the case of a smartphone, the phone itself can be applied as an input and display device with a robust CPU processor. AR has become both feasible and affordable with the recent growth of mobile devices that integrate more processing power, better cameras and other features, leading to its widespread adoption. Gjosaeter (2015) stated that mobile AR has moved from conceptual prototypes to usable applications, which are easily distributed through smartphone App stores.

In terms of integrating AR in the educational process, the majority of the studies applied image-based rather than location-based AR technology to enhance the teaching-learning process of informal education. Researchers have conducted two systematic reviews on AR in education, in two different periods; the findings indicated the same results, namely that educators and researchers preferred image-based in general and marker-based in particular due to its ease of use (Fatih & Omer, 2017; Bacca et al., 2014). While the development of high levels of AR system demands technical skills that educators may lack, image-based AR is easily reached and used for people with non-technical skills (Fatih & Omer, 2017). Additionally, Bacca et al. (2014) stated a possible reason for this: in contrast to marker-less tracking methods, the tracking process of markers is more convenient and robust. The use of static markers decreases the required tracking work and reduces the number of items to be identified in the real world. Hence, for the educational context, marker-based AR could be recommended over marker-less AR until the tracking issue associated with the marker-less format is solved. However, Bacca mentioned that Microsoft Kinect provides some support for tracking and registering entities that could solve the limitations of marker-less AR. On the other hand, the most challenging aspects reported by previous studies utilised locational-based AR are accuracy, reliability and "low sensitivity in trigger recognition" of GPS technology (FitzGerald et al., 2013; Mekni & Lemieux, 2014; Bacca et al., 2014; Fatih & Omer, 2017). The current GPS obstacles will likely be resolved by new developments in the future (Akcayir & Akcayir, 2017).

2.1.3. AR software (SDKs)

AR Software Development Kit (SDK) provides a coding environment for allowing software professionals to create and implement all functionalities that will compose the core application with the capabilities of AR (Hanafi et al., 2019). SDK facilitates many components within the AR application, such as AR tracking, AR recognition and AR content rendering. The tracking component is simply the eyes of the AR experience. The recognition component works as the brain of the AR application, and the content rendering is imaginative virtual objects in the real-time world (Amin & Govilkar, 2015).

Multiple AR software SDKs have been developed, allowing for easier development of AR experience on mobile platforms. Such as ARKit, ARCore, Vuforia and ARToolkit.

ARKit is Apple's AR application programming interface. It is built-in to IOS 11 and runs on Apple devices that hold an A9 processor or later. ARKit utilises Visual Inertial Odometry (VIO) to track the world around it accurately. VIO fuses the data from the camera and Core Motion sensor to understand its position. ARKit can detect planes and surfaces within the environment to place virtual objects. ARKit allows developers to develop AR experience for iPhones and iPads (Hanafi et al., 2019).

In 2018, Google released their AR SDK called **ARCore.** This SDK was based on Project Tango, one of their previous research. ARCore uses Simultaneous Localisation and Mapping (SLAM) techniques and computer vision techniques to identify flat open spaces, such as floors and walls, then combines the data with the devices gyroscope and accelerometer data to calculate its position within the environment. The SDK allows the users to run AR applications on mobile devices with the Android operating system (Oufqir et al., 2020).

Vuforia is one of the most popular AR SDKs as the Vuforia platform employs a superior, robust, and efficient computer vision-based image recognition technique. It offers several features that enable mobile apps and remove technical barriers for developers (Amin & Govilkar, 2015). The SDK produces cross-platform AR integration for Android, iOS, and Universal Windows platforms via a single API, allowing developers to build their app once and run it on the best available core technology (Hanafi et al., 2019). The Vuforia SDK detects and tracks markers and simple 3D objects placed in an environment using the built-in camera and computer vision algorithms. The targets can be used to place objects in the environment—the users' perspective changes as they move around the object because they are oriented to the targets. Additionally, Vuforia 7 supports Apple's ARKit and Google's ARCore.

Lastly, **ARToolkit** is an open-source computer tracking library. It uses video tracking technology to calculate the real-time position and orientation relative to square physical markers or natural feature markers. Once the real-camera position is identified, a virtual camera can be placed at the exact location, and 3D computer graphics models can be generated precisely overlaid on the real marker (Amin & Govilkar, 2015). However, the open-source SDK has its disadvantages- the most significant is the weak SDK's documentation.

2.1.4. AR advantages

Today, the phrase augmented reality has become more commonly used than augmented virtuality due to the advantages offered by AR systems. By using the real-world, AR applications do not need to model every little detail of the reality, as these details are already physically presented. It only needs to overlie the necessary digital elements to interact with the user in a meaningful way.

Another advantage is that the user can interact with the virtual information without losing contact with the real world (Andújar et al., 2011). For instance, when the user moves or rotates the marker image, the virtual content moves and rotates as well (Yuen et al., 2011). Other advantages of AR over Virtual Reality (VR) is that more users experienced cybersickness with VR than augmented or mixed reality (Day & John, 2019; Uruthiralingam & Rea, 2020).

AR also seeks to simplify users' lives by bringing virtual information to their immediate surroundings. Also, it can add an indirect view of the real environment, such as a live video stream, thus enhancing their perception of interaction with the real world (Carmigniani & Furht, 2011).

Moreover, the affordability of mobile devices and the capability of their hardware to process digital information rapidly, have made the widespread use of mobile AR reasonable. It allows the user to interact with digital information naturally and acceptably. Most modern smartphones are supplied with a sensor, a powerful processor, a camera and other multimedia interfaces, like microphones and speakers, making smart devices one of the most convenient platforms with which to implement AR experience (Yuen et al., 2011).

A systematic review claimed that smart devices offer an optimal platform for AR development applications because it is cost-effective, easy to use, portable and offers independent operability (Akcayir & Akcayir, 2017). Users can engage in AR experiences using their own devices without the requirement for additional equipment. Simply, AR applications can be downloaded at any time from the internet to users' smart devices.

Carmigniani & Furht (2011) defined a successful mobile AR system as an application that enables the user to focus on the AR experience rather than on computer devices. They can move from digital and real worlds or reverse naturally. Also, it provides the user with private content that can be shared if necessary. The smartphones contain sophisticated technologies that enable AR to become more personally meaningful without any specialist equipment (FitzGerald et al., 2013). Integrating multiple devices could become critical in maintaining their stability, as using more devices leads to a greater risk of device failure (K. Wu et al., 2013). In this way, mobile AR provides a more sustainable technology for daily learning and AR experiences.

Finally, in contrast to the virtual reality technology, Table 3 summaries the advantages of AR over the VR.

Table 3: Comparing AR and VR

AR	VR
Adds to the reality	Replaces the reality
Affordable by using smartphone	Extra cost for the headset
Less equipment (input/output in one device)	More equipment
No side effect	Possible cybersickness
Not losing the contact with a real world	Losing the contact with a real world

2.2. [Content-1] AR in education

This section discusses in detail the benefits of utilizing AR in education in general.

2.2.1. The benefits of AR in education

The ability of AR to allow students to be immersed in a realistic experience has attracted educators to use this creative way of learning. Recent researches have shown a positive impact of AR on education, by making the educational processes more active and influential. Many studies aim to determine the state of AR in education, including the trends, applications, benefits, challenges and technical limitations.

Table 4 summarises 24 reviews studies found in the literature from 2011 to 2020. The earlier studies were mostly a general overview; since then, studies have become more systematic or in a specific field such as medical surgeries or anatomy etc. The studies selected were review studies that reported one or more advantage of using AR in the educational process. Despite the limitations in some studies, this section mainly focuses on the advantages of AR in education. It can be seen that the amount of interest in AR research has dramatically increased since 2011 due to the developments in mobile technology and the widespread smartphone usage (Akcayir & Akcayir, 2017). Researchers from different disciplines have adopted AR when teaching students. The table illustrates the benefits that students can gain from AR; for instance, AR is an interactive, visual and engaging learning tool that motivates students to learn. It supports learners in visualising abstract concepts or unobservable phenomena that are difficult to understand or which they cannot directly detect with their senses. The mind-map (Figure 6) categories the benefits in

Table 4, and the number presents the specific review study in the same table. The map shows for example AR is an authentic, interactive, tangible, engaging and visual learning tool.

It is easy to access material in a real-time location. Most of the studies reported that AR is a motivational learning strategy that enhances students' learning and supports knowledge acquisition and retention. As academic achievement is hugely affected by students' motivation, it

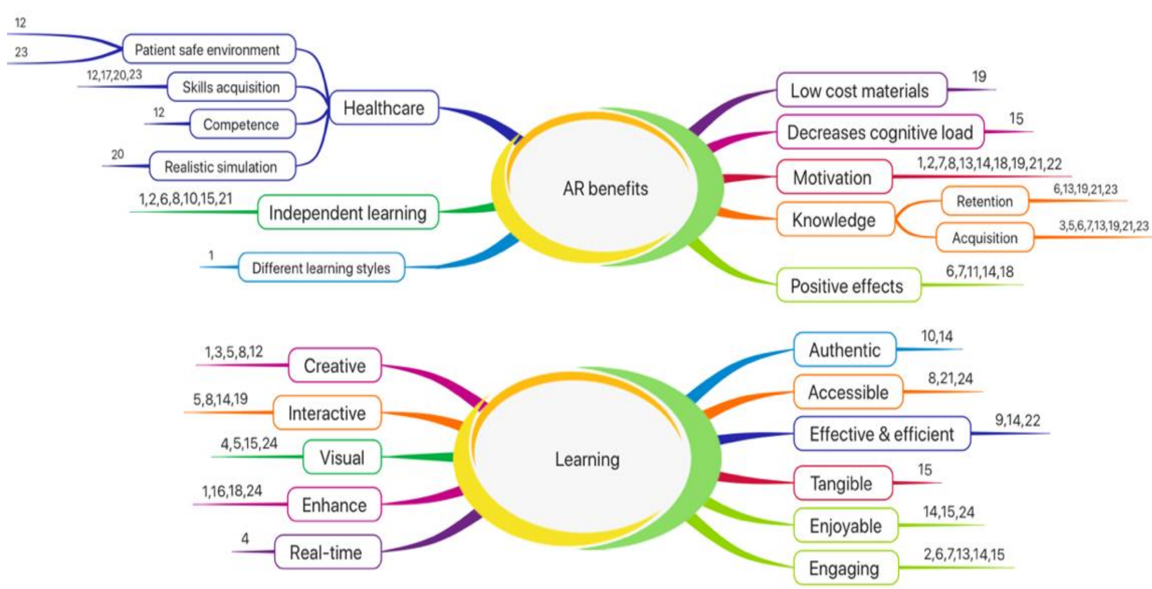


Figure 4: mind-map of AR benefits in education

The numbers refer to the articles in table 5 is obvious why it is considered the most in the literature (Arici et al., 2019). AR was also found to promote self-learning and enhance independence.

In addition, AR provides a creative way of interacting with materials; when the learners interact with both virtual and real-time information, this immediacy and immersion provides a natural experience to the user (Saidin et al., 2015). Another advantage of AR is the ability to transfer smoothly between the real and virtual world (Gavish et al., 2013). Moreover, utilising mobile AR in teaching can improve students' learning performance and help them to engage in the classroom because boring materials can be made more entertaining (Zhu & Zary, 2014). Well-integrated AR and organised relevant materials (e.g. videos, text, images, and links) help to prevent incidental cognitive loads which may lead to students' performances improving (Zhu et al., 2015).

In addition to promoting realism-based practices, AR encourages self-directed learning between students (Mat-jizat et al., 2017). It supports student-centred learning (SCL), which is a new learning approach; this can replace traditional teaching methods by creating an active and self-based learning program. In SCL, the teachers' role is as a facilitator who will enable students to learn independently and individually, while the learners are more responsible for their educational progress (Diegmann et al., 2015). AR helps students to control their learning at their own pace and location (Yuen et al., 2011). This result is in line with the study findings showing that AR supported the students' ability for self-control and self-study (Karagozlu, 2018). Diegmann et al. (2015) claimed that SCL with AR learning tools could be a significant new education trend.

Table 4: The educational benefits of AR in general

	Article	Year	Period	No. studies	Field	Benefits
1	Yuen et al. (2011)	2011	overview of AR		Any	Motivation, enhanced learning, enhanced creativity, support independent learning, and different learning styles.
2	FitzGerald et al. (2013)	2013	N/A	N/A	situated learning in outdoor settings	Motivation, engagement, support problem-solving activities, encourage independent learning.
3	Bower et al. (2013)	2013	NA	NA	learning by design	A creative way of learning that enhances students' knowledge and thinking

	Article	Year	Period	No. studies	Field	Benefits
4	K. Wu et al. (2013)	2013	2000-2012	54 empirical studies	Any	3D and visual learning, Real-time learning, visualising the invisible content.
5	Mekni & Lemieux (2014)	2014	This paper surveys the current state-of-the-art in		AR in different domains, Education one of them	Visual learning, interactive learning, creative way of learning, enhanced learning
6	Antonioli et al. (2014)	2014	literature Review		Any	Positive attitude toward AR in and outside the classroom, knowledge acquisition and retention, engaging learning, support independent learning.
7	Bacca et al. (2014)	2014	2003-1013	32	Any	Motivation, engaging learning, enhanced learning, positive attitudes.
8	Diegmann et al. (2015)	2015	N/A	25	Any	Motivation, support independent learning, accessible learning, interactive learning, creative way of learning.
9	Tekedere & Göker (2016)	2016	2005 - 2015	15	Any	Effective and efficient learning.

	Article	Year	Period	No. studies	Field	Benefits
10	Koutromanos et al. (2016)	2016	2000-2014	8	The natural sciences and took place within informal learning environments,	Enhances active and authentic learning.
11	Altinpulluk & Kesim (2016)	2016	until 2014	46	AR book	A creative way of learning, a positive attitude.
12	Barsom et al. (2016)	2016	up to August 2015	27	Support medical professionals training	Enhance surgical training skills in a patient safe environment, Achieving the actual competence needed.
13	Fatih & Omer (2017)	2017	2012-2016	23 studies from numerous countries	Formal education	Motivation, engagement, satisfaction, knowledge acquisition and retention, enhanced learning
14	Chen et al. (2017)	2017	2011 to 2016	55	Any	Motivation, realism, interactive, enjoyment, engaging learning, effective learning, positive attitude.
15	Akcayir & Akcayir (2017)	2017	1980 - 2015	68	Any	Decreases cognitive load, engaging learning, enjoyment learning, support independent learning, promote self-learning, visual and tangible learning.

	Article	Year	Period	No. studies	Field	Benefits
16	Ozdemir et al. (2018)	2018	2007-2017	16	Any	Enhance learning and academic achievement.
17	Wüller et al. (2019)	2019	until April 2018	23	Nursing	Has a positive effect on nursing education.
18	Arici et al. (2019)	2019	2013 and 2018	62	Science education	Motivation, enhance learning and a positive attitude.
19	Quintero et al. (2019)	2019	2008 and 2018	50	Educational inclusion	Motivation, interesting and interactive learning, low cost, knowledge acquisition and retention.
20	Munzer et al. (2019)	2019	NA	24	Emergency medicine and training	Realistic simulation, enhance training skills.
21	Garzón et al. (2019)	2019	2012-2018	61	Any	Motivation, accessible learning, knowledge acquisition and retention, self-learning.
22	Uruthiralingam & Rea (2020)	2020	from 2007	31	Anatomy	Motivation, useful and effective tool for learning anatomy.
23	Gerup et al. (2020)	2020	2013 - 2018	26	Healthcare education	Effective learning and training tool, patient safety, knowledge acquisition and retention.

	Article	Year	Period	No. studies	Field	Benefits
24	Chytas et al. (2020)	2020	2010-2018	7	Anatomy	A highly acceptable and enjoyable anatomy teaching tool, visual 3D learning, enhance academic achievement.

Cognitive load

Cognitive load is a factor in the AR learning environment which has not been investigated in much detail. For example, the systematic review by Akcayir & Akcayir (2017) showed contradictory results associated with AR and cognitive load; two studies reported that it decreases the cognitive load, while another two stated that it causes cognitive overload. These negative effects seem to be consistent with previous review studies that claimed students with AR learning tools could experience cognitive overload by the amount of information and the complexity of the tasks (Akcayir & Akcayir, 2017; Kanaki & Katsali, 2018; K. Wu et al., 2013).

In contrast, systematic review findings showed that AR helps with immediate memory, and develops cognitive skills in inclusive education (Quintero et al., 2019); those positive effects mirror the benefits in Table 3 which show that AR supports knowledge acquisition and retention, indirectly indicating a low cognitive load. For instance, two studies utilised AR in teaching anatomy, directly and indirectly supporting the positive effects of AR on cognitive load. The first study found that AR enhances students' learning and improves their ability to retain anatomical information (Salmi et al., 2015). However, the findings of the second study were "*higher achievement and lower cognitive load*", the study utilised the cognitive load scale to measure the students' cognitive load (Küçük et al., 2016). Two reasons have been cited for this positive effect: visualising the abstract information in 3D animation, as well as providing immediate access to the information while students' minds were engaged with the subject, required less cognitive effort.

Nonetheless, Wu et al. (2018) developed a system called "the mindtool-based AR" learning system, it was designed with the purpose of overcoming the cognitive overload issue in the conventional AR learning tool. The study experimented on an elementary school for natural science subjects to compare two AR learning systems. The results showed that both groups with mindtool-based AR and conventional AR learning systems perceived low cognition load during the experiment. The observed correlation between visualising the complex concept and low cognitive effort might be the explanation for the positive effect. Moreover, students' levels, subjects, tasks, and well-designed systems are factors that should be considered. Uruthiralingam & Rea (2020) claimed that technology offers accessible and available information, but that this is insufficient to facilitate learning, meaning that cognitive load theory should be treated too.

2.2.2. Digital native DN

Prensky pointed out that the new generation thinks and processes information differently from their antecedents, and their thinking patterns have been changed. They were born in a digital age, and have spent their entire lives surrounded by digital and computer devices. Considering how they grew up, it is very likely that our students have changed. Their different types of experiences lead to their brain being structured differently. The new generation is no longer the students that our educational systems were built to teach. This distinction goes further and deeper than most educators think or realise. Prensky calls them "Digital Native - DN" (Prensky, 2001).

Also, Schofield & Honore (2009) characterised learning preferences of Digital Native in her study as follows:

- They have low attention and a lack of concentration;
- They value interaction, networking, active participation and staying connected;
- They are more oriented towards non-linear and non-sequential learning;
- They prefer visual learning;
- They are comfortable when they are engaged simultaneously in multiple activities;
- Doing is more important than knowing - results and actions are now more valued than the accumulation and memorisation of facts (knowledge);
- A need for immediacy – they have little tolerance for delays;
- Issues of time and difficulty in obtaining information are usually of more concern than accuracy;
- They seek knowledge as an active creation process and are used to contributing and customising their work/knowledge to the community;
- They are more interested in problem-based learning.

The authors recommended high quality learning to improve the DN's skills. They stated that learning must be meaningful to the learner, instantly applicable and linked to an experience in real life. It must be interactive to encourage them to establish their missing skills (Schofield & Honore, 2009).

On the other hand, teachers need to utilise technological and exciting teaching methods which will fit the DN learning requirements, who were born in a world filled with technology. In other words, AR that is combining images, audio and animation provides an enjoyable, interactive experience to help the DN understand their learning material; mobile AR showed a significant impact on students' learning performance (Mat-jizat et al., 2017). The creative way of AR learning environments such as 3D modelling and interactive experience is likely to appeal to DN students (Yuen et al., 2011).

2.2.3. Limitations in AR researches

Despite the rising interest in AR and a large amount of development studies, there are still many obstacles and problems that need to be overcome. Technical limitations are the most significant challenges reported in many of the studies, for example complex devices (Garzón et al., 2019) and usability (Akcayir & Akcayir, 2017; Bacca et al., 2014; Fatih & Omer, 2017; FitzGerald et al., 2013; Mekni & Lemieux, 2014; Munzer et al., 2019); other problems were caused by cameras, the internet or indoor users and a lack of technical skills (Küçük et al., 2016).

Another limitation that is often reported is the small sample size in short-term studies (Bacca et al., 2014; Diegmann et al., 2015; Fatih & Omer, 2017; Wüller et al., 2019). Thus, the generalisability of much-published research in small sample sizes is problematic. Moreover, the researchers suggested the need for future longitudinal studies. Additionally, the scoping review in nursing reported that there is a lack of use of objective data to evaluate AR systems (Munzer et al., 2019).

Below is a brief description of some of the limitations found in the literature, classified as technical limitations, a lack of tracking accuracy, distractions and teacher resistance.

The technical limitation

The technology still has hardware and software obstacles that need to be addressed; the AR system has to handle large amounts of information in real time. Consequently, the hardware should be robust, easy to use, portable, and fast enough to process and present the digital content. It also requires some form of internet access or devices connected to each other. Ensuring a sustainable quality of the signal and sufficient charge of the batteries depend on the devices used and the internet service providers.

For example, using wearable glasses with hand gestures for an AR system in a large classroom may be prohibitive, and the class duration might not be adequate to complete all of the learning activities. Moreover, the limited market of wearable devices is another obstacle, alongside the short battery life and poor wireless connection of those devices (Fatih & Omer, 2017). Additionally, difficulty and usability issues cause time to be wasted and additional lecture time being required (Akcayir & Akcayir, 2017). A review reported that technical problems and minor crashes reduce students' motivation to use the technology (Fatih & Omer, 2017). Although the usability is the primary technical issue reported, mobile AR applications have been reported to be more usable than desktop applications (Fatih & Omer, 2017). In terms of technology supported learning, it is vital that learning is not constrained by the limitations of the technology (FitzGerald et al., 2013).

Lack of tracking accuracy

AR tracking in a marker-based format is more accurate than location-based due to less computer processing being needed. AR location tracking uses GPS to identify the user's location and then displays the associated information. The lack of accuracy generates errors with the identified location, leading to nearby information being presented rather than the actual learner's location. This irrelevant content causes learners to waste time and effort to identify the relevant information (FitzGerald et al., 2013). Moreover, there is a need for software that filters large amounts of data and retains only useful information, which does not yet exist (Mekni & Lemieux, 2014). One of the sensitive issues connected to the user's location is privacy. The user may not be aware of the data being collected from third-party companies which offer personalised marketing (FitzGerald et al., 2013). Blending the fantasy with the real world is attractive, but it could confuse the students, especially if they lose track of the real environment, which could threaten their physical safety (K. Wu et al., 2013).

Distraction

The technological ability required to use AR systems demands more attention, which can be a distracting factor; the essential skills required to manipulate and interact with the digital content could be a challenging experience the first time. The novelty of the technology may also distract students by focusing on shiny devices rather than the learning experience (FitzGerald et al., 2013). Students who used the AR document reported that too many items on the page can also be distracting (Fatih & Omer, 2017). Moreover, different levels of students' visual ability can affect their interaction with the system. Students with high visual ability can easily create a mental map of both environments compared to low visual ability students (Uruthiralingam & Rea, 2020).

Teacher resistance

School restrictions or teacher resistance could be encountered when adopting AR in a classroom; some of the teachers expressed worry over how they can manage all the technologies, and technical difficulties during their classes (Antonioli et al., 2014). Other educators were concerned that when students experience the creativity of AR, they may not go back to their previous methods of learning (Antonioli et al., 2014). AR can change the teacher-centred approach into a student-centred format; teachers reported that learners engaged in their learning experience with AR and took responsibility for their learning, meaning that the educators become facilitators for their learning (Sural, 2017). Furthermore, the teacher's ability to use the technology (Akcayir & Akcayir, 2017), and lack of technical skills such as programming experience, developing 3D or multimedia content (Küçük et al., 2016), are possible reasons why teachers resist using the technology. Although implementing AR in a classroom is considered a low-cost technology, due to the affordability of the mobile devices, designing and developing the system is too costly (Quintero et al., 2019). Inflexible content is another issue when teachers are unable to revise or create AR learning activities in an AR system that has been developed by the AR company (K. Wu et al., 2013). A study reported that the expensive retraining of staff on how to utilise the system can be one reason against using AR in a healthcare setting (Carmigniani et al., 2011).

Recently, the new generation of smart devices has been integrated with AR features; this development of MAR technology could overcome some of the hardware limitations. Accordingly, it is always important to consider technology capability and pedagogical aids when designing AR learning activities. Wu et al. (2013) stated that instructional design should include carefully distributed information and the flow between the two worlds and various devices.

Further research needs to be undertaken in usability studies for AR applications in education, along with guidelines for designing AR-based educational settings (Bacca et al., 2014).

2.3. [Content-2] AR in healthcare education

AR has been utilised in many cases within the healthcare sector; for example, the practice of neurosurgery (Pelargos et al., 2016), emergency care (Munzer et al., 2019), and medical training (Barsom et al., 2016), to reduce failure rate by improving performance accuracy (Zhu et al., 2015), and learning the anatomy (Chytas et al., 2020). Moreover, there are several potential areas for adopting AR in a nursing setting, such as saving time, visual and individual tools, supporting simulations and reducing anxiety (Wüller et al., 2019).

This section discusses three main themes: anatomy, training and acquiring skills, and clinical nursing education.

2.3.1. Anatomy

Conventionally, learning human anatomy is based on traditional techniques, including cadaver dissection, static anatomical illustrations, photographs, physical models and 2D images in textbooks.

In the healthcare discipline, anatomy is fundamental, as the human body is the target for investigation. Romand et al. (2020) showed that sufficient anatomical knowledge leads to safe and quality healthcare practices, through understanding the decision and action taken. Due to its importance, learning anatomy should be as effective as possible in terms of accurate information and resilience. In this way, cadaver dissection is rated the gold standard for learning human anatomy (Triepels et al., 2020). However, there are several practical constraints, such as the limited availability of cadavers, high-cost of maintaining them and limited lab opening hours. Other challenges associated with learning anatomy include its complexity; learners find difficulties in learning and remembering anatomical information (Triepels et al., 2020; Uruthiralingam & Rea, 2020).

The possible explanation for this difficulty could be practical limitations, such as difficult concepts in a large group of students, leading to passive participation during the class, and a massive amount of material to be learned (Romand et al., 2020). This issue is confirmed by Triepels et al. (2018), who that showed although students believed the importance of sufficient anatomical knowledge, almost half of them rated their knowledge as insufficient; the study suggested that using three-dimensional techniques could help to solve this issue. With the 3D model, students can rotate and manipulate structures from different views to recognise the anatomical structures (Munzer et al., 2019). In contrast, a scoping review study argued that there was no substantial evidence that using 3D models is better than traditional teaching methods. However, 3D models in digital and physical formats were favoured by students in comparison to textbooks (Azer & Azer, 2016). A recent systematic review stated that computer-based, virtual or augmented reality learning methods were more effective anatomical tools in general compared to traditional methods based on learners' test scores. Students were motivated and interested in using the new visual methods to learn anatomical structure (Triepels et al., 2020).

Several advancements in technologies and techniques have provided more resources that aid in teaching anatomy and providing easy access to educational resources, such as AR and VR (Uruthiralingam & Rea, 2020). AR provides adequate 3D visualisation of anatomical structures (Chytas et al., 2020), that can also help students to understand the shape and the location of the organ (Thomas et al., 2010). Previous studies' findings reported significant improvements in acquiring anatomical knowledge by utilising AR learning tools (Gerup et al., 2020; Salmi et al., 2015).

A recent systematic review study by Uruthiralingam & Rea (2020) revealed that most of the articles were on the use of AR and VR in anatomical education. However, they should not replace human cadaver dissection; instead, it can be used to complement the resources available to the learners. Similarly, a review study by Chytas et al. (2020) also showed there was an acknowledgement in the literature that AR can be an accepted anatomy learning tool offering enjoyable learning.

2.3.2. Training and acquiring skills

Many AR applications have been viewed as valid and reliable methods of training in the field of medical professional training; it provides a fundamental and situated learning experience. For example, in a high-risk environment such as the operating room, AR has the potential to bridge the gap between achieving the required competence in the real world and making mistakes. Better training the surgeons in a virtual environment, ultimately, leading to making fewer mistakes in the operating room by creating an authentic simulated experience that is enhancing learning acquisition and retention (Barsom et al., 2016).

Bifulco et al. (2014) investigated the feasibility of using AR to guide the untrained user with limited knowledge to correct usage of ECG medical devices with minimal errors. The study reported that when all the participants completed the ECG test with only AR supported instruction, they were able to carry out the completed test firstly on a manikin then on a real patient. The possible explanation for achieving independent training could be the well-designed procedure. The study implemented a careful analysis of each ECG procedure with subdivided it into simple steps considering all possible sequences.

Additionally, AR has been used in training and acquiring skills in an ultrasound simulator with a head-mounted display; the system allowed the user to visualise the simulated ultrasound slice and human anatomy, the training procedure including synchronised feedback. In reality, teaching how to use the ultrasound can be achieved through training on volunteers, who are generally in a healthy condition. However, using AR simulation can enhance the training by including unhealthy patient cases such as internal bleedings (Blum et al., 2009). Similarly, (Magee et al., 2007) used low-cost AR ultrasound-guided procedure to simulate images and anatomy for interventional radiology training and education, due to there being no specific mechanism for actual feedback in the study; participants were therefore not considered to feel realistic about the procedure. With regard to the goal of effective learning in simulation-based medical education, fifty-one of the 109 studies in a systematic review by Issenberg et al. (2005) reported that providing feedback is an essential feature. Educational feedback enhances acquiring the proper medical skills and allows students to self-assess and monitor their progress. The feedback can be in 'real-time' during the simulation or post hoc after it (Issenberg et al., 2005). Thus, feedback and careful analysis of tasks should be considered when developing an AR learning tool in a clinical setting. Moreover, AR shows potential in supporting the blended learning of medical training, when the students can learn outside the class (Barsom et al., 2016).

2.3.3. Nursing clinical education

In any healthcare curricula, clinical education is an essential component; clinical practice occurs when the learners are exposed to real patients in a clinical setting environment (Rowe et al., 2012). Alternatively, patient simulation is a practical approach for training students before entering the clinical environment; it utilises patient manikins that allow learners to acquire mandatory skills and practice without worrying about harming real patients (Chaballout et al., 2016). Practicing with a manikin can be achieved in a clinical or a simulation laboratory. The terms "clinical skills lab", "clinical lab" or "skills lab" throughout this work refer to patient simulation training approaches.

The goal of a clinical skills lab in nursing education is to prepare students to develop, apply and practice the theoretical knowledge and skills as safely and effectively as professional nurses (Häggman-Laitila et al., 2007). Moreover, most universities adopt clinical skills labs, considering the facilitation of nursing students' clinical preparations. It improves the transition as smoothly as possible to the real-life nursing experience, by bridging the gap between theory and practice, and providing a safe environment for nursing students to practice the necessary skills. Consequently, the clinical lab is essential to nursing education in order to achieve clinical learning outcomes and improve students' competence. Simulating a critical situation by blending digital elements with the physical in a clinical skills lab creates a promising opportunity for the education of nursing professionals in a safe environment (Barsom et al., 2016). However, developing practical knowledge in nursing education is a complex process and it is difficult to teach. The primary evidence in the literature states that integrating blended learning, which utilises technology-enhanced teaching alongside traditional approaches in clinical education, offers the opportunity to improve clinical competencies among healthcare students (Rowe et al., 2012).

Within a clinical skills context, where outcomes are measured in terms of clinical competence, the challenge for educators is to maintain the careful balance between giving instruction and promoting inquiry, so that efficient and effective skills acquisition occurs in a short time (Docherty et al., 2005). AR, on the other hand, can build capacity in the lab session, as having the AR resources available on mobile devices and at the bedside reduces the learner's frustration from not getting immediate support from the lab supervisor (Garrett et al., 2018). Also, with AR learning, teachers can support an active role in directing the students and facilitating their learning, rather than being the centre of the learning experience.

Additionally, providing students support to facilitate the development of clinical skills education is another challenge (Rowe et al., 2012). Camba & Contero (2015) stated that learning a complex concept can be improved if the teachers incorporate teaching methods that are interactive, student-centred and take advantage of new technology. In this regard, AR technology supports attractive and engaging learning materials by promoting the development of visualisation, self-assessment and self-regulated learning (SRL). Moreover, AR has been used in nursing education to provide a more authentic learning experience than manikins can. It holds the promise of improving the realism of the simulation lab, and students have reported that practicing in a real experience environment enhances their motivation (Vaughn et al., 2016).

On the other hand, "situational learning" describes the uniqueness of healthcare education, when the learners are required to be in a real or simulated environment to boost their familiarity with a clinical setting (Sen et al., 2018). After facilitating nursing clinical skills acquisition outside the lab, a previous literature review demonstrated the need for directed learning away from practice and limited class time; the study claimed that an effective technology-enhanced environment could play a role in learning outside the lab (Petty, 2013). Another review study of the use of AR in medical education revealed that AR helps to facilitate real-life situational learning, which leads to enhanced competencies in clinical procedures (Sen et al., 2018).

Additionally, the COVID-19 pandemic has brought unprecedented challenges to many schools of nursing worldwide; learners are restricted from attending face-to-face classes and "hands-on" clinical experience. Most schools have been required to shift to an online teaching format only. Consequently, there is a need to find an online clinical replacement solution during the crisis (Benner, 2020). AR and VR simulations have been used alongside other educational strategies, during the pandemic to support clinical competency utilising the online format (Konrad et al., 2020). There is evidence that practicing simulated experiences at any level is an effective way to support students' learning and the development of clinical skills (Aebersold, 2018). An authentic experience provides more reliable patient information that is similar to clinical practice.

Accordingly, the importance of realism in a clinical lab cannot be neglected. A pilot study integrated AR (wearable google glass) on top of a manikin to project a simulated video of a patient scenario into the student's field of vision. The result showed that enhancing realism in clinical simulations increased the students' confidence to perform necessary tasks in a real clinical environment (Vaughn et al., 2016). An equivalent experience was reported by Chaballout et al. (2016); the result proved the feasibility of AR in enhancing realism in the clinical lab by using Google glass. However, technical challenges were also reported. For example, it took longer to train participants on how to use Google glass, which may affect their perception of the usefulness of AR as a learning tool. Thus, the affordability of mobile AR provides one of the best platforms for setting a real clinical or laboratory environment as a background to classroom activities (Sen et al., 2018). Moreover, the enjoyment of interacting with AR may impact on nursing students' learning and motivating them to be active learners.

This research integrates 3D models to support realism and blended learning concepts to achieve a connection between the theoretical explanations and the laboratory practices by using AR as a nexus.

2.4. [Content-3] Related work

The number of empirical studies focusing on AR in nursing is limited, and most have evaluated the AR prototypes used in a broad clinical setting or nursing education (Wüller et al., 2019). This result is unsurprising; a similar result was reported in other disciplines; a possible explanation, besides the expensive development of the AR system, is that there is a lack of people with the required technical skills. According to Immerse UK and Digital Catapult (2019), mind and skills gaps are barriers to immersive UK's economic growth; there is a lack of technically skilled and creative workers, so a leader who understands both the technical and creative aspects of the technology is needed. Not having sufficient skills when graduating from universities is another reported issue. Those challenges prevent researchers from developing large scale AR project.

However, this section describes previous studies conducted in teaching anatomy or clinical nursing skills by utilising AR technologies. It discusses the learning theories, learning activities and the type of input/output devices. The section ends by proposing features of the nursing MAR learning environment.

2.4.1. Virtual 3D atlas of a human body by (Hamrol et al., 2013).

The study has developed an application which is divided into four main sections: (1) lecture, (2) exercise, (3) immersive exercise (Figure 7) and (4) test. In the lecture mode, the lecturer used a predefined scenario to carry out class activities on a specific physiological, pathophysiological or anatomical problem. He used the system instead of traditional lecture materials. However, students observed the system through a large-screen projector during the classroom.

In the exercise mode, students were able to interact freely with the virtual human body. They utilised standard computer monitors as display screens during their practical classes. Also, they received copies of the system for practicing the exercise mode on their private computers.

The third mode was immersive exercise; the user was wearing the HMD, which was equipped with markers of the optical tracking system. S/he has been moving around the virtual body by literally moving around the room. Gestures performed by the user achieved all of the system functionalities. For example, they were touching of the selected tissue to hide it or using a two-hand slide to change the position of the section cut.

In the fourth section the authors suggested adding tested mode, but it was not functional and it did not test during the evaluation phase.

Even though the concept of the interactive 3D application has a positive influence on the educational process, the system was hard to operate. This was especially true in the immersive mode, as a qualified VR technician was needed every time to ensure the comfort and safety of the HMD during the exercise. Also, students were not able to practice the immersive mode outside the classroom due to the difficulty with making the system available to the students. Unfortunately, the very complicated input/output devices lead to the need for another simpler and cheaper solution. For example, in the case of mobile AR, the input and output is the same device, and its mobility feature allows the student to practice the immersive mode much more accessible and cheaper at any time and everywhere. However, the researcher should investigate the latest AR technology, which is a mobile AR system. It is a smartphone application that is integrated with an AR feature in one device. This new technology offers a learning experience which is linked to the formal classroom activities, so students can learn outside of class hours and outside of school limits (Saidin et al., 2015).

Missing the pedagogical approach is another limitation. The study did not clearly consider learning theories while developing the system. According to the review of AR in education, most of the studies did not define using the pedagogical approach. Instead, they just focused on integrating AR technology into classroom activities and evaluated the findings concerning educational outcomes (Fatih & Omer, 2017). Therefore, there is still a lack of guidance for integrating AR technology with learning theories and a lack of guidance evaluating AR educational applications (Da Silva et al., 2016).

Figure 5: Immersive exercises, Image source (Hamrol et al., 2013).

2.4.2. Using AR to learn human anatomy by (Salmi et al., 2015).

This study developed a prototype of the mobile AR application called Human Anatomy (HuMAR) as an educational tool. It was designed to enhance students' motivation in learning skeletal structure in a complex subject such as anatomy. This subject includes learning anatomy in the practical dissection laboratory, where the students exposure the structure of the human body and internal organs. The practical class allows students to learn more complex parts of the human body. Even though the practical session is essential, students have difficulty accessing the laboratory due to the limited operating hours and limited physical material. This problem could be solved by introducing MAR features which support learning complex subjects.

The study adopted ubiquitous learning concepts which mean learning to accrue in the workplace in educational place, and the home. The simplicity and mobility of the mobile device allow more effective learning and the detainment of knowledge. With the MAR application, students should be able to enhance their learning environments and improve their ability to retain information. An experimental method was conducted to measure the reliability of the HuMAR application. The students evaluated the MAR reliability features. The table 6 below describes each feature and its learning benefits.

Table 5: Learning benefits of each MAR feature

MAR Feature	Learning benefits
The realism of the 3D model	The 3D model characteristics provide a realistic environment which can increase an individual's motivation to learn. This is due to the ability of an object in 3D to hold interest and attention in the learning process.
learning improvement	The 360° angles (x, y, z-axis) enable the learner to learn about an object with more precision, especially in identifying the exact position of the subject matter
View angle for stimulating interest and motivating learning	The ability to change the view position of the 3D model makes for more motivating and exciting learning
Object manipulation	The power to control the objects (e.g., rotate, scale, and move) within the AR learning environment encourages learning and makes it more exciting. It provides the ability to manipulate the object and to see the subject in detail. This manipulation signifies the capability of interaction.

The study results showed that students were satisfied with MAR features and interested in utilising it in their learning process. Also, they rated the object manipulation with the highest score, which led to MAR having a substantial capacity to convey info and make learning interactive. According to the author, object manipulation was considered as one of the essential factors in the MAR learning environment.

Moreover, the study stated the positive impact of MAR in stimulating students' learning environments and promotes their motivation to learn. Studies showed that the level of motivation and enhancing the learner's experience could lead to a more robust student-centred learning concept. They impact the ability of individuals to achieve their learning objectives in their learning process (Huang et al., 2010; Petty, 2014; Rahn & Kjaergaard, 2014).

There is a need for further investigation into the effects of MAR on students' independent learning. MAR could be very useful in motivating students' learning and enhancing their ability to become passionately involved in their learning process (Iván et al., 2015; Lee & Hutchison, 2014; Sampaio & Almeida, 2016; Solak & Cakir, 2015; Wei et al., 2015).

2.4.3. Using AR to enhance the realism in clinical simulation by (Vaughn et al., 2016).

As the current manikin has limited capability to supply sufficient realism in the simulation lab. This study described the piloting of utilised an innovative hybrid simulation to incorporate video film using an augmented reality headset. It was designed to increase the perception of realism in high-fidelity simulation. While students performed assessments on a manikin in a simulated lab scenario by wearing Google glass, a wearable head device was simultaneously projecting video onto the students' field of vision. The video combined visual images and cues seen in a real patient and created a sense of realism that the manikin alone could not provide. It allows learners to more fully engage in the scenario and understand what is happening to the patient.

The scenario was developed and recorded on YouTube because Google glass has easy access to YouTube videos. The video combined the visual images and auditory cues that would be seen in a real patient experiencing a respiratory deterioration and created a sense of realism. A simulated patient is an actor who portrays specific physical symptoms in a scenario to fulfil the learning objectives. The video displayed these clinical manifestations and functioned as a prompt for students in their assessment of the patient.

The students who completed the simulation were then asked to respond to a Web-based survey immediately following the experience.

They reported that the simulation gave them confidence that they were developing skills and knowledge to perform necessary tasks in a clinical setting and that they met the learning objectives of the simulation. Also, they stated that using such a learning tool better prepared them for caring for a patient in respiratory distress, explicitly improving their recognition of signs of respiratory distress and improving their knowledge base. An unexpected result from the study was that students reported that they found that realism enhanced their motivation. The realism of the technology contributed to independent problem solving, which they found motivational. They enjoyed utilising AR during the simulation lab. The learner is engaged and becomes a motivated problem solver in this enhanced more authentic simulation.

In term of the assessment, one to two Certified Healthcare Simulation Experts (CHSEs) evaluated students' skills during the simulation lab. They were present to facilitate the simulation and evaluate whether the students met the objectives or not.

2.4.4. Using AR to learn the anatomy of the lower limb by (Ferrer-Torregrosa et al., 2015)

The motivation to learn science is defined as an internal state that maintains science-learning behaviour; for this reason, the development of tools promoting motivation and independent learning is widely justified. The study developed a new learning tool called ARBOOK (Figure 8). It was designed based on augmented reality technology focusing on teaching the anatomy of the lower limb. The book had two sections: descriptive and cards. The card was a marker that can be recognised by a webcam connected to the desktop computer. Then, the virtual 3D model appeared on the screen. Students were able to interact with the model and modify the actual position of the virtual structure by moving the card. The study investigated the role of AR in terms of motivation and independent learning. A total of 211 students from 7 public and private Spanish universities were divided into two groups. The control group received standard teaching sessions supported by books and videos. The ARBOOK group received the same standard sessions but additionally used the ARBOOK tool. Once the learning sessions finished, the application was closed, and all of the students responded to the online questionnaire. In terms of assessment, a short writing test was carried on in order to identify whether ARBOOK could result in a better test performance or not.

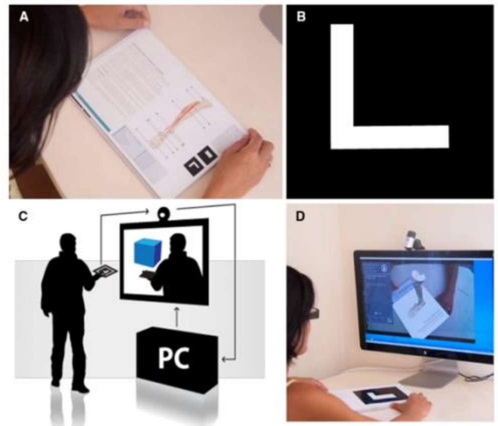


Figure 6: ARBOOK project, image source (Ferrer-Torregrosa et al., 2015)

The study result showed statistically significant differences between the two groups with better scoring for the AR group. The study concluded that ARBOOK is significantly better than conventional methods promoting motivation and autonomy. The author stated that with current technologies, the development of tools promoting self-learning and autonomous work must be seriously considered for anatomical training and other sciences. The motivational learning environment can lead to students developing self-learning skills (Ferrer-Torregrosa et al., 2015).

2.4.5. Using AR as a visualising facilitator in nursing education by (Rahn & Kjaergaard, 2014)

The study worked on a proof-of-concept that the AR application creates an illusion of seeing a person's lungs breathe within that person. The app was developed to show a set of natural-sized, moving and breathing lungs (Figure 9). In the production of the actual images of the lungs, a realistic and accurate representation was more important than a fancy and appealing "wrapping" and interface.

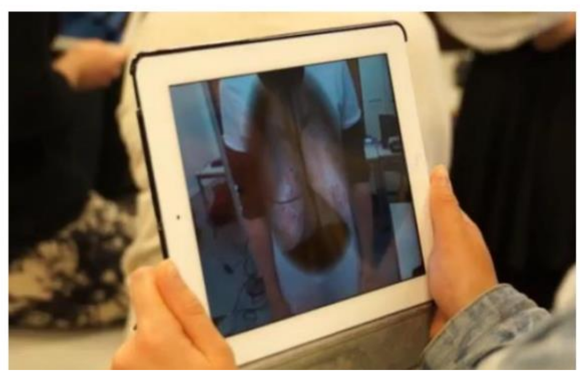


Figure 7: Lungs *in situ* through the iPad, image source (Rahn & Kjaergaard, 2014)

The author discussed the potential of integrating AR app as an educational tool within the context of nursing education to create a learner-centred perspective through an inquiry-based approach. The application focused on the lungs as understanding their working is complicated. Usually, the teaching takes place with students in relatively passive roles and with visual aids that are static or fragmented in their nature, or both. AR might help to facilitate the learning processes through the visualisation of 3D-images *in situ* and through the activity that students are engaged in while working with the app.

The system had an iPad application and T-shirts with printed logos as markers. Students worked in groups of 4-5. For the experiment, three students wore the T-shirts with a tag positioned on the front and back of the shirt. The iPad is providing the illusion of lungs being located and moving inside the person wearing the T-shirt. This allowed other students to investigate with the iPads.

The study drew inspiration from the principles behind Inquiry-Based Science Education (IBSE). It emphasises the way to actively involve learners in the learning process. The approach drew on a social constructivist understanding of learners creating meaning and sense of the world around them through the creation of individual and shared explanatory models. In this way, students construct their understanding through reflection during exploratory processes.

The results showed that the AR app provides a much more realistic image of the lungs than a textbook. Students viewed the images that became available through AR as an essential factor in their whole-body understanding in the subject of anatomy and physiology. Their focus was on the topic, and they sought knowledge of the human body's structure and functions. They were quite explicated about the increased physiological understanding arising from using this new learning approach. Also, the system made the reading less 'heavy' due to the image appearing immediately as the organs look like and how they work.

In terms of the degree to which the app presents real or realistic images and movements, students judged this as more illustrative than other apps they have previously worked with. It was clear that the 3D images provide students with knowledge of the position of the lungs inside the body. Thus, the images aid students in the adaptation of their already constructed mental image.

According to the students, AR enhanced their understanding of lung anatomy and physiology. However, the learning tool was a useful supplement to the textbook, as something to be used together with the textbook, rather than as a replacement.

2.4.6. GIGXR platform

The company GIGXR has developed a healthcare simulation learning platform that includes two sections HoloPatient and HoloHuman. The commercial platform facilitates anatomy learning and clinical skills practising via utilizing mixed reality technology. The HoloPatient section delivers serval patients' scenarios, and the instructor can create a session and share the scenario via wearing Microsoft HoloLens. Students can join the HoloPatient session on their smartphone devices simultaneously, and they can also participate remotely from their homes. The GIGXR aims to support active and collaborative learning by enabling learners and instructors to interact with immersive materials. However, the learners are not able to access the HoloPatient after ending the session (https://www.gigxr.com/).

2.5. [Content] Conclusion

The Table 7 below summarises the studies discussed above. Even though some stated that AR enhances independent learning and supports shifting to a student-centred learning approach, they did not describe how the AR system was designed to achieve that. This research addresses this gap and proposes a new learning approach that might support self-regulated learning by adding self-assessment and feedback features to the AR system. More details about the theoretical background are provided in the next section.

Table 6: Summary table

Article	Learning theory	Anatomy	Pathophysiology	Scenario	self-assessment	Input/Output devices
Virtual 3D atlas of a human Body by (Hamrol et al., 2013).	-	√	√	x	x	(large-screen projection) for lecturer (standard computer monitors or mobile application) for home studying (Head-Mounted Device equipped with markers of the optical tracking system) for Immersive exercise
Using AR as a visualising facilitator in nursing education by (Rahn & Kjaergaard, 2014).	Social constructivist Inquiry-Based Science Education	√	√	x	x	IPad
Using AR to learning human anatomy by (Salmi et al., 2015).	Ubiquitous learning	√	x	x	x	Android tablet
Using AR to learn the anatomy of the lower limb by (Ferrer-Torregrosa et al., 2015).	-	√	√	x	x	digital webcam connected to a computer
Using AR to enhance the realism in clinical simulation by (Vaughn et al., 2016)	-	x	x	√	x	Google Glass, a wearable head device
GIGXR platform	The clinical reasoning cycle	√	√	√	x	Microsoft HoloLens, smartphone devices.
Proposed MAR	**Problem Based learning**	**√**	**√**	**√**	**√**	**Mobile device**

2.6. [Pedagogy] Theoretical background

One of the benefits of utilising AR in the educational process is supporting self-learning. From the pedagogical point of view, terms such as self-learning, independent learning, learner control, or self-management can be translated into Self-Regulated Learning (SRL) theory.

This section covers the pedagogical aspect of the research. It reviews the existing relevant literature on SRL, especially with technology-enhanced learning. It proposes the theoretical background that guides the educational perspective during the development phase. The outcomes of this section achieves **OB2** and contributes to answering **RQ1.**

2.6.1. Self-regulated learning SRL

SRL contains metacognitive, cognitive, motivational, behavioural, and emotional aspects of learning. Zimmerman (2002) described SRL as a process comprised of metacognitive, motivational, and behavioural strategies that students use to acquire academic skills.

Also, it can be described as an active, constructive process whereby students set goals for their learning based on experience and the contextual features of the current environment (Zhao, 2016). The individuals take responsibility, with or without the help of others, in diagnosing their learning needs. Therefore, it is an extraordinary umbrella under which vast numbers of learning-influencing variables are studied within a comprehensive approach such as self-efficacy, volition and cognitive strategies (Panadero, 2017). As a result, SRL has become one of the most important areas of research within educational psychology, and many models of SRL have been introduced, such as models proposed by Boekaerts (1997), Greene and Azevedo (2007), and Zimmerman (2002).

Although some complex models exist, most have a relatively simple structure. In many models, self-regulation is depicted as a cyclic process which involves (1) goal setting, (2) monitoring process and strategies, (3) feedback and (4) self-evaluation (Steffens, 2006).

2.6.2. Challenges in self-regulated learning

SRL is a fundamental attribute in higher education. SRL is learning in which students manage their thoughts, emotions, and behaviours for successful learning outcomes (Zimmerman, 2002; Zumbrunn et al., 2011). Higher education usually expects students to proactively plan, monitor, and assess their learning while maintaining high motivation for their academic learning. However, few students naturally do this well, even at university level.

Authors agree that self-regulation involves several components, “cognitive, affective, motivational and behavioural components”, which supply the learners with the capacity to adjust their actions and goals in order to achieve the desired results in light of changing environmental conditions (Zeidner et al., 2000). Some refer to the components which are considered to play an important role in self-regulated learning: "Students can be described as self-regulated to the degree that they are metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 2002). Others describe the process: self-regulated learning "can help describe the ways that people approach problems, apply strategies, monitor their performance, and interpret the outcomes of their efforts" (Puustinen & Pulkkinen, 2001).

Research indicates that knowledge of SRL strategies is usually insufficient in promoting student achievement; students must also be motivated to use the strategies and regulate their cognition and effort. This interpretation is in line with the research on self-regulation of learning that suggests students must be able to understand cognitive strategies, and how and when to use strategies appropriately. Despite the importance of SRL in learning, research indicated that learners have difficulties with SRL behaviour: students often do not realise that they should regulate their ideas. They do not know how to regulate productively (Kramarski & Gutman, 2006).

However, despite a large number of studies on SRL having been published in the last decades, there is still no universal definition of SRL and each model emphasises different aspects (Roth et al., 2016).

Pandero (2017) has argued that

"SRL models are comprehensive models. Therefore, the validation of the models becomes complex, as it requires either (a) conducting one study with a very large number of variables, or (b) conducting a number of studies with a narrower approach".

Due to the complexity of the SRL research area, there are diverse types of assessment methods; for example, some studies evaluate SRL components, and others evaluate the SRL process (Roth et al., 2016). This research adopts the SRL process as a roadmap to guide the educational perspective in developing the AR artefact. However, evaluating the SRL perspective is out of its scope.

2.6.3. Technology-enhanced learning and self-assessment

New advances in technology have brought challenges and opportunities to education and instruction methods. E-learning environments provide students with dynamic, interactive, nonlinear access to a wide range of information represented as text, graphics, animation, audio, and video, as well as to SRL in online communication as hypertext, e-mail, and forums. Technology-enhanced learning has the potential to be a powerful learning tool for fostering students' will and skill for learning about complex topics. Studies have reported a positive correlation between self-regulation and success rates in e-learning (Liaw & Huang, 2013; Zhao, 2016).

Researchers stress the importance of a cyclical and recursive process in SRL, which utilises feedback mechanisms for students to monitor and adjust their learning accordingly. Recent meta-analytic findings reveal that self-assessment is recognised as an effective evaluation outcome; it has a strong correlation with students' motivation and reaction (Nath Neerukonda et al., 2018). Hence, self-assessment is a key component in SRL (Raaijmakers et al., 2018), and when students adopt an SRL strategy, they are taking responsibility for their own learning, and with self-assessment they are able to assess their own work (Panadero et al., 2017a). West and Sadoski (2011) stated that a study strategy including self-testing is a strong predictor for medical students' grades in the first year, and the authors explained that self-testing with some form of formative assessment increases the acquisition and retention of knowledge.

Moreover, many varied forms of self-assessment have been implemented in the learning process; for example, a very simple type is self-assessment that awards a mark to the student's own work, also called self-grading, while a complex type of self-assessment may include the formulation of formative feedback (Panadero et al., 2016). Researchers have called for moving away from the simpler forms of assessment into more formative self-assessment, allowing the learners to make qualitative judgments about their own work (Panadero et al., 2017).

The aim of designing formative assessment is to aid the students during their learning process by generating feedback that leads them to control their learning outcomes. It should happen in a non-threatening situation, where they can be an active part in the learning process. It has been recommended that integrating formative assessment into the learning process will encourage adoption of independent learning (Evans et al., 2014).

According to a review study, self-assessment interventions have a positive impact on learners' SRL strategies (Panadero et al., 2017). Similarly, a review in healthcare education stated that an interactive technology-enhanced SRL tool has a positive impact on learners' satisfaction and users were engaged and interested in being active learners and participating in their own learning in the form of independent knowledge acquisition. This kind of learning approach is ideal for nursing students with limited opportunity to be engaged in a direct face-to-face class (Petty, 2013). However, the study reported that a technology-enhanced SRL tool might not suit all students, especially those who are not comfortable or familiar with the technology; those students prefer a conventional learning approach.

Finally, previous studies have shown that self-regulation in an e-learning environment is the predictor which explains both learner characteristic, and useful environmental characteristic (Balapumi, 2015; Liaw & Huang, 2013). Moreover, self-regulated students are more inclined to transfer their knowledge successfully from an e-learning system into real-world situations. Thus, this study aims to design an interactive formative assessment with feedback, that may encourage the students to be independent learners.

2.6.4. Automation process

The skills of SRL are developed on the basis of individual and environmental characteristics (Zimmerman, 2002). According to Zhao (2016), the environmental characteristics play an essential role in shaping the self-regulated process in e-learning. Thus, the focus of this study is to create a learning environment that supports SRL strategies by adopting Zimmerman's cyclical model (Figure 8), which is the most cited model in SRL literature. The model has three phases called forethought, performance and self-reflection, as follows.

- **In the forethought phase** the learners analyse the task, set goals, prepare how to achieve them, enthuse about the process with a variety of motivational beliefs, and control the activation of learning strategies.
- **In the performance phase** the learners actually perform the task while observing how they are progressing and using a variety of techniques for self-control to keep themselves cognitively focused and motivated to complete the task.
- **In the self-reflection phase** the learners judge their performed task, making attributions about their achievement or failure. Such attributions produce self-reactions that can impact positively or negatively on how they later perform the task.

Those phases have been considered when designing the NMAR platform that enhances clinical nursing learning.

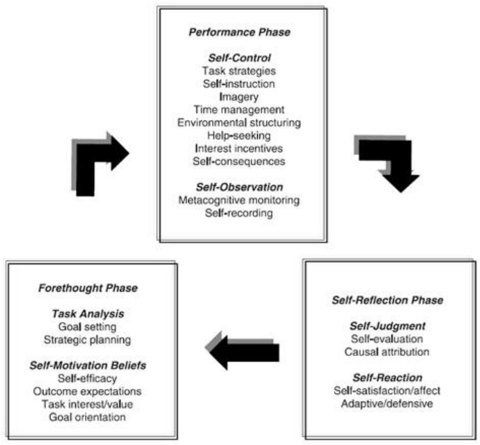


Figure 8: Zimmerman's (2000) cyclical model of self-regulation

Automaticity in SRL usually refers to underlying processes that have become automatic response patterns. It is frequently used to refer to (meta)cognitive processes. Some authors maintain that, for SRL to occur, some processes must become automatic so that the student can have less cognitive load and can then activate strategies (Panadero, 2017). However, it can also refer to motivational and emotional processes that occur without the student's awareness (Boekaerts, 2011).

Within the self-regulation cycle, the proposed NMAR platform has been designed with three automatic processes, which are goal setting, self-evaluation, and feedback. The students play an active role in monitoring their learning progress by adopting MAR learning technology.

2.6.5. Self-regulation goals

In general, studying self-regulation serves the twin goals of providing both theoretical understandings of learning and practical information for designing better educational environments to support learner self-regulation (Pintrich, 2004). In order to achieve those goals, the study adopts the theoretical model proposed by English and Kitsantas (2013) and proposes a new software framework for designing mobile AR in nursing education. Further details about both structures of the model and the framework are discussed in the following sections.

2.6.6. The theoretical model

The current nursing curriculum relies heavily on conventional teacher-centred approaches to student learning. Studies challenge educators to implement student-centred learning approaches (Murphy et al., 2011). For instance, in clinical skills acquisition, the student-centred approach was composed of lecturers providing information and demonstrating activities in a traditional, teacher-centred manner, where students were passive recipients with limited practice under direct supervision. Teachers should step back from their traditional role, and allow students to develop analytical and decision-making skills in simulated practice, by providing quality assured learning resources for students, facilitated by learning technologies (Docherty et al., 2005).

Problem-based learning (PBL) is promising as a pedagogy of integration when applied to the gathering of both internal (class-based) and external (real-world-based) knowledge to solve a problem (Mary et al., 2005). As the problem is presented at the beginning of the learning process, before other curricular inputs, students engage in aspects of self-directed and lifelong learning, taking greater responsibility for their own learning.

Additionally, as human error is inevitable, educators need to plan learning activities to safeguard students and patients alike. Teachers who use PBL in simulation labs can guide unexpected events to ensure that students will be exposed to commonly occurring critical situations, rather than depending on chance during real-life situations. Also, PBL guides the students to think aloud, discover knowledge, think critically and develop self-confidence. It provides a practical clinical teaching approach to guide them in the acquisition of critical reasoning and practical skills (Williams & Beattie, 2008).

In other words, within the clinical skills laboratory context, where outcomes are measured in terms of clinical competence, the challenge for educators is to maintain the fine balance between giving instruction and promoting enquiry, in order that efficient and effective skills acquisition occurs in the short-term (Docherty et al., 2005). A well-designed mobile AR application with mobility and content accessible features provides an opportunity that might overcome this challenge. The next section discusses the link between problem-based learning (PBL) and self-regulated learning (SRL).

2.6.7. Problem-based learning PBL and self-regulated learning

PBL is an instructional approach that students learn through facilitated problem solving that centres on a complex problem and does not have a single correct answer (English & Kitsantas, 2013). Studies show that improving self-regulated skills leads to improved problem-solving learning skills (Kramarski & Gutman, 2006; Raaijmakers et al., 2018). A nursing education study indicated that students can be more active in developing their self-regulated skills when they use problem-based learning. It enhances their deeper understanding of the topic and improves their individual skills (Nguyen et al., 2016).

For example, in this research, the patient scenario section follows the PBL approach, each scenario has a different answer based on the patient situation. Students should investigate each patient's history, age and understand the ECG heart monitor to solve the patient scenario question.However, in order to be successful with problem-solving skills in a course, students should take responsibility for their learning process by setting goals, monitoring, reflecting, and sustaining their motivation from the beginning of the course until the end. This study will adopt the widely used Zimmerman's cyclical phase model (Zimmerman, 2002) and a theoretical model of the relationship between PBL and SRL by English and Kitsantas (2013).

The role of the teacher in the face-to-face classroom has been replaced with the interactive MAR platform. In PBL, the teacher's primary role is to structure activities, stimulate motivation, facilitate access to learning materials, provide feedback, and prompt for thinking. However, the student's role is to take responsibility for their learning and control their understanding. To perform those roles effectively, the learning environment should motivate the students to learn and support themselves to focus their efforts and attention appropriately, monitor and evaluate their progress, and seek help as needed.

Zimmerman (2002) states that "*Self-regulation is not a mental ability or an academic performance skill; rather, it is the self-directive process by which learners transform their mental abilities into academic skills*".

2.6.8. Proposed NMAR learning strategy

Research shows that self-regulatory processes are teachable and can lead to increases in students' motivation and achievement (Raaijmakers et al., 2018). However, the most crucial task for instructional designers and educators is to develop effective learning environments that encourage students to become active, autonomous, and self-regulated learners.

The diagram below (Figure 9) illustrates the proposed new learning strategy in the nursing clinical lab by creating an interactive MAR environment. It shows the relationship between the three phases of PBL and the three phases of SRL based on the proposed model by English and Kitsantas (2013). The teacher's role is to facilitate and support students' development of their SRL skills, especially for those who do not know how to do so. The direction by the teacher will be faded out once the students' self-regulated skills have improved. In the end, students can use the NMAR platform with or without teacher assistance in acquiring clinical skills.

The framework shifts the learning approach from teacher-centred learning to student-centred learning. It supports nursing students with the needed skills to activate their self-regulated learning in acquiring clinical skills, as well as in solving a patient scenario.

Moreover, Table 7 describes seven important aspects of SRL process, the top five aspects were generated from the model, while two more aspects (motivation and awareness) were adopted from the literature. Those seven aspects will be used during the evaluation phase.

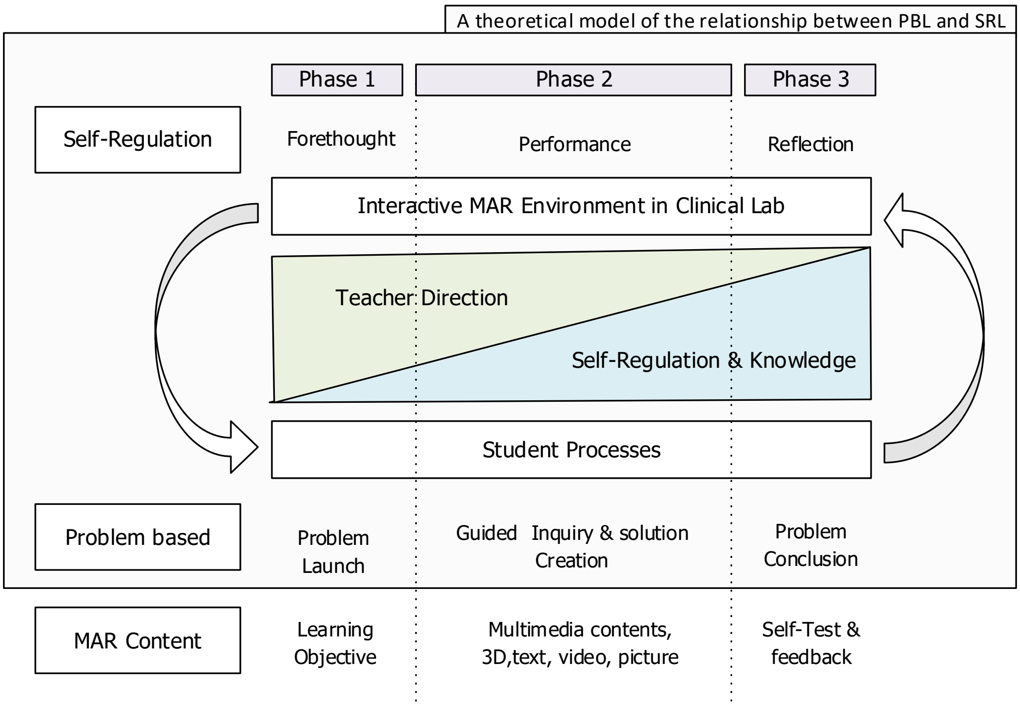


Figure 9: Links between Zimmerman's cyclical and problem-based learning

Table 7: Considerable SRL aspects in the evaluation phase

SRL aspects	Description
1-Goal setting	**During phase 1 (Problem Launch)** a problem is defined with clear learning goals and structured activities leading to support for independent learning and achieving the learning objectives. It supports the SRL skills of goal setting and strategic planning. Moreover, enjoyment is the key factor of AR design technology which might support self-motivation skills through SRL. On the developed NMAR platform, for example, heart disease is the problem in the patient scenario and students should learn heart

	anatomy, blood flow through the human heart, and the reasons behind heart failure in order to solve the patient scenario (where "solving the patient scenario" means achieving the learning objectives).
2-Tasks strategies	**During phase 2 (Guided Inquiry/Solution Creation)** the NMAR platform supports the SRL skills of self-control and self-observation by providing students with sufficient content related to heart diseases. Also, it allows them to interact with the manikin independently. In order to solve the scenario, the NMAR has a video which shows a real patient's symptoms, audio, and a 3D heart model. It allows them to think critically as active learners and to discover the solution.
3-Assessment 4-Feedback 5-Monitoring	**During phase 3 (Problem Conclusion)** the system can support the SRL skills of reflection through self-assessment features. It allows the students to correct their thinking after solving the patient scenario and receiving feedback on their answers.
6-Motivation	Students must also be motivated to use the strategies and regulate their cognition and effort (Kramarski & Gutman, 2006).
7- Awareness	Despite the importance of SRL in learning, research indicated that learners have difficulties with SRL behaviour: students often do not realise that they should regulate their ideas. They do not know how to regulate productively (Kramarski & Gutman, 2006).

2.7. [Pedagogy] Conclusion

The pedagogy section has served to shed light on the theoretical research framework. It has modified the theoretical model of English and Kitsantas (2013), and replaced the teacher's role in a face-to-face classroom with an interactive MAR environment. Also, it has described how the NMAR features fit within the cycle of SLR. The heart's anatomy and diseases form the example case used when developing NMAR platform. Using NMAR allows students the freedom to discover the solution independently and activate their learning. The outcomes have achieved **OB2** and contributed to answering **RQ1**, as well as guided the educational perspective during the development phase.

CHAPTER 3

3. INVESTIGATIVE STUDY

3.1. Introduction

This chapter contributes to the problem identification phase of SDR. After identifying the gap in the literature (discussed in chapter 2), the aim of this chapter is to ensure that the problem has practical relevance.

According to Offermann et al. (2009) achieving this goal requires two sub-goals. Practitioners in the field should be helping to identify relevance and addressing the problems and they should agree with the proposed solution.

In our case, nursing students are the practitioners of the field, and the investigative study was conducted to explore the current learning activities in acquiring clinical skills. The exploration is to understand how the current approach supports independent learning as well as to identify any challenges and limitations (relevance). The investigation also determines the students' willingness to foster their independent learning by using MAR.

To accomplish the chapter’s goals, two research questions and four research objectives were created. The chapter is divided into two sections (Table 8); each section aims to answer one of the research questions and its relevance objectives as follows.

Table 8: Chapter five objectives

	RQs	Research objective
Section 1	**RQ2:** To what extent is independently acquiring clinical nursing skills supported in the current approach?	**OB3:** Conduct an investigative study, aiming to explore how nursing students acquire clinical skills. **OB4:** Identify any limitations of the current approach in terms of supporting independent learning from the students’ perspective.
Section 2	**RQ3:** To what extent do nursing students intend to foster their independent learning?	**OB5:** Identify if the students needed a new learning platform that supports their independent learning. **OB6:** Identify the characteristics of the platform supporting independent learning from the students’ perspective.

The data collection method used was an online questionnaire with descriptive statistical analysis. Therefore, this study focuses on exploring data rather than testing a hypothesis. The outcome helps to understand the limitations of the current learning method of acquiring clinical skills. It also helps to understand the possibility of integrating MAR technology in terms of supporting students' independent learning. Through an HCI lens, this investigative study is the starting point to understanding the users of the system.

3.2. Method

The primary quantitative data collection method was achieved by using a questionnaire as a survey instrument (Robson & Kieran, 2016). It is widely used in nursing research in order to understand the research issues and formulate the problem (Rattray & Jones, 2007). Also, it allows us to easily reach a large number of students from different levels at low cost. In HCI, a self-selected and non-probability-based survey may be the most common data collection method for investigating new user populations or new phenomena of usage (Lazar et al., 2017).

3.3. Questionnaire design

The questionnaire was designed to collect nursing students' perceptions of their current learning in a clinical lab, and their perceptions about mobile AR technology. The questions related to the current learning approach and used a nominal scale, chosen to label and categorise the quantitative data using a simple and straightforward approach. Also, the questionnaire had a section labelled "other". The reasons were giving more flexibility to the respondents' answers and giving the researcher a better understanding of their users.

Moreover, a Likert-type Scale was used to obtain numerical data. The range of the scale was from 1= not important to 5 = very important. The questionnaire was divided into four sections. The first was about demographic information. The second was about current learning activities in the clinical lab. This section helped to explore the limitations and challenges of practising independent learning in the lab.

The third section was about the new technology AR. The last section was about the features of mobile applications that students would prefer to have to support their independent learning.

3.4. Data validity

As threats of validity and reliability cannot be entirely erased, the possible approach that can be taken should minimise invalidity and maximise validity. The validity of the data might be improved by carefully selecting the target group (Cohen et al., 2011). For example, new students were excluded because they did not have sufficient work experience with a manikin in a clinical lab.

Demographic data form another way of determining the validity of the data. They help to establish the validity when respondents are self-selected (mailing list). These data are used to ensure that the responses represent a diversity of respondents, such as students with different levels and ages, and that the responses are somewhat representative of the targeted data (Lazar et al., 2017).

Moreover, increasing the number of respondents can help to establish informal validity. One research suggested that "30 responses should be considered a baseline minimum number of responses for any survey research" (Lazar et al., 2017). This study obtained 108 responses.

To ensure the validity of the instrument, a face validity survey was conducted (Bolarinwa, 2015). The questionnaire was reviewed by 5 participants from the nursing department and 5 participants from the computer science department. They reviewed all the items for readability and clarity. All their feedback and suggestions were considered, and, accordingly, the questionnaire modified.

3.5. Respondents

The population of interest in this study was all levels of nursing students who had to attend clinical skills lab at The University of Salford. The online questionnaire was distributed electronically via an official nursing department email and the WhatsApp group of Salford nursing students on the last term of the year 2018. It included a cover letter that outlined the study's aim and the some definition related to the study objects. The students were asked to provide their perceptions regarding the current learning method in the clinical lab. Participation was voluntary, and all the ethical approvals were obtained before the study was conducted (see the appendix section). The collected number of responses from the students was 120. Among the completed responses, only 108 were found usable for analysis. According to Lazar et al. (2017) the larger the number of responses the better. However, the number of responses gathered was the largest number the researcher was able to obtain for this study.

3.6. Data analysis

Descriptive statistics were used to analyse the data from 108 nursing students. A descriptive evaluation of the data was applied using the Statistical Package for the Social Sciences tool (SPSS). Thematic analysis was also employed to analyse the qualitative data. However, during the analysis, the researcher looked at any statistical differences between the demographic groups by using SPSS, but she did not find any results.

The result helps to explain to what extent the current learning approach for acquiring clinical skills supports independent learning. Also, it determines the willingness of nursing students to activate their independent learning.

3.7. Demographic information

Table 9 below shows the general overview of the participants' demographic information. According to the analysis, 84% of the participants were female and 13% male. Also, the majority of the responses were from year two and their age group was above 30.

Table 9: Demographic information (N=108)

Year	1	25%
	2	38%
	3	28%
	Postgraduate	9%
Age	18-21	26 %
	22-25	11%
	26-30	19%
	Above 30	44%

3.8. Section one: Limitations

This section analyses the collected quantitative and qualitative data associated with the current learning approach, including students' perceptions about independent learning, the current learning methods, the motivating factors as well as preventing factors affecting their ability to learn independently. The section ends by discussing the revealed limitations found through the data.

3.8.1. Quantitative data

The students were asked to rate how important is learning independently when acquiring clinical skills and how often they do that. Table 10 shows that 81% of the students believed that independent learning is important in learning clinical skills, while 18% rated it neutral. However, most of the students reported that occasionally or frequently they learn the patient's scenario independently in a clinical lab, at 53% and 15%, respectively. Only 35% of the students said they never learn clinical skills independently without a teacher assisting.

Table 10: Students' perceptions of independent learning

Independent Learning	Very Important	46%
	Important	35%
	Neutral	18%
	Not Very Important	0.9%
Practising individual learning in clinical lab	Frequently	15%
	Occasionally	53%
	Never	32%

3.8.2. Motivation factors

There are many reasons for motivating students to learn independently in a clinical skills lab. Students were asked what are the factors that motivate them to adopt independent learning in acquiring clinical skills? Table 11 shows that more than half of the responses, 59%, agreed that independent learning is important to increase their confidence and competence. Also, 40% of the responses showed that independent learning forces the learners to use their critical thinking to answer the patient's scenario. Only 1% of the students rated that independent learning in the clinical skills lab will save class time when the lab supervisor is busy helping other students. The participants also commented that borrowing equipment, supporting hands-on learning, and realism are factors motivating them to work independently.

Table 11: Motivation factors

Motivation (N=148)	It forces me to use my critical thinking	59	40 %
	It increases my confidence and competence	88	59 %
	The lab supervisor is busy with helping other students	1	1 %

3.8.3. Learning methods

This part investigates the primarily used method while learning in the clinical skills lab. Table 12 shows that a teacher explaining the patient scenario was the highest-rated method, selected by 82 students. 67 students also practised the patient scenario from written papers while 30 students accessed online resources during the clinical skills lab sessions.

Accessing online resources was the less-common learning method among all students' levels. The crosstab (Table 13) shows that the proportion of year two students commonly using a learning method with a written scenario (31.1%) was more significant than that for using a method with the teacher's explanation (23.6%).

Table 12: Learning methods in clinical lab

Current learning methods (N=179)	Teacher explains the patient scenario	82
	Scenario has been written on a paper	67
	Scenario is accessed from an online resource	30

Table 13: Year2 students commonly used a written scenario

			Student level				
			Year1	Year 2	Year 3 or 4	Postgraduate	Total
learning_methods[a]	The teacher explains the patient scenario	Count	23	25	24	9	81
		% of Total	21.7%	23.6%	22.6%	8.5%	76.4%
	Scenario has been written on paper	Count	10	33	19	5	67
		% of Total	9.4%	31.1%	17.9%	4.7%	63.2%
	Scenarios are accessed from an online resource	Count	7	13	7	3	30
		% of Total	6.6%	12.3%	6.6%	2.8%	28.3%
Total		Count	26	40	30	10	106
		% of Total	24.5%	37.7%	28.3%	9.4%	100.0%

Percentages and totals are based on respondents.

a. Dichotomy group tabulated at value 1.

Many students selected more than one learning method. For example, Figure 10 shows that 25% of the participants learnt through three types of activities, a written paper and online resources alongside a teacher's explanation, while 18% of them learnt through two methods, a written paper and a teacher explanation. Among the participants, few students, 24%, were likely to be independent learners, 56% of them reported they occasionally learnt patient scenarios independently. The figure also shows that 32% of the students who used a written paper or online scenarios needed teacher guidance. It is noticeable from Figure 10 that the current learning depends heavily on the conventional teacher-centred approach in nursing education.

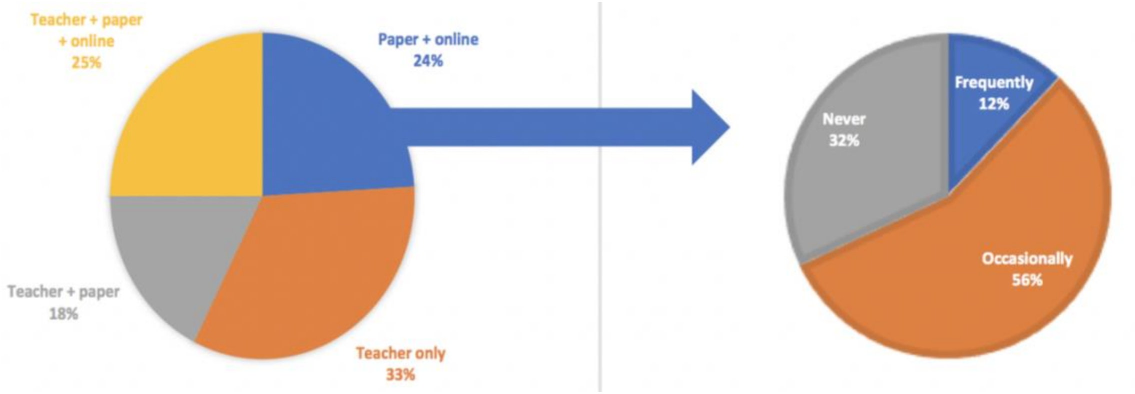


Figure 10: The left chart shows 24% were likely to be independent learners. The right chart shows occasionally they work independently.

3.8.4. Level of independence skills

The selected learning methods of the participants can be categorised into low or high levels of independent learners.

The low-level independent learner: A student who uses teacher explanation methods only is most likely a low-level independent learner.

The high-level independent learner: A student who uses a written paper method or online resource, or both of them, is most likely be a high-level independent learner.

There was a group of students who selected the teacher explaining method alongside other methods. Those students were classified into low or high groups on the basis of their selected answer on factors preventing them from activating independent learning. If the student selected the factor "difficult to understand a patient's scenario without teacher explanation", they were classified as a low-level independent learner. If not, they were classified as high-level independent learners.

The graph in Figure 11 shows that the numbers of students in both groups were nearly the same, with two more students in the low-level independent learners' group compared to the high-level independent learners' group, amounting to 55 and 53 students, respectively.

It is noticeable from the graph that the common learning methods used by each group are different. The high-level independent learners commonly learn more from written paper scenarios during the clinical lab than the teacher explanation.

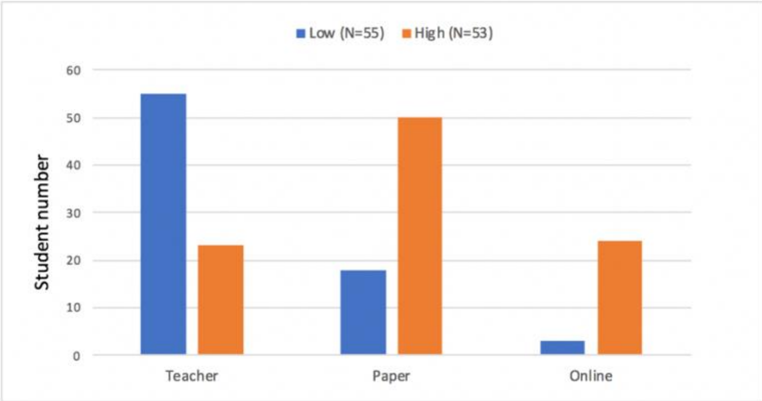


Figure 11: The high independent learners use the written paper

In comparison, the low independent learners rely more on learning the clinical skills from the teacher. The high independent learners also used online resources more compared with few students from the low independent learners' group.

3.8.5. Preventing factors

This section explores the factors preventing nursing students from activating their independent learning in a clinical skills lab. Table 14 shows that there are five main factors preventing students from activating their independent learning in acquiring clinical skills. Many participants (42%) reported that the interactive environment is needed between the patient's scenario, the manikin, and the monitor in order to create an environment that supports their independent learning. As the manikin does not represent a real patient, it eliminates their ability to understand the patient's symptoms correctly, and 38% of participants reported that an explanation by the teacher is necessary to understand the patient's scenario in a clinical lab.

Table 14: Preventing factors

Preventing factors (N=108)	Difficult to understand a patient's scenario without teacher explanation	41	38%
	The manikin does not represent real patient symptoms	47	44%
	I do not have enough experience to create the clear mental image needed for a simulated scenario	33	31%
	Lack of motivation to work independently	12	11%
	Interactive environment is needed between the patient's scenario, the manikin and the patient's monitor	45	42%
	Other	13	

The graph in Figure 12 illustrates that low- and high-level independent learners are facing similar obstacles with different rating scores when they learn independently in a clinical lab.

The low independent group reported that difficulty understanding the scenario without a teacher was the main factor in preventing them from being active learners. Also, they did not have sufficient experience to allow them to work independently. However, the high-level independent group reported that the nature of the learning environment was the main factor in preventing them from working independently. For example, the manikin does not represent a real patient's symptoms, and this group were seeking an interactive environment in order to activate their independent learning.

In terms of motivation, the low-level independent learners had a higher score for the lack of motivation factor, compared with the high-level independent learners.

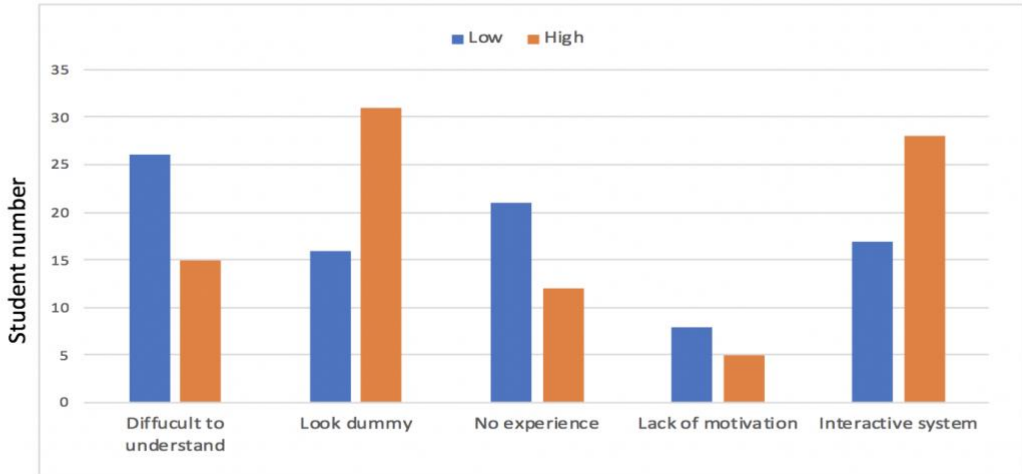


Figure 12: The dummy-manikin is the main preventing factor for the high independent learners

Generally, the realism of the manikin is not sufficient and does not represent the real patient, causing difficulty for the participants in creating a clear mental image to understand a scenario, especially if they do not have enough experience dealing with a real patient. For this reason, the two most commonly rated factors preventing them from learning independently in a clinical lab. They have difficulty understanding the patient's scenario without the teacher's explanation, and a manikin looks like a dummy. Thus, they were seeking an interactive learning environment between the entities of the clinical lab, such as the manikin and the monitor.

In terms of motivation, few respondents were seeking motivation for activating their independent learning. However, many of them requested an interactive environment between the patient's scenario, the manikin and the patient's monitor to activate their independent learning. Figure 12 shows that in general lack of motivation has the lowest rate of all the factors preventing students from activating their independent learning. It indicates that students are motivated to be independent learners, but the current learning environment is preventing them. The findings illustrate that an interactive learning environment and the realism of the manikin are essential to motivate the students to work independently in acquiring clinical skills.

Table 15 compares between the low-level and high-level independent learners in terms of commonly used learning methods, the highest two factors preventing them from activating their independent learning. Then the table classifies the type of obstacles they are facing.

The findings illustrate that the high-level independent learners are facing environmental obstacles whereas the low-level independent learners are facing personal obstacles preventing them from being active learners. The possible explanation is that the learners in the low-level independent group do not have sufficient experience working with real patients; this might be because they did not have sufficient placement hours. In nursing placement students work in a hospital with real-world situations alongside qualified nurse mentors and professionals. It is a chance to apply theoretical knowledge gained in the classroom to real patients in a hospital. Students who have insufficient experience working with real patients rely more on a teacher explaining the scenario for acquiring clinical skills. However, students who are confident to control their learning are most likely to be active learners, if they are provided for by a system that supports independent learning.

Table 15: Comparison between low-level and high-level independent learners (Quantitative data)

	Low-level independent learners	**High-level independent learners**
Learning method	Teacher explaining	Written paper
Preventing factors	• Difficult to understand a patient's scenario without teacher explanation • They do not have enough experience	• The manikin does not represent a real patient's symptoms • More of an interactive environment is needed
Obstacles	**Personal**	**Environmental**

3.8.6. Qualitative data

The questionnaire was designed to allow the participants to write their notes and comments. This section analyses the participants' comments on two questions:

- The reasons for not working independently in a clinical lab
- The factors preventing them from adopting independent learning.

The word cloud of the participants' responses in Figure 13 shows that time is the vital issue preventing students from activating their independent learning. It could be a student's timetable, class duration time, classmate time or time available for booking the class.

Figure 13: Time is the vital issue preventing independent learning

Table 16 below presents the thematic analysis outcomes of the qualitative data. Thematic analysis is a method that aims to identify, analyse and report patterns (themes) derived from data (Braun & Clarke, 2006). The process of creating the themes has been done by following Braun and Clarke's (2006) approach. In practice, NVivo software was used to carry out the analysis. It provides a flexible way to create, examine and revisit the themes and categorise the data. The data included 74 comments written by 62 students.

The results show that there are two main factors preventing students from activating their independent learning in acquiring clinical skills: environmental factors and personal characteristics, each of them has sub-themes, and they are discussed in detail as follows.

Table 16: Thematic analysis results (Qualitative data)

Personal	**Learning environment**
• Lack of awareness • Lack of motivation	• Insufficient class duration • Facilitating conditions • Insufficient number of lab sessions • Lack of realism • Location and time restrictions • Teacher-centred approach • Group study

Insufficient class duration and facilitating conditions

The duration of the class is not sufficient for all the students to practise the scenario independently and increase their confidence. Students reported that "*we only get 30 minutes taught each session*", it is "*not enough time in the actual lab*", so "*the lecturers struggle for space*" and no "*time given to us to use the lab facilities*". Moreover, the participants reported that facilitating conditions is another factor preventing them from activating their independent learning. According to their comments "*rooms are kept locked*" or they "*do not get time or access at university*" and they "*have been told no access*". They added "*it is difficult to book the class*" with "*not enough opportunities*".

Insufficient number of skills lab sessions

According to the respondents, the number of clinical skills sessions within the nursing curriculum is not sufficient for all levels. For example, one student reported that "*the opportunity was never offered within our 1st year of study or to date within my 2nd year*", "*not enough time devoted to clinical skills*", "*we have not had the opportunity to do this for over ten months*". Students from year 3 mentioned "*no simulation time in year 3, have been told no access*". Year two students also noted that they "*are rarely spending time in skills lab maybe once a term or the class is cancelled*", "*we are rarely in there, classes always seem to get cancelled*".

Lack of realism

Students reported that "scenarios just aren't as good for learning as meeting real people", they "prefer dealing with the real patients in placement" because the manikin "is not the same as practising on a real-life patient". The current manikin has limited ability to supply sufficient realism for the students to understand a scenario, and "it would be better if [an] actual patient can say everything". They feel strange when learning with a manikin rather than a real patient. One student commented, "interacting with the manikin is very different from interacting with a real patient, and so it feels very strange".

Lack of awareness or motivation

There are noticeable factors related to the students themselves. Their beliefs or lack of motivation may prevent them from activating their independent learning. For example, students who believe that independent learning is not essential in the skills lab and do not feel comfortable working on their own reduces their ability to activate independent learning and find a time slot within their busy timetable. Example of their comments "*do not feel the need*", "*do not feel comfortable*", "*not on my own*", "*prefer meeting real patient*", "*we have teacher assisted skills which I think I benefit from more*", "*I am focusing on assignments, exams or placement*".

Another factor that stops them from learning independently could be their lack of awareness of the opportunities offered by the university and facilitating booking a room if its available.

A student might neglect to find out how to book and use the equipment outside of the class hours, due to their lack of awareness. They stated "*not aware that this was an option*", "*not aware of how to book time*", "*I never knew I can do it*" and "*do not think we have had the opportunity*".

Location and time restrictions

The location could be a factor related to student or the learning environment. The manikin and its related equipment are placed in the lab; students are not able to borrow them outside the university. Otherwise, they have to study a scenario online on the Blackboard system. However, students commented that they *"need more opportunities to do this at home*" on the basis of their location and availability. Their home location could be far away from the university: "*It is a long way for me to travel to attend a skills session for students only*". Location restriction is another factor preventing students from activating their independent learning.

Furthermore, learner availability is another factor preventing them from attending skills lab in the university, they reported "*never had time*", "*I do not have the time*", "*it is difficult to book the class when I need it*", "*I am too busy*".

Teacher-centred approach (difficult to monitor learning)

It seems difficult to activate independent learning by using the current learning approach. This is because the learning activates follow a teacher-centred approach rather than the student-centred approach. It is difficult for students to track their learning and correct their mistakes independently, especially if the students were not confident about their performance, and they need feedback or confirmation from the teacher. Students expressed their lack of confidence by adding comments such as "*I will practice a skill incorrectly", "it is difficult for you to perform correctly", "unless I am very confident", "to ensure it is being carried out properly*".

Additionally, participants reported that guidance from a professional is essential to "*maximize their learning*" and to ensure that they perform the skills correctly. Their confidence affects their ability to work independently or not. One student said, "*Lack of guidance if issues occur*" prevents them from adopting independent learning, "*especially with no guidance from a professional*".

Group study

Working in a group is a vital activity when it comes to practising scenarios in the current learning approach.

Students sometimes create a scenario, but participants reported that it is difficult for them to practise a scenario outside the class time because "*fellow classmates do not want to take part*", "*other students are less willing to take part actively*" or "*finding time to plan in sessions with other students proves hard most times*".

One of the participants said that in order to practise clinical skills outside the class hours, they need to be "*able to work exclusively with students who want to learn correctly and with the* *same mindset as myself*". However, a classmate may cause trouble "*when they have not listened to the instructions carefully, so do not perform the activity correctly. This makes it difficult for you to perform correctly*".

One of the students recommended that having virtual patients, such as in video clips, on top of the manikin will enhance realism and a better understanding of the scenario, which might activate their independent learning.

3.8.7. Discussion

The quantitative findings in Section 3.8.1 concluded that the majority of students agreed that independent learning is important in acquiring clinical skills. It increases their confidence and competence. Also, it enhances their critical thinking by solving patient scenarios correctly (section 3.8.2).

Section 3.8.5 illustrated that the capability of the current learning process in a clinical lab is limited in facilitating a learning environment that supports independent learning. Students do not have the experience needed to create a clear mental image for a patient scenario. Much of their context comes from learning in the form of classroom lectures or Blackboard resources.

Introducing a new learning environment such as an interactive environment between the patient's scenario, the manikin and the patient's monitor is needed, according to the students. It may maximise the students' ability to activate their independent learning alongside their characteristics, such as their level of confidence and motivation.

The qualitative findings in Section 3.8.6 also demonstrated the environmental and personal limitations of the current learning process in terms of supporting independent learning, such as location and time restrictions, the nature of the learning process, the number of provided lessons, insufficient realism, lack of motivation, and student awareness. All of those factors play a vital role in reducing the opportunity to activate a student's independent learning when acquiring clinical skills.

Our results seem to be consistent with other studies claiming that the teachers are still the centre in the learning process, and they have called to change the focus to more student-centred learning activities. Nursing students could be active learners, and empowering nursing students can be done by adopting new strategies of active learning (Murphy et al., 2011; Willemse et al., 2019; ZarifSanaiey et al., 2016).

Similarly, Solvik and Struksnes (2018) stated that although the clinical lab allows nursing students to understand the concepts of care in a safe environment, a single training session is insufficient to assure their level of skills, students are prompted to familiarise themselves with their clinical procedure before and after the session. In the same study, students reported that the average number of training sessions is very low, thus they have to prepare on their own before their practice at the hospital. Together these results provide important insights into how facilitating students' independent learning is essential.

3.8.8. Section one conclusion

This section has aimed to answer **RQ2** and met the research objectives **OB3** and **OB4**. The outcomes reveal that the learning activities in the current approach rely heavily on the teacher-centred approach during the clinical skills lab. At the same time, students use written scenarios in the class and outside the class by accessing the Blackboard system. The results show that the current learning environment is less supportive of independent learning, due to many obstacles such as lack of feedback, accessibility issues, and lack of realism. Table 17 below combines the current limitations from the findings of the quantitative and qualitative analysis.

Table 17: The quantitative and qualitative findings of current limitations

Personal	Environmental
• Lack of awareness • Lack of motivation • Lack of experience • Difficult to understand a patient's scenario without teacher explanation.	• Insufficient class duration • Facilitating conditions • Insufficient number of lab sessions • Lack of realism • Lack of feedback • Location and time restrictions • teacher-centred approach • Group study • More interactive environment is needed

3.9. Section two: Potential use of AR

This section analyses the collected quantitative data associated with students' willingness to foster their independent learning, including students' perception of AR technology, types of devices carried, and students' preferable features for potential use of AR.

3.9.1. Devices carried

There are different types of devices among students: 88% of the respondents have carried smartphones, followed by laptops and tablets at 26% and 19%, respectively. Although the majority of the students took their smartphones to the class, only 48% of them reported they accessed their devices. They differed from 51% of students who did not access their devices during the lab.

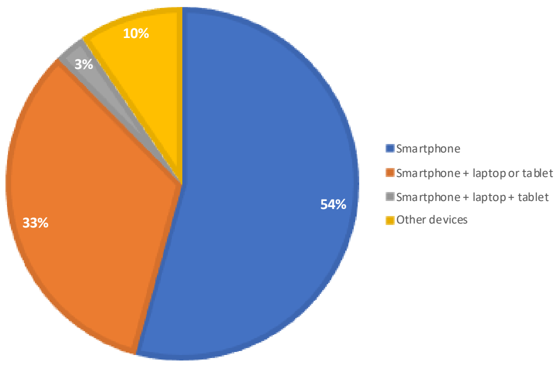


Figure 14: Devices carried during the lab

A possible explanation is that accessing online resources was not necessary during their learning, as our analysis shows that online resources are less common learning methods in a clinical lab.

Figure 14 illustrates that many students carried more than one portable device in the university; 33% of them carried two devices, such as a smartphone and tablet or laptop, while 3% reported that they were carrying three devices. It is evident from Figure 14 that smartphones are wide-spreading among students.

3.9.2. AR background

Students were asked to describe their knowledge of the term “augmented reality”. Figure 15 illustrates that 39% of the students did not have any idea about AR, whereas 36% reported that they have some idea and 9% reported that they have just heard the term. However, few of them, 9%, were able to explain the technology clearly.

An additional investigation was conducted to identify to what extent the participants used mobile AR without knowing the technology itself. Figure 16 shows that most students have used several types of MAR applications such as PokemonGo, Ikea AR catalogue, Google Translate and GPS navigation. Snapchat was the most popular AR application among the participants, as selected by 74 /108 participants. Twenty-two of them reported they had not used any mobile AR application before.

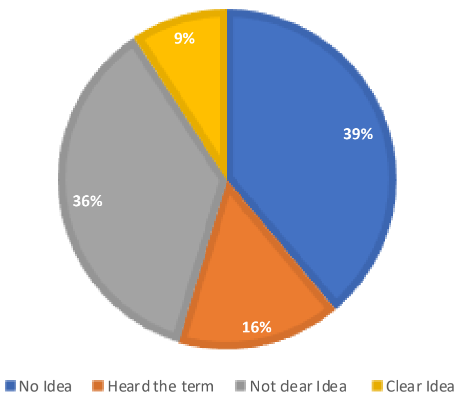


Figure 15: Students' knowledge about AR

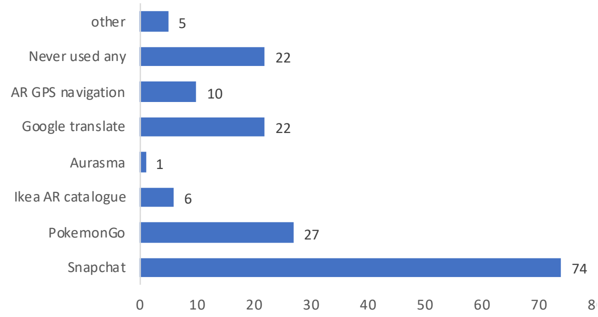


Figure 16: Number of students who used MAR applications

In terms of the purposes, Figure 17 shows some of the reasons why participants downloaded MAR applications, students were asked to identify the purposes of using any AR application. Some of them selected more than one reason. Entertainment was found to be the highest rated reason for downloading MAR, followed by map navigation and shopping, 44%, 18% and 14%, respectively. For example, one of the students commented that she used a "*photo editor like Snapchat, and puts filters over photos, for fun with [her] kids*". Another student commented that his aim was "*social media interaction*". It is remarkable from the chart in Figure 17 that education was rated the least reason for downloading AR applications.

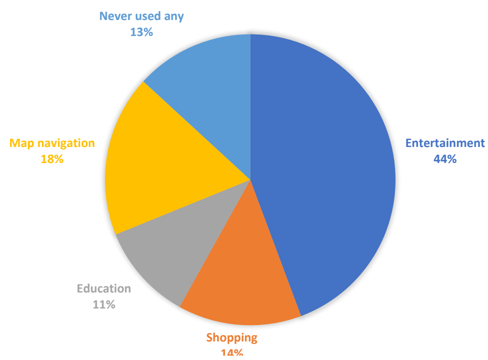


Figure 17: Reasons for using MAR

3.9.3. Discussion

The analysis indicates that many participants used AR technology, but they did not clearly understand its description or definition. Additionally, it shows that the majority of the students downloaded AR applications for entertainment purposes, as selected by 72 students, and this was in agreement with the literature which reports that enjoyment is the key factor for utilising AR technology (Balog & Pribeanu, 2010). Other than entertainment few students download AR applications for educational purposes.

In terms of affordability, the investigation's results pointed out that the majority of nursing students bring their own smart devices to a clinical lab. Other types of devices, such as laptops and tablets, were also carried out during clinical nursing labs. According to Arici et al. (2019), the availability of mobile technology everywhere has attracted educators to adopt mobile learning. The widespread availability of the technology has been confirmed by the Statista website, which shows that recently mobile ownership has increased dramatically, especially among the young age groups. Currently, more than 95% of the population aged 16–24, 25–34, and 35–54 years old have a mobile phone, compared to 88%, 84% and 72%, respectively, in 2014 ("Smartphone ownership penetration in the United Kingdom (UK) in 2012-2020, by age," 2020).

The findings in section one reveal that adopting independent learning for clinical skills with current learning methods are challenging. Ninety-nine percent of the students mentioned that they appreciated having a new mobile application to enhance their independent learning in acquiring clinical skills, indicating they are willing to be active learners once the learning environment supports it. The next section discusses the crucial features of the proposed solution.

3.9.4. AR platform characteristic

This section looks at students' preferred learning media as well as the essential features of the proposed AR system in order to enhance their independent learning.

Preferable learning media

Students were asked if they had tried to learn anatomy by using a 3D model before or not. Also, they were asked to select all their favourite learning media when they study human anatomy concepts.

The majority of them reported they had not learned by 3D before, 79% compared with 39% who had tried 3D models. Figure 18 illustrates that video media had the highest preference score, followed by 3D models and images among both groups who had tried or had not tried the 3D model before.

The text format has the lowest preference as learning media among nursing students, indicating that students prefer visual learning materials compared to text. The possible reason is that visualising the concept may be more attractive and easier to understand than reading text, especially a complex concept that has more details. This result is in line with the multimedia principle that stated that learners learn better from pictures and words than from words only, and presenting both formats allows the students to construct verbal and graphical mental models as well as connect between them (Mayer,2014).

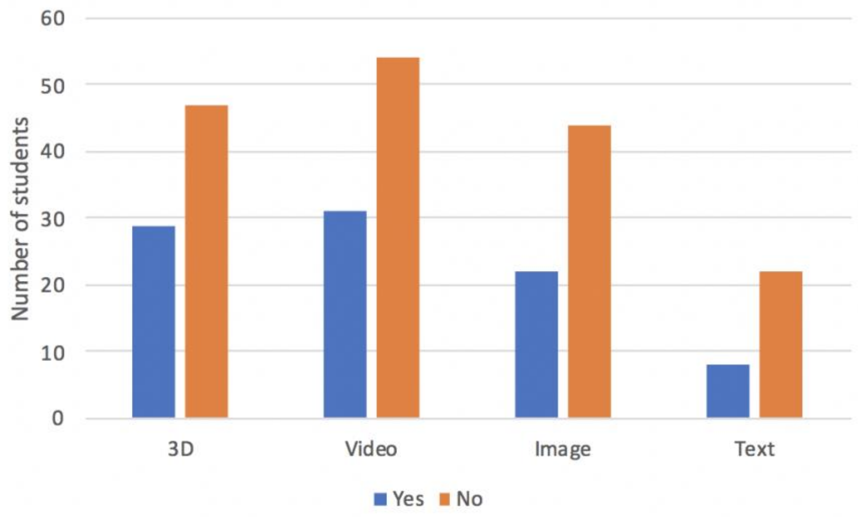


Figure 18: Video is the preferable learning media among the students

Mobile AR features

This section measured the importance of AR features according to a five-point Likert-type Scale ranging from 1 (not important at all) to 5 (very important), the scale items as follows

1. Accessing learning resources when and where I need;
2. Easy to use;
3. Enjoyable tool;
4. Interactive learning environment between manikin, scenario and monitor;
5. Representing a real patient;
6. Resources available "at the bed side" in the clinical lab.

A box-and-whisker (also known as boxplot) presents the respondents' opinions regarding the above six features that were perceived as important in developing a new AR platform to support independent learning. The boxes represent the first and third quartiles, with the thick horizontal line's median values, while the stars indicate outliers (Figure 19).

The analysis shows that the median for all the features has a similar value which is 5. Additionally, it is noticeable that four features "Accessible", "Easy to use", "Real patient", and "At-bedside"; have no boxes or whiskers, indicating that most students scored those features as very important. However, "Enjoyable" and "Interactive" features have more variability opinion among the students. About 50% of the respondents scored those features as very important, and 50% scored as very important, important or neutral. The graph reveals that all the features can be considered important due to the range is between neutral and very important (3 to 5).

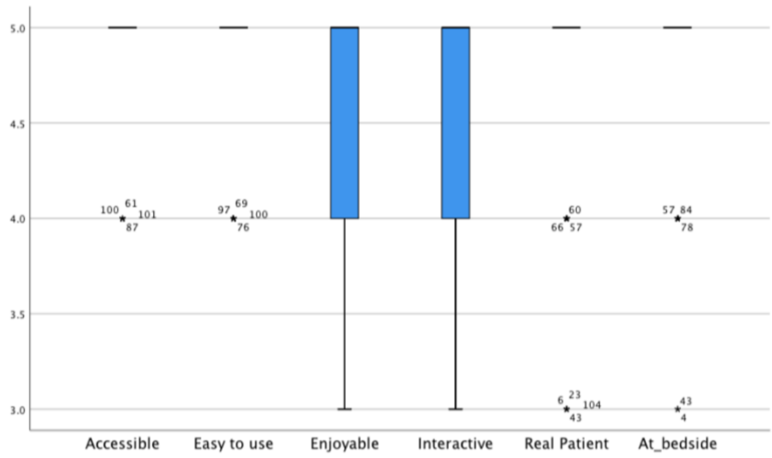


Figure 19: All features of the proposed AR system are important

3.9.5. Section two conclusion

This section has aimed to answer **RQ3** and met the research objectives **OB3** and **OB4**. The findings reveal that some students utilised AR applications for entertainment purposes, others had not utilised it before. Also, the analysis shows that the majority of the students carried their smartphones during the lab. Moreover, 99% of them showed their ability to activate their independent learning if they were supported by a mobile AR learning environment that supports their independent learning.

In order to integrate AR technology into the clinical nursing lab, the current obstacles should be considered when designing the learning platform.

Firstly, the platform should be free of time and location restrictions. Students should have the flexibility within their timetable, so they can learn when or where they need.

Secondly, the platform should be easy to use and free of usability issues. Students should not spend a long time trying to understand how it works. Furthermore, it should support the interactivity between the manikin, monitor and scenario.

Also, it should represent a real patient's symptoms; most of the students reported that they do not have enough experience to create a clear mental image needed for the simulated patient symptoms of the scenario. This is why they prefer the teacher to explain the patient's symptoms during the clinical lab.

If the students need to practise the patients' scenario independently during the lab, the platform should be accessible; for instance, the marker of the scenario which triggers the virtual patient should be placed at the bedside of the clinical lab.

Lastly, one of the key factors in the acceptance of AR technology is its enjoyment. It can influence the intention to use the system significantly. Students who experience pleasure or enjoyment from using a system are more likely than others to develop intention to use it (Balog & Pribeanu, 2010). The enjoyment factor may provide greater intrinsic motivation to learners, as novelty and versatility will result in an element of interest and pleasure associated with usage.

3.10. Summary

This chapter has contributed to the problem identification phase of DSR. After identifying the gap in the literature, it has verified that the problem has a practical relevance.

The findings of the investigative study (in section 1) identify the obstacles of the current approach which have been faced by nursing students while learning independently. For example, during the skills lab, learning activities are more likely to use a teacher-centred approach. The teacher explains the scenario then guides the students to the solution by giving them feedback. After, the class students face many challenges such as accessibility, time restriction, location restriction, lack of feedback and challenges to control their learning.

Also, this chapter has investigated the students' perspectives regarding the new platform, which might enhance their independent learning. Students appreciated having a new platform that will overcome the current learning limitations in term of supporting their independent learning.

The next chapter will propose the solution by adopting a mobile AR technology, and propose a new learning strategy to bridge the gap between the current learning method and independent learning. It intends to solve the environmental obstacles and any relevant learning environment challenges.

CHAPTER 4

4. DEVELOPMENT OF THE NMAR PLATFORM

4.1. Introduction

This chapter focuses on the development process of a nursing learning environment that employs mobile AR technology. The platform is called Nursing Mobile Augmented Reality (NMAR), and the learning activities were designed based on the theoretical background in chapter 2. The heart anatomy and diseases formed the example case used when developing the system. Learning with NMAR introduces a new learning strategy, aiming to enhance students' independent learning by adding interactive self-assessment. Utilising NMAR allows students the freedom to discover the solution independently and activate their learning. The waterfall was the model followed to guide developing the NMAR platform. The chapter ends by proposing the software framework and developing the NMAR prototype in order to meet research objectives **OB7** and **OB8.**

4.2. Immersive learning environment

Learning starts when people are trying to solve problems. With the problem-based learning method, people need to explore real-life situations in order to solve problems and find answers. Using this learning approach within the curriculum leads students to a high level of thinking. In the constructivism paradigm, learning is considered to be an active process in which learners build and create their own knowledge which may consequently be applied in practical real-world situations (Bada & Olusegun, 2015). Moreover, the environment is a key factor in the construction of knowledge because learning occurs in a real-life situation based on problem-solving and critical thinking by integrating pre-existing theoretical builds with new experiences.

An immersive learning environment is described as a technology-based educational system that involves deeply individual senses giving a realistic sense of reality even when the situation is virtual, supporting the user experience. Research indicates the affordances of such a system to facilitate the learning tasks that lead to increased intrinsic motivation and engagement (Ke et al., 2016). Also, it facilitates learning tasks that lead to improving the knowledge and skills transferring into a real situation through the contextualisation of the learning (Dalgarno & Lee, 2012). However, a challenge being faced by educators with today's learning tool is that students should learn wider skills and principles required for work in real life, such as critical thinking, creativity, lifelong learning, and ability to communicate effectively with others (Friedman & Friedman, 2011). Those skills are named "twenty-first-century skills", and acquiring them early in a school may prepare the students more to succeed in their future (Wang et al., 2018). AR technology, laboratory and practical learning activities can be an ideal scenario to promote twenty-first-century skills.

Furthermore, multimedia is characterised as presenting the learning material using both words and pictures. Mayer (2014) stated that students learn better from words and picture formats than words only. Words could be printed or spoken text, while pictures refer to graphs, photos, animation and video formats. Thus, the AR learning environment is applicable in supporting learning materials designing by using multimedia principles.

According to Wang et al. (2018), AR offers learners the ability to explore interactive content actively and incorporate new information into their knowledge on an individualised path of discovery.

4.3. NMAR platform

Our proposed solution introduces a new learning strategy by adopting AR technology and multimedia principle. The solution is to develop a new learning platform known as NMAR, which is designed to allow nursing students to acquire clinical skills independently by utilising their mobile devices. Also, it aims to bridge the gap between the current learning approach and independent learning. The NMAR platform intends to solve the environmental obstacles and any learning environment challenges. Table 18 presents a solution for each environmental obstacle found in the investigative study (chapter 3).

Table 18: The proposed solution

Current environmental obstacles	Proposed solution
1. Teacher-centred approach. 2. Limited access. 3. Manikin looks like a dummy. 4. No feedback mechanism on the blackboard resources. 5. Difficult to control learning. 6. There is a need to facilitate nursing clinical skills acquisition outside the lab. 7. Insufficient class duration for a large group.	1. Student-centred approach. 2. Access anytime anywhere. 3. Virtual patient. 4. Self-assessment. 5. Instant feedback and score. 6. An effective technology-enhanced environment could play a part in achieving learning outside the lab. 7. More independent learning during the class.

4.4. NMAR development waterfall model

A system development life cycle (SDLC) in project management should be planned carefully to ensure all tasks are manageable. The SDLC model describes what the application is and how it should be developed. Fundamentally, it is combined with different phases, from planning to testing and implementing the application (Ragunat et al., 2010). The waterfall model in Figure 20 is one of the most commonly used to determine the success of the system development life cycle (Salmi et al. , 2015). It provides straightforward guidance for developing an application in a linear and sequential approach to delivering at the end, and means for collecting outcomes via evaluation. This model is divided into phases, and the output of one phase is used as the input to the next phase. Each phase has to be completed before the next one starts, and there is no overlapping between phases.

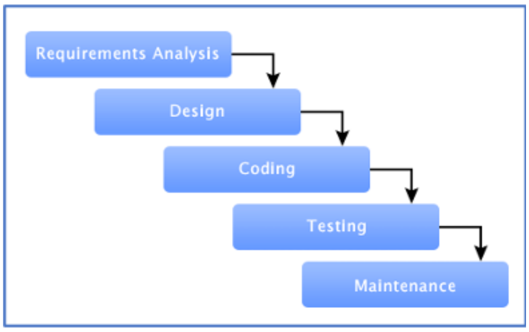


Figure 20: Waterfall model

4.5. Requirements and analysis

Besides the literature review and the investigative study findings, the researcher needed an intensive understanding of the current teaching methods and how students perform during the skills lab. Thus five face-to-face informal discussions with two nursing instructors and one nursing lab technician were conducted. Also, the researcher had an observation session by attending an actual clinical lab. The outcomes can be summarised as follows. During the clinical skills lab, students are not able to view the internal organs of the manikin. Also, the manikin looks like a dummy and students have to deal with imaginary patients in order to solve the patient scenario and imagine their symptoms. In terms of interaction, the patient parameters that are being monitored have to be updated manually by the lab technician based on the scenario. For most of the cases, students are working in groups, since the learning environment does not support working with patient scenarios independently. Finally, the main challenge with practising clinical skills is location restriction, as the manikin is not a portable object.

However, outside the class students access the written scenario via the Blackboard system. The researcher requested a sample of a written scenario which could be used in developing the NMAR platform.

The nursing school at The University of Salford provided a written-paper scenario on heart disease. The paper presented the way to teach students that particular type of scenario. It included the learning resources such as text and video links as well as information related to help students understand the patient's scenario. The researcher analysed all the information about the current approach, then converted it into a mobile interactive learning platform. For example, the initial idea of having three sections in one mobile application was proposed by the nursing educator, and the virtual patient was adopted from the literature (Vaughn et al., 2016), adding the self-assessment section to enhance students' independent learning. Finally, some of the text was replaced by images or 3D models, and the written patient symptoms were replaced by a simulated patient video (Figure 21).

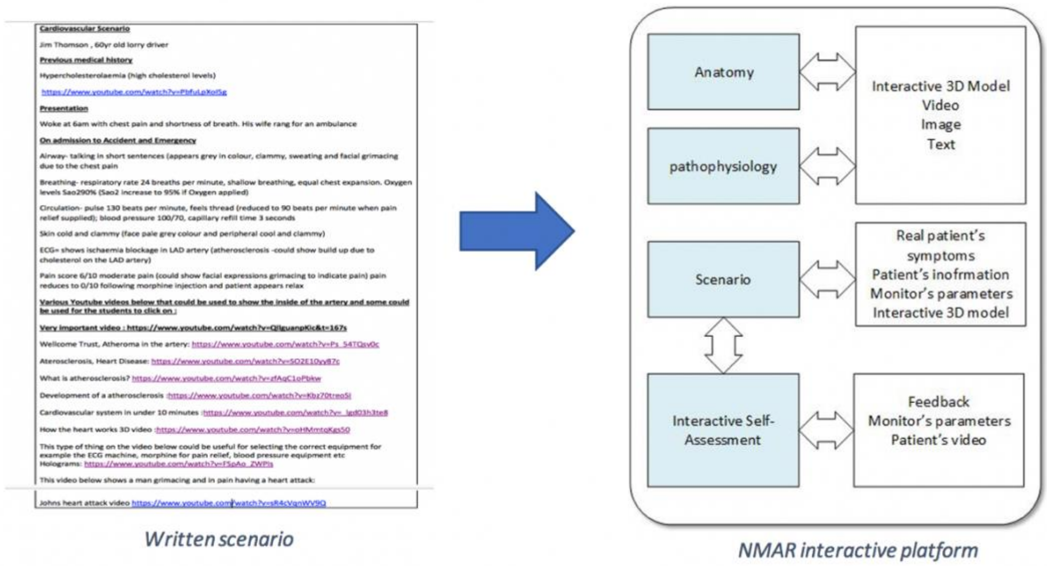


Figure 21: Converted current approach into interactive NMAR platform

4.6. The educational aspects of the NMAR platform

Any educational learning tool should consider its learning objectives. NMAR was developed with the aim to enhance independent learning. In order to achieve that, the platform was split into four sections. Each section has been designed for a particular learning objective, as illustrated in Table 19. Moreover, the initial design of the system sections and their learning objectives was discussed with two nursing educators, they expressed their agreement with the proposed design of NMAR as a nursing learning environment.

Table 19: The educational perspective of NMAR platform

Sections	Learning objectives	Design aspects
Heart anatomy	Understanding the blood flow and internal, external of heart sections	The accuracy of 3D real human heart model helps learners remember the real heart in terms of placements, indentations, and textures. The ability to change the view of the 3D model and interact with it makes for more motivated and interesting learning. Enhancing learning experience influences the ability of individuals to achieve learning objectives. This can lead to enhancement of the self-regulation concept.
Pathophysiology	Understanding how blockage happens inside the human heart.	The virtual contents associated with the pathophysiology of the heart failure section are related to the patient's health condition in the nursing clinical skills lab practice. This achieves the connection between the theoretical explanations and the laboratory practice using AR as a nexus.
Patient scenario	Enhance student's individual learning.	This section allows students to view the real patient symptoms independently, as well as enhancing their independent problem-solving skills when solving the scenario.
Self-assessment	Control students independent learning and correct their mistakes.	The platform presents instant feedback based on the student's answer. Also, it shows their result as a percentage allowing them to track their mistakes.

4.7. Design and architecture

AR markers are defined as "*graphic symbols that contain patterns that are easily recognized by the software of AR*" (Quintero et al., 2019). Any kind of image can be specified as a marker within AR technology by using Vuforia Cloud Target Recognition System (VCTRS).

The NMAR platform adopted the marker-based technique for the registration of the augmented information. The image tracking is based on scanning with a mobile camera and at the same time the corresponding virtual content is displayed on its screen.

In presenting the augmented 3D computer-generated content, NMAR utilised a handheld mobile device (iPad). Its operating system should be at least IOS 12.1.1. Also, it must have a back camera to track the specific AR markers. The back camera captures the real-world surroundings, and the front display screen views the augmentation information.

The NMAR platform uses client-server architecture, where the iPad application communicates with VCTRS. When the user scans the AR marker, a request is sent to VCTRS, and the corresponding metadata is returned as a response.

VCTRS is an enterprise-class image recognition solution that allows developers to host and manage online image targets. It functions as a recognition system that compares mobile application requests with the targets stored in the cloud database in order to find a match. Once a match is identified, the relevant target-bound metadata is returned to the client as a response. Oluwaranti et al. (2015) demonstrated the architectural model of the AR system for a mobile learning application, as shown in Figure 22. AR markers, which are target images, were uploaded to the cloud database utilising the target management system supplied by Vuforia (https://developer.vuforia.com/targetmanager). Vuforia was integrated into the Unity game engine software in order to develop a mobile AR system.

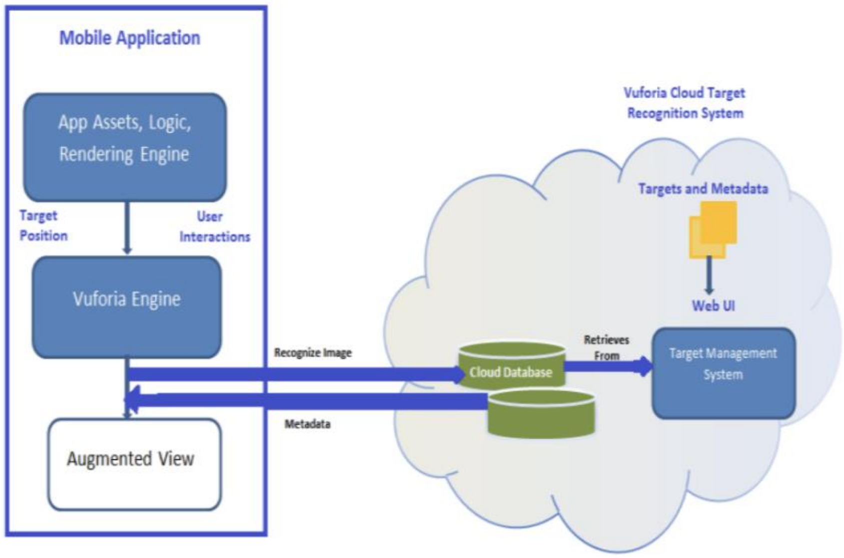


Figure 22: System architecture of Oluwaranti et al. (2015)

Figure 23 explains the dataflow of NMAR platform architecture. The interaction begins with NMAR running on the iPad device. The first step is to point the iPad's camera at the AR marker (image target), the architecture of NMAR starts with a new database, created from Vuforia AR online toolkit and Unity software, the system processes the request, and then the augmented information is displayed on the iPad's screen, allowing the user to interact with the content as shown in Table 20.

Table 20: Fingers gesture in NMAR

Finger gesture	Interaction
Two fingers drag	Zoom in/out
Three figures drag right/left	Horizontally rotate around the object
Three figures drag up/down	Vertically rotate around the object

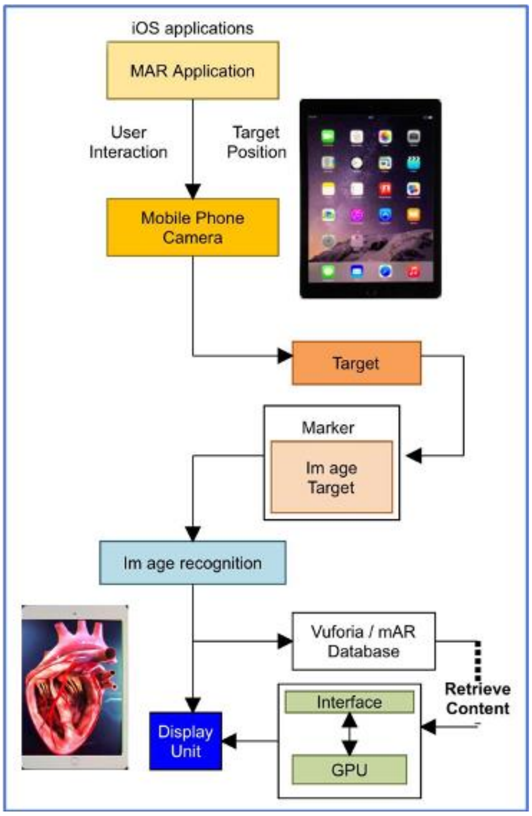


Figure 23: Overview of NMAR architecture

Through an HCI lens, there are four key elements of the design perspective of any product. According to Hassenzahl (2018), they are content, presentational style, functionality, and interactional style. Table 21 below details NMAR features under each of these elements. Those elements will be used later on in the evaluation section to identify the users' thoughts and feelings about their experience with the NMAR platform.

Table 21: A design perspective

Content	Presentational style	Functionality	Interactional style
Heart anatomy Pathophysiology Patient scenario including: Patient's information Patient's symptoms Monitor's parameters Patient's 3D heart Patient's electrocardiogram (ECG)	Simple interface Authentic design of 3 sections Visual information 3D heart Video Image Text	Rotated finger Zooming in/out Self-assessment Instant feedback Showing the correct answer Calculating the score in percentage Interactive patient scenario	Mobile application

4.8. Development process

The implementation of the NMAR platform was divided into two stages: the creation of the content itself, such as video, audio, image and 3D models, and then integrating it with the mobile device.

4.8.1. Content creation

- The nursing educator provided the required learning material on heart disease and its scenario from The University of Salford in text format, including video links.
- Two human heart 3D models were purchased from the Unity asset database.
- The lab technician played the actor role to simulate a patient, he portrayed specific physical symptoms in the scenario to fulfil the learning objectives.
- To enhance the realism of the scenario, NMAR has to present the patient monitor information before and after the treatment. To create real monitor information, the lab technician configured the monitor parameters of the given scenario in the nursing lab. Then the researcher filmed two monitor screens before and after the treatment (Figure 24).

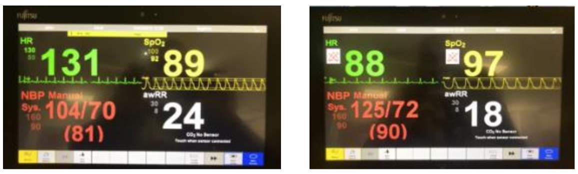


Figure 24: Patient's monitor before and after the treatment

4.8.2. Development techniques

As mentioned in chapter 2, section AR hardware, there are two techniques in developing an AR system, marker-based technique or marker-less technique. Two review studies have found that MAR and marker-based techniques are the favourite learning materials due to their accuracy, reliability affordability and practicality, also they are easy to develop (Akcayir & Akcayir, 2017; Arici et al., 2019). Accordingly, this study adopts MAR and marker-based tracking materials. The second reason for using marker-based is the flexibility of learning different scenarios with only one mannikin by changing the marker of the mannikin. Also the ability to transfer the marker from one mannikin to other. By using the marker-based technique we do not have to associate the patient's scenario with a particular mannikin.

4.8.3. Development platforms

NMAR consists of three development sections, each one contributes different functionalities to the accomplished application. These sections are: Vuforia, Unity3D and Xcode.

Vuforia SDK

Vuforia is one of the most popular platforms to help to work with an AR development system. The popularity of Vuforia could be due to its free version, and it is "*stable and efficient and offers several features, which allows the capacity of mobile applications and frees the developers of the technical limitations*" (Quintero et al., 2019). In this work, Vuforia SDK version 7.1.35 was used with Unity3D game engine platform version 2017.3.0P4 in order to develop the NMAR platform (Figure 25).

Vuforia website handles the image targets (markers), it stores them in databases. After all of the required markers have been uploaded to the selected database, the database can be downloaded and utilized in unity3D via AR plugins.

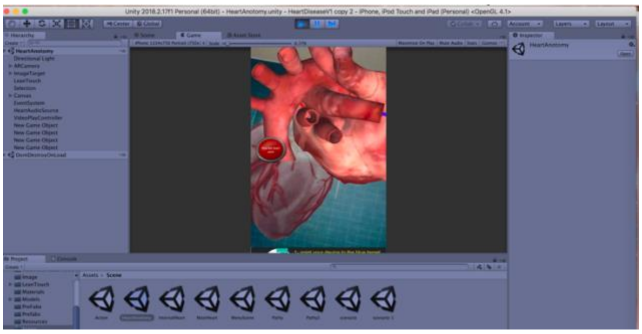


Figure 25: Unity software platform

Unity 3D

The Unity3D platform was used to assign 3D objects to image targets set in the Vuforia database. The image target was generated by dragging the image from the Vuforia prefabs folder, and the 3D model was downloaded from the asset store.

Moreover, the LeanTouch library was utilized in Unity3D to receive the user touch inputs and recognizing them effectively. It is an open-source library that can be downloaded from the asset store. With Unity3D, we do not have to create the code script that runs the mobile application, because Unity generates it for us. However, we need to write the script for our instructions. Thus C-sharp (C#) programming language was used to develop NMAR features.

For example, the code snippet below shows how NMAR controls the self-assessment section, it calculates the final result based on the student's answers.

```
public class NursingController : MonoBehaviour {
    // Use this for initialization
    private bool spray , ox , mo , aspirin , wrong1 , wrong2 ;
    private Animator anim;
    public GameObject myText;
    public GameObject donePanel;
    public GameObject resultText;
    void Start () {
        spray = false;
        ox = false;
        mo = false;
        aspirin = false;
         anim = donePanel.GetComponent<Animator> ();
        wrong1 = false;
        wrong2 = false;
    }
    public void Spirin ()
    {
        myText.GetComponent<Text>().text = "\n [ CORRECT ] \n \nPatient's feel thread reduced \n to 90 per minute";
        aspirin = true;
        Debug.Log ("aspirin applied");
}
    public void Spray ()
    {
     myText.GetComponent<Text>().text = "\n [ CORRECT ] \n \n GTN spray contains type of medicine called a nitrate. \nIt is used to help t
he heart work more easily. ";
        spray = true;
        Debug.Log ("aspirin applied");
    }
    public void Oxygen ()
    {
        myText.GetComponent<Text>().text = "\n [ CORRECT ] \n \nPatient's Sao2 : increase to 95% ";
        ox = true;
        Debug.Log ("oxygen applied");
    }
    public void Morphine ()
    {
        myText.GetComponent<Text>().text = "\n [ CORRECT ] \n \nPatient's pain reduce to 0/10 ";
        mo = true;
        Debug.Log ("morphine injection ");
    }
```

```
public void Panadol ()
{
    myText.GetComponent<Text>().text = "\n [ WRONG ] \n \npain stays elevated , will not help ";
    wrong1 = true;
    Debug.Log ("paadol is not working  ");
}
public void OxCanuula ()
{
   myText.GetComponent<Text>().text = "\n [ WRONG ] \n \nSaO2 remain low , will not help   ";
    wrong2 = true;
    Debug.Log ("Ox canuula is not working  ");
}
public void NotApplicable ()
{
    myText.GetComponent<Text>().text =  "\n this option not applicable in this case";
}
public void checkResult ()
{
    anim.SetTrigger ("playDonePanel");
    if (aspirin && ox && mo && spray) {
        Debug.Log ("Well Done");
        if (wrong1 && wrong2) {
            resultText.GetComponent<Text> ().text = "your Result : 70 % Good";
            Debug.Log ("your Result : 70 % Good");
        } else if (wrong1 || wrong2) {
            resultText.GetComponent<Text> ().text = "your Result : 80 % VERY GOOD";
            Debug.Log ("your Result : 80 % Very Good");
        } else {
            resultText.GetComponent<Text> ().text = "your Result : 100 % Excellant";
            Debug.Log ("your Result : 100 % Excellant");
        }}
    else
        resultText.GetComponent<Text> ().text = "your Result : Fail ";
        Debug.Log ("your Result : Fail");
}
public void desableDonePanel ()
{
    anim.SetTrigger ("goBack");
    spray = false;
    ox = false;
    mo = false;
    aspirin = false;
    wrong1 = false;
    wrong2 = false;
    Debug.Log ("reset ");
```

```
    }
  }
```

Xcode

The platform of NMAR is on IOS operating system. So, to build an IOS app, Apple's requirement is that all IOS apps be compiled with Xcode. Unity iOS creates an app by first creating an Xcode project, which is then compiled into the completed app by Xcode, to actually run it on a test device. Submitting the app to the App Store requires a complicated sequence of procedures as well as registration in Apple's IOS Developer program.

Finally, with the advent of AR technology on common smart devices, there are a wide variety of AR-capable devices running on a different platform, each supporting a different set of functionalities. Although Unity3D is a cross-platform engine that supports development for all popular operating systems, the applications are not easy to port from one platform to the other. Currently, there is no infrastructure solution that allows users with different AR devices (such as smart glasses and smartphones) to interact and manipulate AR objects in a localized environment.

4.8.4. Development challenges

AR technology is still in the developing phase, and the main technical challenges of research in the AR field is the rapid development of hardware and software with a lack of available resources. Extra effort has been added during the development phase to solve compatibility issues whenever a new update was released, to overcome this challenge the researcher had to stop the auto-update features. Also, it is worth noting that the development of the NMAR platform was started before Apple ARkit was introduced, during the development process the updated platform available at that time was used. However, the process ended after collecting the data. Utilising an updated platform for iOS devices could affect the development process and reduce effort.

4.9. Interactive self-assessment mechanism

Interactive self-assessment is the novel aspect of the NMAR platform. It aims to support the students to control their learning and learn from their mistakes, by following the formative assessment concept, which aids the students during their learning process, as well as generates feedback that makes it possible to control their learning outcomes (Panadero et al., 2017). Figure 26 illustrates the mechanism of the NMAR interactive self-assessment. The system presents the answer as a list of 6 options. The correct answer contains four options, the other two incorrect options were added to the list. The incorrect options were carefully selected to encourage students' thinking. For instance, the patient needs oxygen, the options list includes oxygen mask and cannula oxygen. The students should not select both of them unless they are answering without thinking.

When the students click on one option, feedback appears immediately with details explaining why this option is correct or incorrect. The students can then check their final score by pressing (check the result) button, their final score with the correct answer appears in a pop-up window.

The scoring mechanism assesses the result as fail, 70%, 80% or 100%.

- The score 100% was given if a student clicks the four correct answers only.
- The score 80% was given if a student clicks three correct answers and one incorrect answer.
- The score 70% was given if a student clicks all the six options, which indicates that student does not think when trying to answer.
- The score fail was given if a student clicks fewer than four answers.

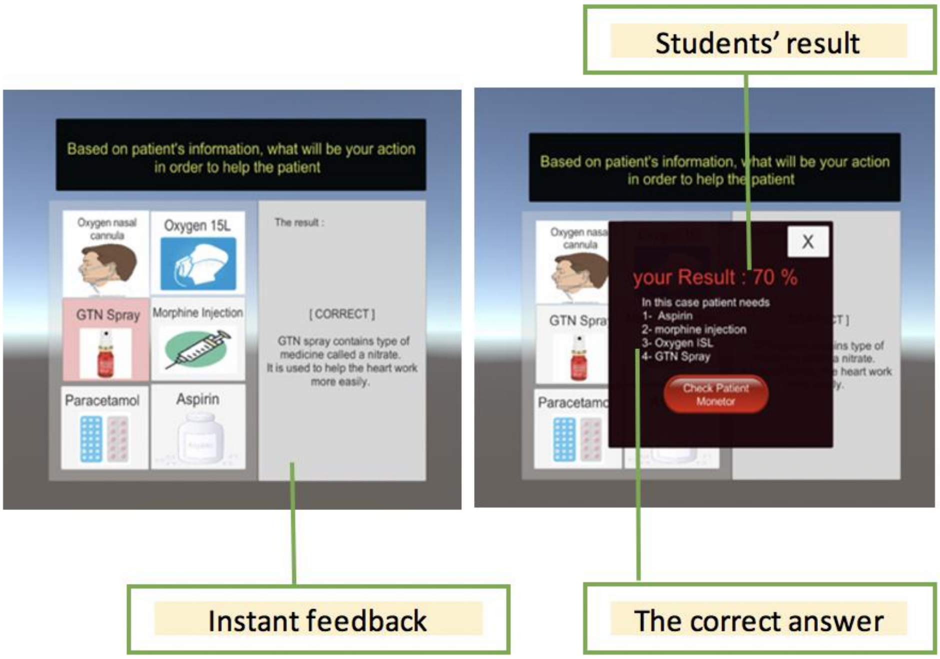


Figure 26: Interactive self-assessment interface

4.10. Validation

The validation process of the NMAR platform was conducted to measure its reliability. The testing included three procedures with different types of subjects. These were academic reviewers, technology experts, and nursing students. The development process has a multi-iteration design considering feedback from each group. The feedback was taken into account to determine the suitability and usability of NMAR prior to its use in the main lab experiment. The first phase was technological validity, and five PhD students from the computer science department at The University of Warwick assessed the usability of the NMAR platform as follows:

- Identify the relative malfunction system (All buttons, links and content display);
- Determine the nature of the interactions (All interactive functions such as finger and touch sensing);
- Evaluate NMAR hardware for optimum performance (camera performance of the device, the comfort of carrying the device).

4.10.1. Academic validity

The academic validity aimed to validate the NMAR platform in terms of suitability of the learning content. The validation covered five aspects:

1- The appropriateness of the content related to the topic presented in NMAR;
2- The adequacy of information for the topic;
3- The realism of the 3D objects;
4- Supporting independent learning;
5- Meeting the learning objectives of each section.

The evaluation was conducted by interviewing four nursing educators. Their nursing background is shown in Table 22.

Table 22: Experts background

Experts	Position	Experience in nursing education
Expert 1	Nursing Lecturer	13 years
Expert 2	Nursing Lecturer	Five years
Expert 3	Nursing Lecturer	Five years
Expert 4	Nursing Lecturer	15 years

Independent learning skills in the nursing clinical lab

All the experts agreed that independent learning skills are very important in the clinical nursing lab. They explained there are many benefits from enhancing students' independent learning. It leads to enhance their confidence, knowledge and critical thinking. They comments were "*it enhances the quality of care*", "*enhances skills and knowledge*", "*increases confidence*", "*ability to handle patients independently*", *"it will give them flexible time to learn without teacher assistance*", "*self-learning enhances critical thinking"* and *"it allows them to practice skills and build confidence*".

Content suitability

This section investigated the suitability of NMAR's content and understanding of the human heart topic. The experts were required to rate each item on a scale of five, with one being very poor and five being very good. Table 23 below shows their results.

Table 23: Content suitability results

Content suitability	Expertise			
	Expert 1	Expert 2	Expert 3	Expert 4
The appropriateness of the content related to the topic presented in NMAR	Very Good	Good	Very Good	Very Good
The adequacy of information for the topic	Very Good	Very Good	Good	Good
The realism of the 3D objects	Very Good	Very Good	Good	Very Good
The learning strategy supports independent learning	Very Good	Very Good	Good	Very Good
The application supports achieving the learning objectives	Very Good	Fair	Good	Very Good

NMAR features application in learning environment

This section aimed to validate the NMAR features in terms of enhancing students' independent learning. It had two questions, the first question asked the experts to rate each NMAR section on a scale of 5, with 1 being very poor and 5 being very good. The Table 24 below shows their rating.

Table 24: The results of NMAR features

MAR section	Expert 1	Expert 2	Expert 3	Expert 4
Anatomy	Very Good	Very Good	Good	Good
Pathophysiology	Very Good	Very Good	Good	Good
Scenario	Very Good	Good	Very Good	Very Good
Self-assessment	Very Good	Fair	Very Good	Very Good

The second question asked their opinions about the proposed new learning strategy. According to the investigative findings, in order to practice clinical nursing skills independently, an interactive environment is needed between the patients' scenario, the manikin and the monitors. NMAR introduced a new approach of interacting with the scenario and manikin by utilising a mobile device. In this regard, the experts described how the new interactive learning environment might enhance students' clinical skills. Table 25 shows their comments.

Table 25: Experts comments about NMAR learning strategy

Expert 1	"This will enable the students to practice their skills in a scenario enabling the combination of knowledge and skills, such as self-assessment, realism of the scenario, details of the symptoms and treatment".
Expert 2	"The real patient's signs and symptoms, self-assessment will enhance students' independent learning."

Expert 3	"Presenting real patient feeling, symptoms, on time feedback, viewing internal pathophysiology enhance their self-learning".
Expert 4	"The NMAR will enhance their knowledge, 3D looks real, able to link this to clinical skills, interventions practices".

The main objective of this section is to validate the NMAR's features, content and learning strategy from a nursing education perspective. The overall concepts of the understanding a human heart topic presented in NMAR were acceptable and positive. Expert (1) commented that "*This application will be really useful for independent student learning, motivation and confidence to learn and will suit a verity of learning styles*". Expert (4) agreed by saying, "*I believe this could enhance teaching and learning and the opportunities are endless*". Expert (3) mentioned that they preferred learning by doing especially in understanding the theory part, and such a tool will be useful for similar students who require more hands-on sessions to understand the theory.

The academic reviewers agreed that NMAR is beneficial in general for supporting clinical lab learning and enhancing independent learning in particular. The self-assessment and feedback features will reduce the teacher assistance required during the clinical lab by providing appropriate guidance. Also, the immediate results highlight the wrong answers that were selected by the students, which will enhance their clinical knowledge. Moreover, the content can be easily learnt and understood because of the realism of the 3D heart, real patients' symptoms and interactivity approach. However, the mobility feature of the application allows them to practice the patient scenario outside the clinical lab wherever and whenever they need.

Although the reviewers gave positive comments, one of the purposes of validating the system is to discover any bug or usability issue of the learning platform. Expert (2) advised more clarification on the way of calculating the student's result, and suggested that it should be presented clearly in the platform. For example, students should be aware that if they did not select all the four correct answers, their result would be a fail. However, if they selected more than four, their marks would be calculated based on the number of extra options they answered. The expert comment was "*Students need more clarification in the assessment section, to understand clearly how they will be assessed once they got their result*".

In addition, Expert (3) mentioned another usability issue related to the sequence of presenting scenario sections. He advised that the platform should be modified by allowing students to view the patient's information and then the internal 3D model of a patient's heart before pressing the assessment button. His comment was that the "*student should view patient's heart before answering the scenario*".

All the reviewers' comments and suggestions were considered by the researcher and the platform was modified accordingly.

4.11. Pilot test (students)

This pilot test was carried by four nursing students on 27th June 2018 at Salford clinical lab (Figure 27). The participants were undergraduate nursing students, one was male and three were female. They volunteered to test the prototype of NMAR. Firstly, the participants were welcomed and introduced to the new learning strategy. Then, they performed tasks using the AR application individually. The participant had to solve the cardiovascular disease scenario while interacting with the manikin via the AR application. Finally, participants were asked to rate the learning strategy out of 10.

In terms of learning heart anatomy with the 3D model, before the experiment all the students selected the video as the preferred media form of learning anatomy instead of the 3D model. During the experiment they were saying words like "WoW, OMG". One student after finishing the tasks returned back to the 3D heart section and was enjoying [smile] interacting with the heart model. After the experiment, all the students mentioned that they had never used a 3D model in learning human anatomy and they found it very useful. Additionally, they found the real patient video very helpful, and one student said "*written paper is not very clear normally, this application is better than paper to understand a patient scenario*". Another student stated that learning by doing with such an application is very useful and easy to use for her, as she has dyslexia and faces difficulty reading. Her self-assessment result was 80%, but she had a second attempt at trying to solve the scenario with an improved result of 100%. Table 26 shows participants' assessment results and their ratings out of 10, they were asked to rate the application in terms of enhancing their independent learning in the clinical skills lab.

Table 26: Students result and rating

Self-test result	70%	80%	70%	80%,100%
Rating the learning strategy	8/10	8/10	9/10	10/10

Overall, the students enjoyed using AR in the lab and were satisfied with the interactive 3D model. They found that NMAR is useful and that it enhanced their independent learning. Two students mentioned that they usually had to search for YouTube videos in order to understand human anatomy, but NMAR combines video, 3D models and pictures in one place, which makes it easy for them to learn.

All the students agreed that solving a patient's scenario independently increases their confidence and competence in learning basic nursing clinical skills. However, they found the section on solving the scenario was unclear and confusing. One student suggested adding a sequence number to inform the users what they have to achieve at each step. The system was redesigned accordingly by adding sequence numbers in the scenario section (Figure 28).

Figure 27: Pilot test

Figure 28: Patient's scenario section

4.12. Summary

This chapter has described the development process of the NMAR platform. The heart's anatomy and diseases formed the example case used when developing the system. Learning with NMAR introduces a new learning strategy, aiming to enhance students' independent learning by adding interactive self-assessment. The chapter has proposed an NMAR software framework (Figure 29), and then developed the prototype. It has been validated by nursing educators and tested by nursing students. Thus it was ready to use in the main experiment. The platform was utilised as a medium to assist in the data collection process. Accordingly, the next chapter discusses the main research experiment, which is the evaluation of the user experience with the NMAR platform.

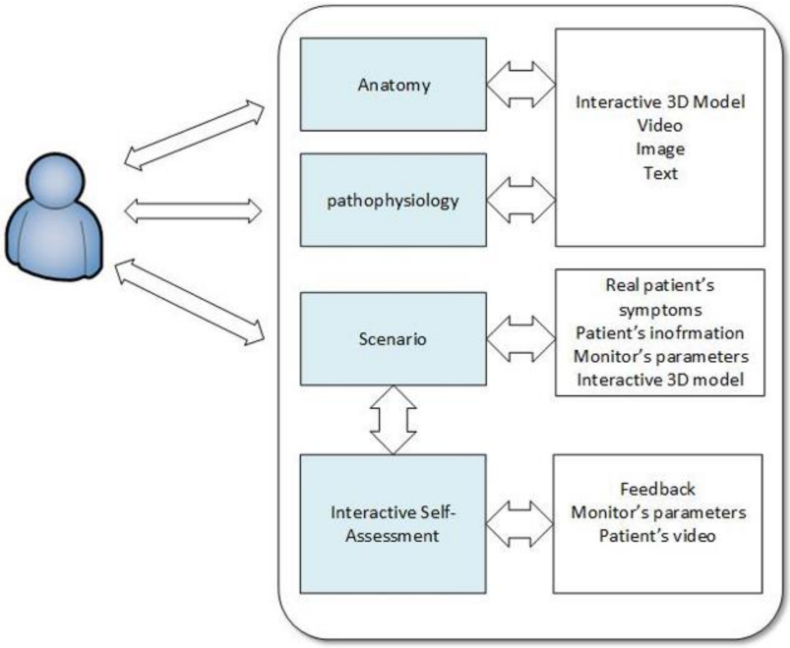


Figure 29: Software framework

CHAPTER 5

5. METHODOLOGY OF EVALUATION

5.1. Introduction

This chapter addresses the evaluation phase of the DSR with the help of the developed NMAR platform (chapter 4). As we discussed in the literature review, the usability is the most technical challenge in the AR learning environment (Akcayir & Akcayir, 2017; Fatih & Omer, 2017; Palmarini et al., 2018). However, usability is an essential technical factor that affects the effectiveness of the educational platform. The usability perspective focuses on the interaction between the devices and the human users, which is known as Human-Computer Interaction (HCI). Accordingly, the evaluation measurement adopts the lens of HCI methods and focuses on evaluating the overall user experience, which is the broader level of usability.

Moreover, the chapter discusses in detail the evaluation design and the user experience measurement. Different research methods were adopted in order to evaluate the students' overall user experience. The experimental study was carried out to explore the role of AR technology in facilitating SRL process in terms of students' experience.

5.2. Evaluation design

According to Lazar et al. (2017), the research field of HCI is "*fascinating and complex*". The development of technologies over time creates so many interesting research questions. However, it is complex because it involves human beings' perceptions. Also, HCI includes many disciplines such as computer science, psychology, communication, human factors and so on. Research methods might borrow from different fields and be modified for use in HCI research.

The majority of HCI research investigates either the system used or the people who use the system, and sometimes a combination of both (such as this work), where a prototype is developed and users evaluate it. HCI researchers aim to understand how a technology is used by users, and how users interact with a system and how people think and feel about the system used. In many of HCI studies, there is a focus on the users, tasks, and the environment.

In the early days of HCI, a measurement was based on standard usability metrics which consider how a user uses the system and completes the task successfully, and these metrics are very much based on a task-centred model. However, today's phenomena that interest the researcher at a broader level, such as motivation, collaboration, feeling, and thoughts, are not easy to measure using existing metrics methods. Using multimethod approaches such as interviews, data logs, and other techniques may help form a deeper understanding of the phenomena (Lazar et al., 2017; Tullis & Albert, 2013).

This research evaluates mainly the user experience. Tullis & Albert (2013) distinguished between usability and user experience. Usability is "*the ability of the user to use the thing to* *carry out a task successfully*". However, user experience "*takes a broader view looking at the individual's entire interaction with the thing, as well as the thoughts, feelings, and perceptions that result from that interaction*". Thus, the evaluation phase looks at the broader level and focuses on three aspects of students' behaviour while using the NMAR platform (screen-recording), students' perceptions (interview) and 5E usability dimensions of the proposed platform (questionnaire).

Usability testing as a research method can be used to learn more about users and their interactions with a product, even though the goal is not to fix the interface issues (Lazar et al., 2017). The lab test method was chosen because it is common in usability studies and requires only a small number of participants. It involves a one-to-one session between the moderator and the user. The moderator asked the users questions and gives the set of tasks to perform on the product or prototype. The lab test session was designed based on the book "Measuring the User Experience" by (Tullis & Albert, 2013). According to the book "*metrics are a way of measuring and evaluating a particular phenomenon or thing*". Measuring user experience with metrics will add structure to the evaluation process and provide insight into the findings and more information to the decision-makers. The study's goals, users, technology and time, should be considered when choosing the right metrics. The book classified ten types of usability studies with suggested metrics but also recommended discovering new metrics that are meaningful to the study goals. For example, the most common usability study is comparing multiple interfaces in the early design process, and appropriate metrics are issues-based. Other types include increasing awareness and problem discovery, and each has different metrics. However, this research has adopted the study type aiming to create overall positive user experience to answer **RQ4** and **RQ5**. This study type does not just focus on the system being usable, but it needs to be engaging, interesting and enjoyable, and what matters is the users' perception.

5.3. Sampling and sample size

Accessing the data sample is a key factor that must be considered in research. This research is a collaborative work with The University of Salford in Manchester. The researcher was permitted access to the nursing students via the Nursing Department. The population of interest of this study was comprised of all levels of nursing students who had taught clinical skills and attended skills lab sessions.

Regarding the sampling methods, there are two main strategies: probability sampling and non-probability sampling. The difference between them is that a probability sample design represents the wider population, in order to generalise, whereas a non-probability sample only seeks to represent a particular group of people (Cohen et al., 2011). There are several types of each strategy such as random sampling, systematic sampling, cluster sampling, and so on. This work used the non-probability method called convenience (accidental or opportunity) sampling. This approach is widespread in user experience studies, with everyone willing to participate in the study (Tullis & Albert, 2013). The volunteer students came to the lab session based on their availability and time. According to Cohen et al. (2011) non-probability sampling is often a method chosen in small-scale research because it is less complicated, less expensive and can prove perfectly sufficient if the research does not seek to generalise the findings beyond the sample group.

As threats of validity and reliability cannot be entirely erased, the possible approach that can be taken is to minimise invalidity and maximise validity. The validity of the data might be improved by carefully selecting the target group and sample size (Cohen et al., 2011). To maximise the reliability, the researchers collected the data at the end of the academic year 2019, to ensure that level one participants had enough experience in clinical skills to evaluate their current learning approach as well as the NMAR platform. Also, the groups of first-year students who have never attended a clinical skills lab before were excluded from the data sampling. Levels two, three and postgraduate student groups were included.

In terms of the correct sample size, there is no "clear-cut answer", however, it depends on the nature of the study and its purpose. Generally speaking, the larger the better. Thus, in case of intending to use statistical analysis, the minimum sample size is 30 participants (Cohen et al., 2011). In this research, only 34 voluntary students attended the lab sessions due to students' busy schedule during their exam periods.

5.4. Evaluation measures

The evaluation phase was conducted based on a "within-group" lab experiment. The lab experiment is commonly an evaluation method used in usability studies. The evaluation in this study focused on the evaluation of the user experience. It is measured based on user performance metrics and how the user feels and thinks concerning their experience – "students' perceptions". The reasons for using both were to increase the data validity due to the small sample size and to gain a deeper understanding of the students' experience with the NMAR platform. The user performance questionnaire evaluated the platform sections, and the interviews aimed to explore the users' perception. The "perceived usefulness" additionally compared the two learning approaches in acquiring clinical nursing skills independently. Evaluating the prototype, understanding the users, and comparing the current and proposed learning approaches together provided a deeper insight into the comprehensive user experience. Table 27 below summarises the overall user experience metrics.

Table 27: User experience metrics

Overall user experience lab test			
User experience metrics	User performance	User perception	Perceived usefulness

Methods	1. 5E dimensions questionnaire 2. Screen recording	Semi-structured interview	1. Pre and post questionnaire 2. Interview
Purpose	To evaluate the NMAR platform sections.	To understand the students' think and feel about the NMAR learning strategy.	To compare the current learning approach and the proposed AR approach in terms of enhancing clinical skills acquiring independently.
Addressed	RQ4, OB9 RQ5, OB10	OB11	OB12
		RQ6	

- **User performance metrics**

  There are five basic standard performance metrics: task success, time on task, errors, efficiency, and learnability. They evaluate the system features by telling us what is effective as part of the system but not why; thus, we need to supplement other data sources to better understand the user experience. This study used questionnaire and screen-recording methods to measure students' performance and behaviour. The questionnaire was designed based on 5E dimensions, which have a similar meaning to the primary standard metrics: effectiveness, efficiency, engaging, error tolerance, and ease of learning (Quesenbery, 2004 ; Quesenbery, 2013). Also, two open-ended questions were added to the questionnaire asking the students if they have any comments or suggestions. The items of the 5Es were adopted and modified from the literature (Green & Pearson, 2006), more details see chapter 6 section 3.

- **Students' perceptions**

  To understand the users and to dig deeper into their experience with NMAR, students were interviewed after finishing the lab test session by using semi-structured interviews. Interviews are frequently used methods for understanding the participants. The semi-structured type provides an opportunity to follow up and gain more details about students' experiences and thoughts (Baxter et al., 2015), more details in chapter 7.

- **Perceived usefulness**

When we design user experience in an HCI study, we need to answer these questions:

1 Who are the target participants?
2 How many participants do I need?
3 How am I going to compare the data from the same group of users or multiple groups?

Questions 1 and 2 were discussed earlier, and how to compare the data is another important decision to be made. There are two types of comparison approaches: the within-group approach, when the same participants evaluate two different systems, and the between-group approach, when different groups of users evaluate one or more systems (Lazar et al., 2017; Tullis & Albert, 2013). Both approaches have advantages and limitations.

From the statistical point of view, the between-group approach is cleaner, as the users need to complete tasks under one condition, and they do not learn from different task conditions, for instance, comparing between novice and expert users on completion rates of a particular task. Also, each user takes a shorter time during the experiment session. As a result, the fatigue factor, when the user gets tired or bored during the long experiment, and the learning effect factors can be effectively controlled.

On the other hand, in the between-group approach, the data of one group of users are compared against the data of another group of users revealing the hidden impact of individual differences. Consequently, it is difficult to detect the significant differences and impacts on the results. According to Lazar et al. (2017), "*the multiple values that we expect to observe can be buried in a high level of noise caused by the individual differences*". To exclude that impact, a large number of users is needed. However, the individual differences should not be considered in the within-group approach because each user is being compared to themselves.

Table 28 summarises the strengths and weaknesses of each approach.

Table 28: Advantages and limitations of the between-group and the within-group approach (Lazar et al., 2017; Tullis & Albert, 2013)

	Between-group	Within-group
Advantages	• Cleaner • Avoids the learning effect • Control fatigue factor	• Smaller sample size • Effective isolation of individual differences • More powerful tests
Limitations	• Large sample size • Large impact of individual differences	• Difficult to control the learning effect • Large impact of fatigue effect

Because the primary goal of this research is evaluating the proposed NMAR learning strategy and not evaluating two separate systems, the comparison metrics are "perceived usefulness" instead of "user performance metrics". The students compared the current learning approach and the NMAR approach in terms of how they facilitated their independent learning.

The perceived usefulness in IS is defined as "*the degree to which a person believes that using a particular system would enhance his/her job performance*" (Sabry, 2009). Comparing the two learning approaches answers **RQ6**. The comparison was conducted with pre- and post-usefulness questionnaires and interview methods. The reason for using two methods was to increase the data validity due to the small sample size.

5.5. Advantages and limitations of a within-group lab experiment

Laboratory experiment through the lens of HCI, "*users must perform tasks relating to an artefact in a particular and controlled environment, away from interruptions and noise*" (Moumane et al., 2016).

Laboratory experiment through the lens of DSR, "samples may be taken from students or if possible from practitioners. Thereby, the newly designed artefact can be compared to existing solutions in a controlled environment" (Offermann et al., 2009).

The lab experiment of this study applied a combination of DSR and HCI lab experiment lenses. Students compared the new AR artefact with an existing learning approach, and they performed tasks related to the AR artefact in order to create a user experience. The reasons for using the within-group lab experiment can be outlined as follows:

- Reduced the study cost; the researcher travelled to Manchester to meet the users based on their availability;
- Required a small sample size;
- More powerful tests due to isolation of the individual differences;
- Focused on creating an overall positive user experience, rather than evaluating two different designs.

One of the limitations of the within-group study is learning effect, asking the same user to perform the same tasks with two or more designs. Because the processes are often similar, it is very likely that a participant will learn from one experience and may get better in the other experience. In this case "counterbalancing" means changing the order of the tasks in each design, and this may control the learning effect (Tullis & Albert, 2013).

However, within this lab experiment, we do not have to worry about the learning effect because the nursing students evaluated the perceived usefulness of the current learning approach based on their previous experience, not performing lab tasks. Therefore, they only performed the lab tasks with the NMAR platform. This design was convenient and served the study goals. Additionally, it kept the duration of the lab test short and simple, to control the fatigue effect, which is another limitation of a within-group study (Lazar et al., 2017).

Moreover, as a result of small sample size, we might tend to have limited data, but asking each student to rate which approach they preferred can be insightful (Tullis & Albert, 2013). Thus two comparison items were added to the evaluation in the questionnaire, asking the students which learning approach they would prefer – the current approach without AR or the with AR approach – in terms of facilitating SRL. Table 29 shows the comparison items.

Table 29: Preferred learning approach

Comparing between the current method and the NMAR	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I prefer using NMAR to enhance my self-regulated learning.					
I prefer using the current learning approach to enhance my self-regulated learning.					

5.6. Recruiting participants

Melanie Rushton, a representative of the Nursing Department from The University of Salford, arranged the room booking and invited the students. She looked at students' timetables and picked the most convenient dates, then booked the room for the whole days. She invited the students by posting on Blackboard, outlining the purpose of the study, mentioning that participation was voluntary, and providing a time slots table. Students who were interested in taking part were emailed by her with a time slot. The data collection process finished in seven days between May and July. A few students booked a time slot but did not attend. She also invited students when they visited her office if they were within the target sample.

5.7. Experiment procedure

A carefully designed lab experiment with consideration to controlling bias can increase the reliability of the data (Lazar et al., 2017). The one-to-one lab session started by welcoming the student and then giving an introduction about the researcher and the aim of the study. Once a student was happy to continue, they signed a consent form. The session was divided into four sections, as described in Table 30. The duration of each session was different, but generally it took 40 to 60 minutes.

Table 30: The experiment process

Lab session	Procedure	Tool
Section 1	Evaluate the current learning approach	Questionnaire A (pre)
Section 2	Using the NMAR platform and perform the given tasks	Instruction and procedure in a written paper. iPad with NMAR platform.
Section 3	Evaluate the proposed NMAR approach	Questionnaire B (post) Questionnaire C (5Es)
Section 4	Interview	Semi-structured interview

After finishing section 1, each student was asked to take their time and to relax while performing the tasks. Also, they were informed that the research involved testing the platform not testing their nursing knowledge, and that each student was free to ask any question or ask for help at any time during the session. The reason for this was to keep them calm and relaxed, to control any bias caused by the participant. Written instructions and tasks were given to the student to ensure instructions were consistent across all the participants, and they received the identically worded instructions. This is because differently worded instructions may lead to different responses and bias caused by the procedure. For example, instruction wording like "complete the task as quickly as possible" will keep the users under time-stress conditions (Lazar et al., 2017). The student had the freedom to use the platform for as much time as needed. The reason for this was to give the participants more space and time to create their own experience. Once the students said "I finished", they completed sections 3 and 4.

Environmental factors such as noise, location and temperature may distract the students and induce fatigue. The lab should be clean, tidy and without any noticeable distractions (Lazar et al., 2017). In this study, the location was the nursing clinical skills lab at The University of Salford. Using the clinical lab, including the manikin to simulate the real classroom environment, students were asked to complete the theoretical parts "anatomy, pathophysiology" as well as the practical parts "scenario, self-assessment". The lab was arranged into two sections – table and chair for the theoretical parts and a manikin for the practical parts. This was done to create a similar experience to the current learning approach, when the students learn the theory using the Blackboard system and practise that theory at the skills lab. It aimed to ensure that students could achieve a fair comparison between the current and the proposed learning approaches. Figure 30 taken during the experiment.

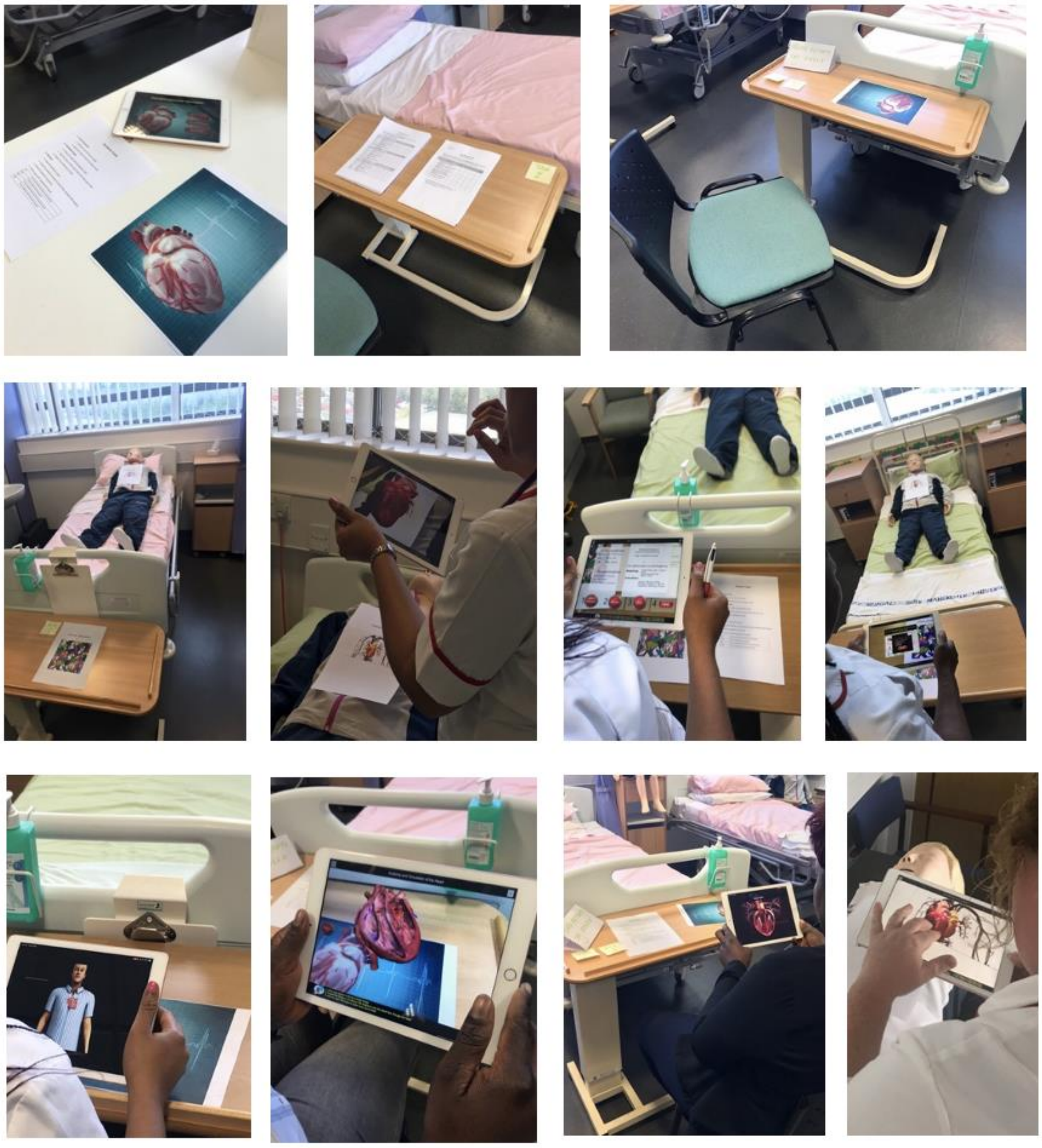


Figure 30: Students performing lab tasks

5.8. Summary

An experimental lab study was carried out to identify the role of AR in facilitating the SRL process. The proposed NMAR learning environment was designed to create an overall positive user experience which might motivate the students to be active learners. A novel NMAR platform to support nursing students has been used individually by 34 students in nursing clinical lab at the University of Salford, and both quantitative and qualitative data were collected from the students via questionnaires, screen recordings and semi-structured interviews (Figure 31). The quantitative data evaluated the NMAR aspects, while the qualitative data explored the users' thoughts and perceptions about their experiences with NMAR. Evaluating the platform, understanding the users and comparing the current and proposed learning approaches together provided a deeper insight into the comprehensive user experience. Each data item collected from the experiment addressed a particular research question and met a specific research objective.

Table 31 summarises each data set and its related research sub-question and objective as well as the data analysis method used.

The results of the evaluation phase will be discussed in the following two chapters: chapter eight for the quantitative data and chapter nine for the qualitative data.

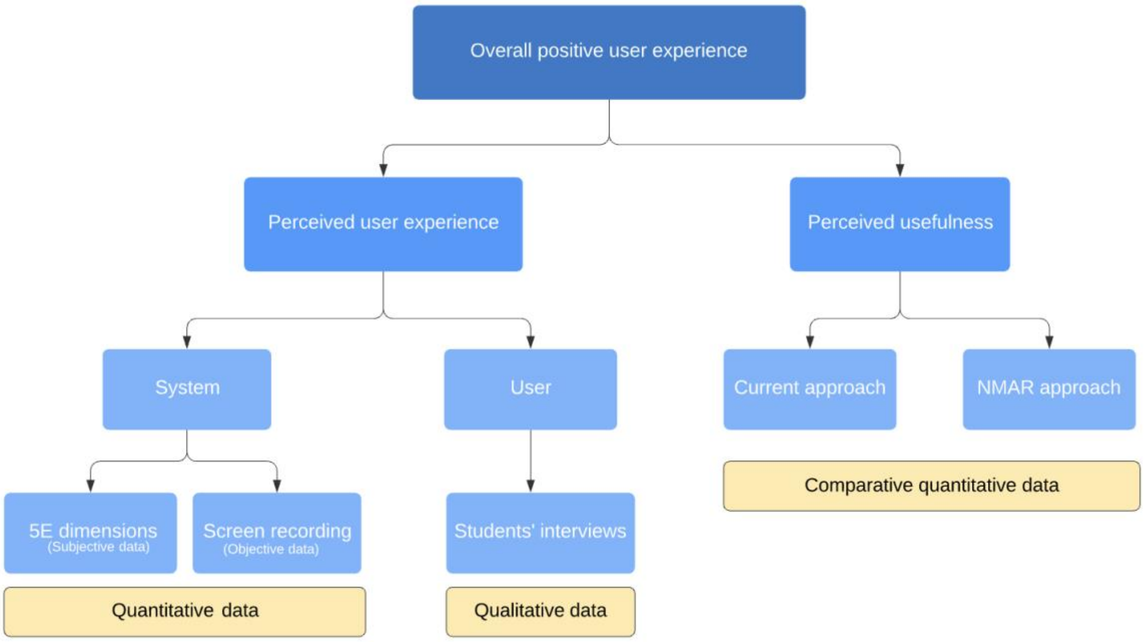


Figure 31: Data collection methods

Table 31: Collected items and their data analysis methods

	Evaluation phase		
Aim	Data collection method	RQs and ROs	Data Analysis method
To create an overall positive user experience	Lab experiment	-	Overall user experience
	Video recording	RQ5, OB10	Descriptive user's behaviour analysis
	5Es Questionnaire	OB9	Descriptive statistics
	Pre-post usefulness	RQ6, OB11	Comparison of statistical analysis
	Interviews	RQ6, OB12	Thematic analysis

CHAPTER 6

6. QUANTITATIVE ANALYSIS

6.1. Introduction

In the previous chapter, a lab experiment was conducted to evaluate students' experiences utilising the NMAR platform. This was achieved through quantitative and qualitative data collected from a total sample of 34 nursing students from The University of Salford. This chapter discusses the quantitative data obtained from three different questionnaires. Moreover, additional objective data were gathered from the screen recording during the experiments exploring students' behaviours while interacting with the NMAR platform, in addition to feedback comments reported at the end of the questionnaire. The comments were obtained from 24 out of 34 students that expressed their thought about the NMAR sections.

The chapter begins with the results of evaluating the system, including students' behaviours and the 5Es usability dimensions. The next part discusses in detail the comparative quantitative data of perceived usefulness between the current and NMAR approaches. The statistical analysis results were enumerated based on the research questions. The analyses used several statistical techniques. For instance, descriptive user behaviour analysis, descriptive statistics analysis for the 5Es dimensions, a parametric paired T-test, a non-parametric Wilcoxon test, as well as Boxplots as a visual method. Lastly, a summary of the main findings is presented.

6.2. Students' behaviours (Screen recording)

This section discusses the result and the analysis of the students' behaviours with the NMAR platform.

6.2.1. Result

This section analyses the screen recordings of 33 students while they were using the NMAR platform. Performing tasks included several activities such as interacting with the 3D model, watching videos or images, reading a text, solving a patient's scenario, and self-assessment. The average time to complete the given tasks without repeating the test was 10 to 20 minutes, but because each participant interacted with the 3D model differently, it was challenging to calculate the accurate time to interact with the 3D model. The duration time was divided into three groups: less than the average time (1–10 min), the average time (10–20 min) and more than the average time (more than 20 min). The graph in Figure 32 shows that the majority of students completed their tasks within the average time range. Two main activities affected a student's duration time, spending more or less time interacting with the 3D model or repeating the test for gaining a higher score. The graph illustrates the number of students in each group and their attempted tests.

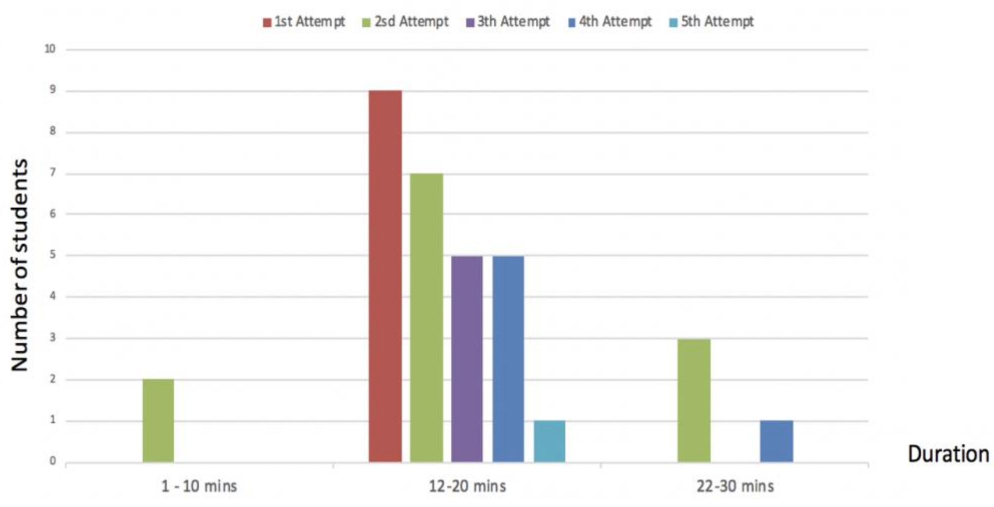


Figure 32: Most of the students completed the tasks in 12–20 min

We can see from the above graph that most of the students were completing the tasks within the average time of 11 to 21 minutes, and 9 of them finished it after the first attempt at the self-assessment section. However, two students were spending time less than the average for completing the tasks. Considering their files to understand their behaviours while interacting with the platform and performing the tasks, the student who spent 7 minutes did not finish watching the video of the pathophysiology section. She was a postgraduate student and familiar with the cardiovascular scenario. She solved the scenario correctly "*with a test result of 100%*", but, interestingly, she repeated the test a second time. Maybe she intended to reread the information for self-revision. She commented on her questionnaire "*I really enjoyed the experience as I am a visual learner*".

The other student who spent 8 minutes failed to solve the scenario twice, and her learning ability may have affected her behaviour. According to her comments, she has dyslexia and it is sometimes difficult for her to use technology but she found NMAR easy to use and navigate compared to other technologies. She noted, "*I found it easy to navigate, I have dyslexia, and sometimes find technology hard; this was not*". Further study should investigate the role of AR in students with dyslexia.

6.2.2. Students' behaviours with interactive self-assessment (ISA)

Melrose (2017) emphasised that "*learning is demonstrated when a change in behaviour occurs as a result of experience*"; however, the grading mechanism within the learning process influences how the students learn and show changes in their behaviours. The grading result guides students or motivates them in their future learning.

Noticeable from the graph in Figure 33 is that students had different behaviours when they assessed themselves on the interactive self-assessment. In order to understand their behaviours towards the self-assessment deeper, they were divided into two groups on the basis of their first attempt: students who failed the first attempt and students who did not fail the first attempt (Table 32), aiming to investigate how they behaved after failing their tests.

Table 32: Students' behaviour after the first attempt

Final Result	100%	80%	70%	Fail	Repeat their test
Not Failed 1st Attempt	9	2	4	0	5 students
Failed 1st Attempt	11	4	1	3	All of them
Total N=34	20	6	5	3	24

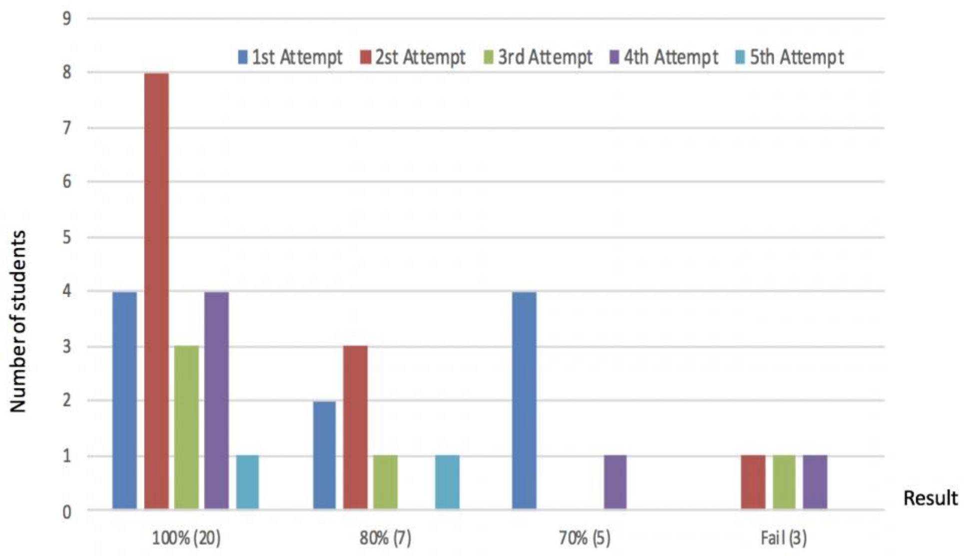


Figure 33: Most of the students tried to achieve 100%

6.2.3. Discussion

Figure 33 above shows that most of the students repeated their self-assessment, in order to increase their grades. For instance, although five students passed their first attempt, they had second attempts to achieve 100% (Table 32). Additionally, all the students who failed their first attempt repeated their tests at least once. The majority of the students aimed to achieve the result of 100%, and most of them reached that goal after the second attempt. The reason could be that the “pass/fail” grading mechanism fosters the intrinsic motivation of the students and increases their motivation to learn and pass (Melrose, 2017).

A study has found that self-assessment has a positive impact on students’ academic performance, and it increases their knowledge. It could be related to the curiosity of the students in judging their work through the self-grading system, motivating them for further learning and test attempts (Sharma et al., 2016). When the students evaluated their results, they expected the next attempt grade, the expectation grade can increase their confidence not only because of the correct answers but also because of the understanding of the incorrect answers (Melrose, 2017). This might be the reason why students had more than two attempts to achieve 100%. The instant feedback of NMAR guides the students to the correct and incorrect answers on the next attempt, and, by receiving this feedback, students can adapt their learning to achieve the desired learning goal (Van Der Kleij et al., 2012). Additionally, the time limit between the assessment and receiving the feedback (in case of NMAR instant feedback) could have affected the willingness of the students to read the feedback and motivated them to learn (Van Der Kleij et al., 2012). The improvement demonstrated by a higher grade enhances a student’s sense of satisfaction and pride (Melrose, 2017).

Moreover, literature found that students pay different amounts of attention to the given feedback, their willingness and ability to use the feedback plays an important role in the effective learning from the feedback (Eberlein et al., 2011; Hattie & Timperley, 2007; Van Der Kleij et al., 2012). Although the correct answers are given after the first attempt in the NMAR interactive self-assessment, few students failed the second, third or fourth attempts. The results of five students were less than 100% after many attempts. Thus it cannot be assumed that students paid equal attention to the feedback. There are three aspects likely driving students to pay less attention or ignore the feedback information: learners’ characteristics, such as lack of motivation, psychological (self-esteem) and individual barriers (dyslexia). The feedback characteristic, its type, time and the way it is presented, can affect students’ attention differently (Eberlein et al., 2011).

The interactive self-assessment supports nursing students to reduce medication errors, thus providing safer care to the real patient. It allows them to pursue areas that needed to be improved in their learning. The degree of confidence that learners have to correct their responses can affect their ability to invest effort into dealing with feedback information (Hattie & Timperley, 2007).

Overall, the result shows positive behaviour towards NMAR interactive assessment. According to Sharma et al. (2016), students find the self-assessment helpful in increasing their knowledge and motivating them to develop self-regulated learning. It has powerful effects on long-term learning, by motivating them to enhance their SRL skills, and become more self-regulated learners. This internal motivation lays a basis for the self-regulated skills required in nursing and health disciplines (White & Fantone, 2010).

6.3. 5E dimensions (usability)

This section analyses the questionnaires related to the user experience in order to answer **RQ4** and achieve **OB9**. Also, it analyses the two open-ended questions added to the questionnaire asking the students whether they have any comments or suggestions. The questionnaire was designed based on the 5E usability dimensions.

The common definition of usability is found in an ISO 9241-11 standard:

"The extent to which a product can be used by specified users to achieve specified goals with Effectiveness, Efficiency and Satisfaction in a specified Context of use"(Moumane et al., 2016).

However, this definition is not sufficient to describe the human interaction usability goals of either the user or the business (Green & Pearson, 2006). In order to overcome this limitation, Quesenbery expanded the three usability metrics of ISO9241-11 to five dimensions: effective, efficient, engaging, error tolerant and easy to learn.

According to Quesenbery (2013)

"These dimensions, the 5 E's, each describe an aspect of the user experience. Taken together, they are a tool to create a more precise description of both the goals for and experience of using a product. this broad view of usability contributes to a successful product."

A questionnaire was designed to evaluate each section of the NMAR platform with 5Es dimensions. The items of the 5Es were adapted from the literature, and the words modified to fit the context of the study. Likert scales were used ranging from 1 = strongly disagree to 5 = strongly agree to measure the levels of the 5Es, with the exception of one reversed item for error-tolerance which was measured in Likert-scale ranging from 1 = strongly agree to 5 = strongly disagree. The reason for using the reversed item is to prevent response bias (Suárez-Alvarez et al., 2018). The questionnaire was pre-tested by 8 participants from the author's Computer Science Department. Table 33 explains each dimension and its definition and the item used to measure it.

Table 33: Usability dimensions and definitions

Dimension	Definition (Quesenbery, 2003)	Item	Source
Effective	The completeness and accuracy with which users achieve the specified goals.	My tasks for this section were fully completed.	(Green & Pearson, 2006)
Efficient	The speed with which the tasks can be done.	I completed the tasks without much effort.	(Green & Pearson, 2006)

Engaging	The degree to which the user likes engaging with the system.	I liked the way in which the NMAR supported the tasks.	(Green & Pearson, 2006)
Error-Tolerant	How well the system prevents errors and helps the user to recover from any problems when they occur.	This section was difficult to complete.	(Suárez-Alvarez et al., 2018)
Easy-to-Learn	How well the system supports both the initial orientation and deeper learning.	I started using this section without any tutorial.	(Sajjacholapunt & Joy, 2017)

6.3.1. Result

The controversies debate about the Likert scale is whether treating them as interval or ordinal scales. Researchers have distinguished between two concepts, Likert items (also called Likert-type scale) and Likert scale. Likert items are single questions related to a single variable addressing a specific dimension of the phenomenon. On the other hand, the Likert scale comprises a minimum of four to more items that measure the participants' collective stance towards the phenomenon(Boone & Boone, 2012; Joshi et al., 2015).

Subedi (2016) stated that

"Regarding ordinal and interval nature of data, Likert items generate the ordinal scale data, and that of Likert scale generates interval scale data. This concept of Likert items and Likert scale contributes to minimizing the confusion."

Accordingly, the Likert data in this section will be treated as interval data, and the recommended descriptive statistics are Cronbach's alpha for internal consistency and the mean for central tendency (Boone & Boone, 2012; Joshi et al., 2015; Subedi, 2016).

The result in Table 35 represent the means and medians of the 5Es dimensions related to the NMAR platform. 34 students answered the questionnaire, but one of them was excluded due to response bias. The boxplots in (Figure 34) represent the overall agreement of the respondents in relation to each dimensions. The boxes represent the first and third quartiles, with the thick horizontal line's median values, while dots indicate outliers. The group 5 (easy to learn) is well separated vertically from the others, indicating more variability agreement levels among the students.

The overall means for each metric are in the range of 3.58 to 4.75, which indicates that the students were satisfied overall with the use of the NMAR platform as a learning tool. They found the system effective and engaging as the effectiveness and engaging metrics have the highest scores. However, the easy-to-learn score has the lowest score 3.58, students comments that they needed a training session to learn about the NMAR platform. An example of their feedbacks illustrates this:

"need training and practice from time to time"; "not altogether confident with laptop usage, however fine once shown easy to learn".

Although three students suggested a training session, all students completed the given tasks successfully.

Table 34: The descriptive statistics of 5Es dimensions N=33

Group	5Es	Min	Q1	Median	Q3	Max	Mean	SD	Reliability
1	Effectiveness	2	5	5	5	5	4.75	0.4845	0.825
2	Efficiency	2	4	4	5	5	4.32	0.7132	0.867
3	Engaging	3	4	5	5	5	4.70	0.4776	0.795
4	Error-Tolerant	1	4	4	4	5	3.98	0.7563	0.775
5	Easy-to-learn	1	3	4	4.25	5	3.58	1.1918	0.774

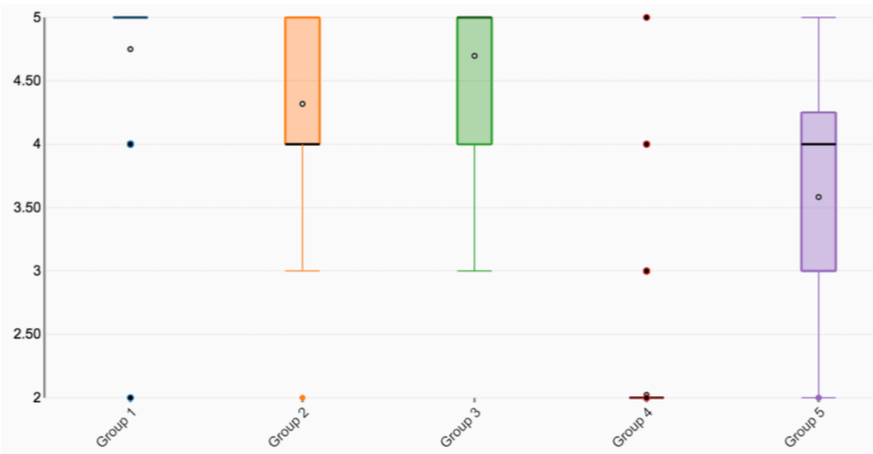


Figure 34: Overall 5Es dimensions results

The group 5 (easy to learn) is well separated vertically from the others, indicating more variability agreement among the students.

Open-ended responses

Thematic analysis was used to organise the data derived from the open-ended questions into themes. It is the most appropriate technique to analyse the text into manageable components simply and effectively (Petty, 2014).

The questionnaire included two open-ended questions as follows:

Q1: Do you have any comment on the NMAR compared to the current learning method?

Q2: Any comments or suggestions?

Only 24 students answered these questions and left their comments. The analysis identified 16 sub-themes from coding of the responses. Those sub-themes grouped into eight main themes, five of them have were from the 5E dimensions, which are related to the learning environment characteristic. The additional themes found related to the students' characteristics and their attitude. Table 35 illustrates the main themes together with the sub-themes.

Table 35: Themes and sub-themes of open-ended questions

	Theme	Sub-themes
System	Effectiveness	Realism, visualisation, enhance the learning process.
	Efficiency	Connected material, easy to use
	Engaging	Interesting, interactive, enjoyable
	Error-Tolerant	Usability issue
	Easy-to-learn	Training needed
	Self-regulated learning	Individual learning, mobility
User	Students' characteristics	Self-efficacy, Lack of experience
	Students' attitude	Preferable, intention to use

6.3.2. Analyses and discussion

This section discusses in detail the aggregated findings of the above quantitative and qualitative outcomes generated from the 5Es questionnaire. The results are classified into the learning environment (system) and the students (user). The learning environment includes effectiveness, efficiency, engaging, error tolerant, easy to learn and self-regulated learning. The next part will discuss each one in detail.

Effectiveness

The overall mean for the effectiveness of the NMAR platform is 4.75, which is a positive result. Having a virtual patient in the patient scenario section increases its realism, resulting in gaining the highest rating score of 4.82 (Table 36). A student reported that "*we have the feeling that it is real life*".

Generally speaking, students found the NMAR to be a "great" and "very effective" learning tool. Using different sorts of learning resources such as 3D models, videos, interactive tests, and linking them together to visualise the information and make them realistic, produces new learning activities that leads to an enhanced learning process. Students report that "*the practical* [scenario] *was very clear and understood*" and "*effective to learn different things*".

Table 36: The descriptive statistics of NMAR's effectiveness

Group	Effectiveness	N	Min	Q1	Median	Q3	Max	Mean	SD
1	Anatomy	33	4	5	5	5	5	4.76	0.4352
2	Pathophysiology	33	2	5	5	5	5	4.69	0.6366
3	Scenario	33	4	5	5	5	5	4.82	0.3917
4	Self-assessment	33	4	4	5	5	5	4.73	0.4523

Efficiency

The efficiency of NMAR is positive with a score of 4.31. The highest mean value is 4.39 for the pathophysiology section; however, the lowest score value is 4.21 for the anatomy section (Table 37). Those are not surprising results, because the learning materials of pathophysiology are image and video. The anatomy has an additional 3D model, which is a new type of learning media. Students were more familiar with images and video than 3D, the investigative study states that 65% of the students have never used the 3D model while learning anatomy, instead they have learned from the video and the textbook.

Overall, students found NMAR "very easy to use" and navigate. Having the anatomy and the pathophysiology and scenario on one platform "links the parts together" and makes it "connect material" so it is "practical in one".

Table 37: The descriptive statistics of NMAR's efficiency

Group	Efficiency	N	Min	Q1	Median	Q3	Max	Mean	SD
1	Anatomy	33	3	4	4	5	5	4.21	0.7398
2	Pathophysiology	33	3	4	4	5	5	4.39	0.6586
3	Scenario	33	2	4	4	5	5	4.30	0.7699
4	Self-assessment	33	3	4	4	5	5	4.36	0.699

Engaging

The overall mean value for the engaging factor of NMAR is 4.70; however, two sections have a mean score of 4.73. It is the highest mean among the engaging means of the NMAR sections (Table 38). Those two sections are the heart anatomy and the patient's scenario, their learning media included a 3D model. Thus the ability to change the viewing position of the 3D model makes for more motivating and interesting learning: "loved the 3D heart". The power to control (rotate and scale) the objects encourages the learning and makes it more exciting, e.g. "did not lose attention". Moreover, manipulating the heart and viewing the subject in detail signifies the capability of interaction.

Generally, students were engaged with NMAR learning activities; they found it to be an interesting, enjoyable and interactive learning tool. They said:

a. "more interesting as my way of learning is through videos and demonstration";
b. "I find being interactive helps with learning";
c. "really enjoyed the experience".

Table 38: The descriptive statistics of NMAR's engaging

Group	Engaging	N	Min	Q1	Median	Q3	Max	Mean	SD
1	Anatomy	33	4	4	5	5	5	4.73	0.4523
2	Pathophysiology	33	4	4	5	5	5	4.70	0.4667

3	Scenario	33	3	5	5	5	5	4.73	0.5168
4	Self-assessment	33	4	4	5	5	5	4.64	0.4885

Error-Tolerant

The error-tolerant dimension was a negatively worded item, it was measured in a reversed way, which means a high score indicates a low error. The mean value for error-tolerant of the NMAR was at the acceptable level with the value 3.98. Students reported some usability issues they faced while interacting with NMAR, such as

1.a "I got confused in the app and closed it rather than going back to the menu";
1.b "3d should stayed on the screen without pointed to the marker, to better navigate the 3D model".

The patient's scenario and the self-assessment sections have the lowest mean scores with values of 3.88 and 3.91, respectively (Table 39). Two reported issues were related to the self-assessment section for example:

a "I would recommend to have an option that says "tick more than one answer" on the self-assessment part";
b "the way how the test is checked should be little bit improved, I have clicked correct answer but it appeared in red colour as incorrect".

Although all the means are at a satisfactory level, the self-assessment interface needs improvement to reduce the error rate and increase the usability, considering the reported issues and comments.

Table 39: The descriptive statistics of NMAR's error-tolerant

Group	Error-Tolerant	N	Min	Q1	Median	Q3	Max	Mean	SD
1	Anatomy	33	2	4	4	4	5	4.03	0.7699
2	Pathophysiology	33	3	4	4	4	5	4.09	0.6307
3	Scenario	33	2	3	4	4	5	3.88	0.82
4	Self-assessment	33	1	4	4	4	5	3.91	0.8048

Easy-to-Learn

The overall mean value for easy-to-learn of the NMAR sections was the lowest among the other 5E dimensions with a score of 3.58, indicating that students were not receiving enough training sessions before the real experiment. Giving the students a brief induction about the platform without proper training was done on purpose. The reason was understanding students' ability to activate their independent learning skills. The lowest mean is 3.33 for the anatomy section because the students are not familiar with 3D, e.g. "*controls a little tricky in the 3D model*" (Table 40).

Despite three students requesting a training session to demonstrate NMAR, all the participants completed the whole experiment successfully, indicating that students were able to activate their independent learning if we provide them an appropriate learning environment with features supporting their independent learning. Additionally, their familiarity with using mobile applications played a vital role here.

Table 40: The descriptive statistics of NMAR's easy-to-learn

Group	Easy-to-learn	N	Min	Q1	Median	Q3	Max	Mean	SD
1	Anatomy	33	1	3	3	4	5	3.33	1.2162
2	Pathophysiology	33	1	3	4	4	5	3.64	1.1407
3	Scenario	33	1	3	4	5	5	3.56	1.2508
4	Self-assessment	33	1	3	4	5	5	3.79	1.1661

Self-regulated learning

Students reported that the mobility features of NMAR would help them to study based on their time and location:

a "NMAR enables you to learn in a more relax way and in your own time";
b "it is easier to go over missed learning on your time";
c "repeat as often as is needed".

Besides the mobility feature, using the NMAR learning approach encourages the students to regulate their learning. They commented "*it will be so much better if we currently regulate learning using NMAR*", "*can be performed individually without supervision*", "*I love the idea of learning independently in a skills lab*". Students showed a positive attitude toward regulating their learning.

Student's characteristics and attitudes

Evaluating the user experience is not just focusing on the system, but the user who interacts with that system also needs to be considered. Students' low self-efficacy may affect their ability to activate their independent learning. Additionally, the lack of experience in using the technology may affect adopting NMAR negatively. Students' characteristics, including their levels, is a factor cannot be neglected. A student from level one said, *"I think some 1st-year students may need more into on normal observation to know what treatment to give*".

In conclusion, students' attitudes toward the NMAR platform were positive, 7 students preferred using NMAR than the current approach in a clinical lab. A student mentioned that *"this is more interesting and realistic compared to current learning method*". Students also wished to apply the NMAR approach in the near future, they showed a positive intention to use NMAR in their learning, e.g., "*I would like to have it as a learning tool*".

The study aims to create an overall positive user experience. This is not just about focusing on the system being usable, but it also needs to be engaging, interesting and enjoyable, what matters is the user perception. The findings above confirmed that students had a joyful experience, and they were satisfied with the NMAR features in terms of effectiveness, efficiency and engagement, with few usability issues reported.

The overall mean score of the 5Es dimensions is 4.27. The result can be interpreted as being that students overall had positive user experience within the NMAR sections. The positive user experience might influence the students and motivate them to activate their role to become self-regulated learners.

6.4. Perceived usefulness

When we design user experience in the HCI study, comparing the data is another important decision to think about. In this section, students compared the usefulness of two learning methods, the current learning approach and the AR proposed approach, in terms of enhancing their independent learning. The outcome of this section answers **RQ6** and achieves **OB11.** The pre and post usefulness questionnaires formed the data collection method used to evaluate the two learning approaches.

6.4.1. Usefulness scale

In the context of this study, perceived usefulness is measured by a scale including 7 items, the two items Q1 and Q2 were created by the researcher and the rest of them, Q3–Q7, were adapted from the literature, the words were modified to fit the context of the study (Balog & Pribeanu, 2010; Mohammadi, 2015). The reason for this is to ensure that the items cover the study aspects and the proposed NMAR sections.

The items asked individuals to indicate the extent of their agreement or disagreement with statements using 5 Likert scales. Likert scale is widely used in the field of research, particularly with a questionnaire (Baxter et al., 2015). In the user experience studies, the Likert scale is a common way of collecting the data and capturing the user's experience (Tullis & Albert, 2013).

Additionally, it is one of the most useful scales available, because it builds in the degree of sensitivity and differentiation of the responses at the same time as generating numbers (Cohen et al., 2011). Using a 5-point Likert increases the response quality and reduce the students' frustration level (Sachdev & Verma, 2004).

For this study, two (pre and post) questionnaires with 5-point Likert scales were developed. Each item has a scale ranging from 1 = strongly disagree to 5 = strongly agree. Moreover, it had a corresponding neutral in the middle to prevent acquiescence bias.

Concerning the validity of the questionnaires, they were pre-tested in terms of wording and understanding by 8 participants from the author's Computer Science Department and one nursing lecturer. The feedback was considered, and changes were made accordingly.

6.4.2. Result and discussion

Following the Likert scale concept by (Boone & Boone, 2012; Joshi et al., 2015; Subedi, 2016), the Likert data here will treated as an interval. The items of the questionnaires and their descriptive statistics are presented in Table 42. All the mean values are within the range of 3.32 and 4.85. To ensure the reliability of the scales, considering the internal consistency of the items a coefficient Cronbach's alpha was calculated for the pre and post scales. It is one of the most commonly used tests for measure reliability. SPSS was used to calculate the reliability, the Cronbach's alpha values are 0.914 and 0.872 for the current and NMAR, respectively, (Table 41) demonstrating excellent internal consistency and reliability. The high internal consistency indicates that all of the items on the scale are measuring the same underlying construct. According to the literature, a value above 0.7 is acceptable; however, a value above 0.8 is preferable (Pallant, 2016). Moreover, because research on AR benefits can be considered at an early stage, reliability of 0.70 or greater is sufficient (Diegmann et al., 2015).

Table 41: Coefficient Cronbach's alpha

Variable	Items	Cronbach's alpha
Current learning approach	7	0.914
NMAR learning approach	7	0.872

Table 42, explains that the idea of using NMAR to enhance students' SRL was acceptable to the students, due to it making it easy to access the learning material besides having the virtual patient scenario with self-assessment features. While comparing all the means of the two learning methods, students found that the learning activities by NMAR platform are more useful than the current learning, in terms of realism, mobility features, effective and efficient learning as well as supporting independent learning skills. The overall mean student's perceived usefulness of NMAR is 4.65, with the lowest and highest means being 4.56 and 4.85, respectively. The lowest value is for supporting independent learning, where the highest value is for the "overall it is useful". It is worth noting that students' personal characteristics play a vital role to explain the result, as the investigative study showed that students' levels, awareness, and confidence are considerable factors that can influence their motivation to activate their independent learning.

The boxplots in Figure 43 below visualise the data of the current and NMAR approaches. When data are presented visually, it is easy to judge the differences between the two results. Boxplots effectively show medians for each question, as a horizontal line inside the box with upper and low quartiles. The relative lack of overlap between current and NMAR groups shows significant differences between the two groups. However, for the students' perceived usefulness of the current learning, the overall mean is 3.55, with the lowest and highest means being 3.32 and 3.68, respectively. The lowest value was found for the mobility feature, while the highest value was found for realism, indicating that students can understand the patient's symptoms from the teacher clearly but they are facing difficulty accessing the clinical resources due to their lack of time and location. These results are consistent with the outcome of the investigative study, which was conducted earlier, and participants reported that facilitating condition of the clinical lab is a factor prevent them from activating their independent learning with the current learning approach (chapter 3 section 8.6).

Despite the fact that all the means are greater than 3, and the results are considered positive also, both learning methods are useful, students preferred to use NMAR when it comes to enhancing their self-regulated learning.

Table 42: Perceived usefulness scale items

Items	Pre- test (Questionnaire A)	Current		Post-Test (Questionnaire B)	NMAR	
		Mean	**Std**		**Mean**	**Std**
Q1	The current learning method helps me to create the clear mental image for the patient's symptoms.	3.68	0.878	NMAR helps me to create a clear mental image for the patient's symptoms.	4.65	0.544
Q2	The current learning method helps me to access clinical learning resources anytime and anywhere.	3.32	1.121	NMAR helps me to access clinical learning resources anytime and anywhere.	4.62	0.493
Q3	The current learning method helps me to be self-reliable.	3.53	1.080	NMAR helps me to be self-reliable.	4.56	0.561
Q4	The current learning method helps me to understand the patient's scenario more quickly.	3.62	0.888	NMAR helps me to understand the patient's scenario more quickly.	4.62	0.604
Q5	The current learning method helps to improve my learning performance.	3.59	0.925	NMAR helps to improve my learning performance.	4.63	0.597
Q6	The current learning method helps me learn effectively.	3.47	0.929	NMAR helps me learn effectively.	4.62	0.551
Q7	Overall, the current learning method is useful.	3.62	.922	Overall, NMAR is useful.	4.85	.359
Overall usefulness		**3.55**	**0.786**	**Overall usefulness**	**4.65**	**0.403**

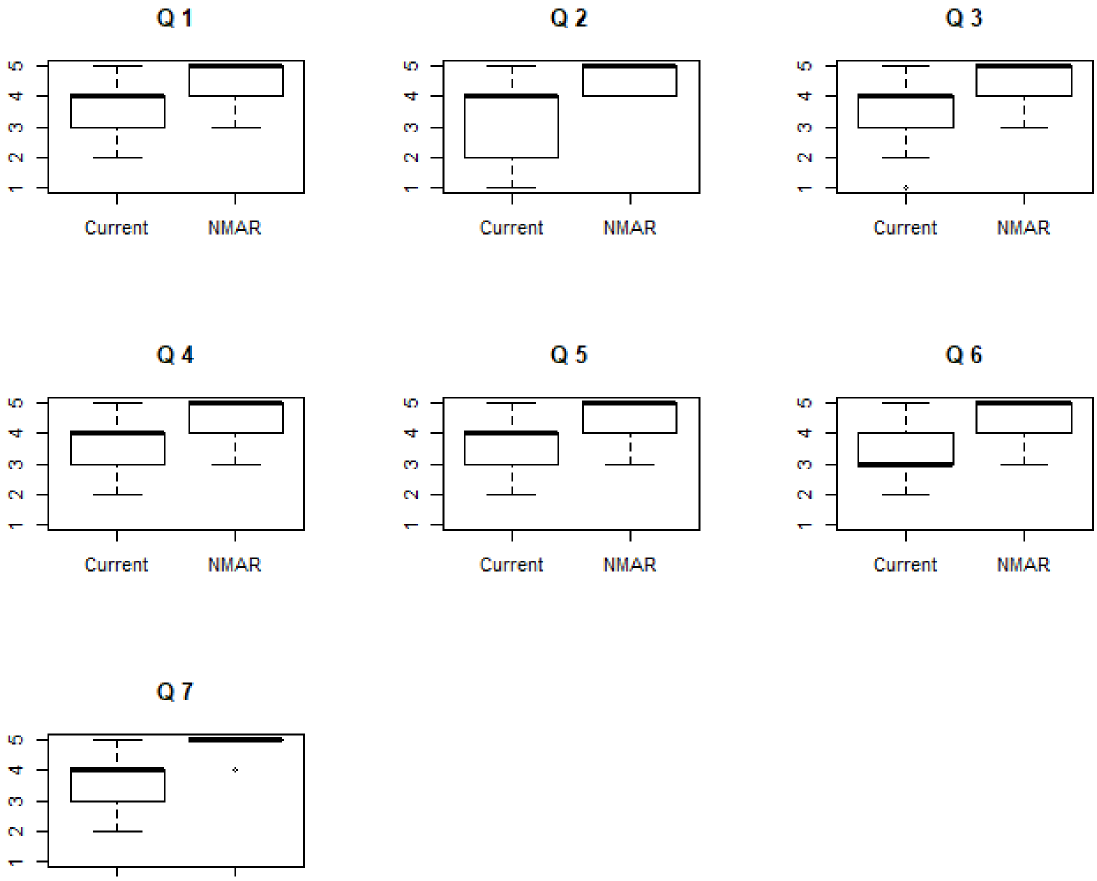


Figure 35: Boxplots result

6.5. Comparison between students' perceived usefulness using current learning approach and NMAR platform, in terms of supporting SRL.

One of the most difficult parts of the research process for beginner researchers is selecting an appropriate statistical technique to analyse their data. There is a variety of techniques available that can be classified as parametric and non-parametric statistical tests.

The parametric tests are more powerful and reliable but the main assumption here is that the data should be normally distributed. However, non-parametric tests tend to be not as powerful as parametric ones, and they may be less sensitive in detecting a relationship or a difference among groups (Pallant, 2016).

One of the factors that influences the normality test is the sample size. Normality tests have little power to reject the null hypothesis of small sample size, and, consequently, most of the small sample sizes usually pass the normality test (Ghasemi & Zahediasl, 2012).

Researchers agreed that the Shapiro–Wilk test is the best normality test for a small sample size because it rejects the null hypothesis of the normality assumption at a small sample compared to the other tests such as the Kolmogorov–Smirnov test and Anderson–Darling test (Ahad et al., 2011; Yap & Sim, 2011).

Shapiro–Wilk

To examine the normality assumption of the data, we used SPSS software to execute the Shapiro-Wilk test. The results of the current and NMAR data are varied, as shown in Table 43. The Shapiro-Wilk test shows that the current approach data is normally distributed, conversely the NMAR data is not normally distributed. Thus the prerequisite of the assumption for using the parametric test is not met with the NMAR data set.

Table 43: Normality test

Shapiro-Wilk		Result
Current	0.519	> (α=0.05) the null hypothesis is accepted and the data in normal distributed
NMAR	0.000	< (α=0.05) the null hypothesis is rejected and the alternative hypothesis that the data is not normally distributed.

On the other hand, (Frost, 2019) claimed that people are not aware of the fact that parametric tests can provide reliable results with non-normal data if the sample size meets the requirements for the analysis. With a large enough sample size (more than thirty), violating the normality assumption should not cause a major issue (Ghasemi & Zahediasl, 2012; Pallant, 2016). Although it has been generally argued that with non-normal distributions data should not apply parametric analyses, approved statistical tests usually provide accurate results (Ghasemi & Zahediasl, 2012; Öztuna et al., 2006). This suggests that applying parametric analyses in this study is possible and will not affect the validity of the result. A paired samples t-test is an appropriate technique when we intent to compare two different data from one group of people, both data should be rated on the same scale (Pallant, 2016).

This study measured the data by using 5-point Likert scales. Despite the fact that the Likert scale is widely used in the field of research, a controversial issue is repeatedly raised about the data derived from the Likert scale, as it is unclear whether the item should be ordinal or interval. Researchers argue that Likert produces ordinal data, which require non-parametric analysis (Frost, 2019; Harpe, 2015; Pallant, 2016). Additionally, is it acceptable to apply parametric analysis for the scale data or not?

Over the years, many researchers have tried to answer this question. De Winter & Dodou (2012) conducted a study that compares the capabilities of parametric and non-parametric tests to analyse 5-point Likert data. The study compared two groups of Likert items by applying t-tests and Mann-Whitney-Wilcoxon (MWW), the result showed that both tests generally have equivalent power. If the difference truly exists, any test is equally likely to detect it. Moreover, on the basis of previous empirical evidence reviewed by Harpe (2015), parametric tests are acceptable and potentially appropriate for rating scale data. Norman (2010) dissected the arguments that the parametric analyses are robust with respect of violations assumptions, he confirmed that:

"Parametric statistics can be used with Likert data, with small sample sizes, with unequal variances, and with non-normal distributions, with no fear of coming to the wrong conclusion".

Furthermore, the power of the test can be influenced by the sample size of the study, a larger sample size (100 or more) is not an issue, a researcher should be aware that insufficient power may cause a non-significant result (Pallant, 2016). However, non-parametric tests are most useful for small sample studies (Fagerland Morten, 2012).

In conclusion, with the advantages of parametric and non-parametric analysis approaches as well as increasing the robustness of the results, both approaches will be performed in the context of this study to compare the two learning methods. The appropriate parametric comparison test of the sample size 34 is paired-samples t-test, and its alternative non-parametric technique is the Wilcoxon Signed Rank test (McCrum-Gardner, 2008; Pallant, 2016).

6.5.1. Statistical significance test

The statistical significance tests were used to determine whether there are statistical differences between the students' perceived usefulness of the proposed NMAR approach, compared to the current approach.

In the comparison of the two learning approaches for supporting SRL, the study found that students favoured NMAR over the current method. The tests were conducted using IBM SPSS statistical software. Table 44 shows there are statistically significant differences in perceived usefulness scores between the current and NMAR approaches.

A parametric paired T-test results show that all the seven items are statistically significant with probability value 0.001. The overall T-value is 7.56 and the p-value less than 0.05 (the significance threshold most commonly used in research), indicating significant findings.

The non-parametric Wilcoxon Signed Rank test was also performed to back up the results of the parametric test. The table shows p values of <0.05, so there is less than 5% probability that the differences between the two groups' answers to questions are due to chance. Hence the results are clearly significant at $p<0.05$.

Table 44: Statistical significance tests

	Paired samples t-test					Current	NMAR	Wilcoxon		
	Mean	Std	T-Test	df	P	Median	Median	Z	S	P
Q1	.971	1.087	5.208	33	0.000010	4	5	-3.830	40	0.00012821
Q2	1.294	1.219	6.189	33	5.5397E-7	4	5	-4.267	6.5	1.98E-05
Q3	1.029	1.029	5.831	33	0.000002	4	5	-4.089	6.5	4.33E-05
Q4	1.0	.985	5.921	33	0.000001	4	5	-4.187	8	2.83E-05
Q5	1.059	1.013	6.093	33	7.339E-7	4	5	-4.183	7	2.87E-05
Q6	1.147	1.019	6.564	33	1.8533E-7	3	5	-4.287	6.5	1.81E-05
Q7	1.235	1.017	7.084	33	4.1327E-8	4	5	-4.396	6	1.10E-05
Overall	1.105	0.852	7.560	33	1.0707E-8	3.50	4.86	-4.632	5	0.000004

The descriptive statistics, the visual methods and the significant test analyses illustrate that students' expressed positive feedback related to their experience with NMAR. According to the above findings, the students' experience as regards the usefulness of the NMAR approach was positive for all the items, concluding that the NMAR platform is more useful than the current learning method, in terms of realism, mobility features, effective and efficient learning, as well as in supporting independent learning skills.

6.5.2. Preferable learning method

In the last part of the comparison between the two learning methods, students were asked to select their preferred learning method, and the result in Table 45 shows that NMAR is preferable, with a mean score of 4.24. However, the mean of the current learning is a cluster around 3, which is the neutral response, suggesting that students were neither satisfied nor dissatisfied with the current learning method in terms of supporting their SRL.

Table 45: Preferable learning method

Preferable learning method	Mean	Std
I prefer using NMAR to enhance my self-regulated learning	4.24	0.890
I prefer using current learning to enhance my self-regulated learning	3.09	1.334

Considering at the actual responses of the current approach, the graph (Figure 36) shows that 15 students agreed that they prefer to enhance their SRL using the current method, while 14 students disagreed that they prefer to enhance their SRL using the current method, and 5 students reported being neutral.

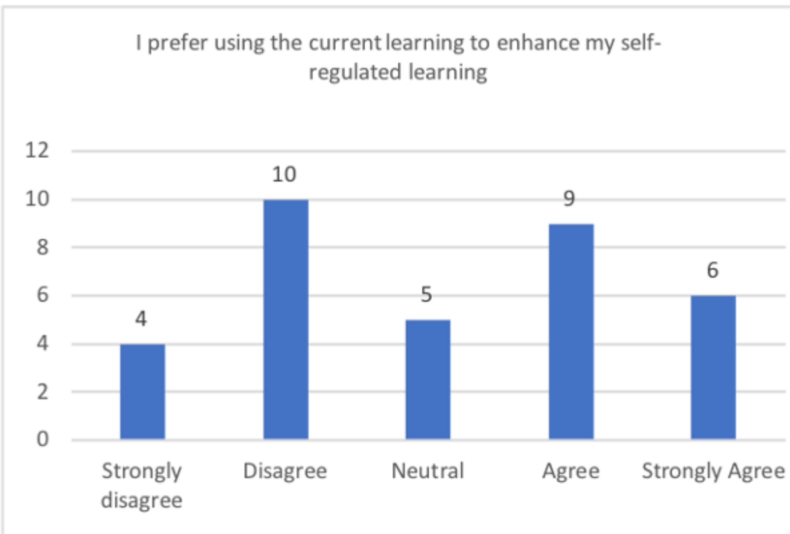


Figure 36: Preferring the current approach result

6.6. Discussion

Overall, the outcomes of sections 6.4, 6.5 and 6.5.2 call to attention the fact that students were more positive toward using the NMAR platform than the current learning, to learn the clinical skills independently. Illustrating that the usefulness of NMAR supports independent learning to a greater extent than does the current approach. These findings are consistent with the result of a previous study (Garrett et al., 2018), using AR in a clinical lab that enables the instructor to provide additional learning resources to the learners on-demand. Students then can use their smartphones to undertake supervised or unsupervised lab practice. Thus the affordances of AR technology encourage them to be more active learners. Moreover, AR provides easy transfer of the supporting resources away from the clinical equipment to review the skills later, which is a positive attribute of supporting SRL.

6.7. Summary

This chapter has provided a discussion of the quantitative results generated from the lab experiment, aiming to evaluate students' perceived experiences using the NMAR platform as well as comparing the perceived usefulness of NMAR learning approach to the conventional learning approach. The findings showed positive students' behaviours towards the NMAR interactive assessment. Additionally, the overall mean score of the 5Es dimensions is 4.27, indicating that students overall had positive user experiences within the NMAR sections. Moreover, the outcomes of comparative quantitative analysis explained the fact that students were more positive toward using NMAR platform than the current learning, to learn the clinical skills independently.

Finally, the descriptive statistics, the significant test analyses, and visual methods, illustrate students' expressed positive feedback related to their experience with NMAR platform. These positive results might influence the students and motivate them to activate their role to become self-regulated learners. The outcomes of the quantitative analysis have addressed the sub-questions **RQ4** and **RQ5**, while the outcomes of the competitive quantitative analysis have addressed RQ6.

CHAPTER 7

7. QUALITATIVE ANALYSIS

7.1. Introduction

This chapter aims to meet research objective **OB12**, which contributes to answering research question **RQ6.** Accordingly, it highlights the key findings generated from the interviews which are qualitative data. Additionally, it compares students' perspectives in both the NMAR and the current learning approach in terms of supporting their SRL.

7.2. Qualitative data collection

The limitation of the questionnaire data collection is that respondents only answer questions that are asked, and open-ended questions which require long written responses are most likely to be unanswered. For those reasons, it often ends up being broad but not deep. However, an interview gives us the ability to go deeper by asking questions and giving the interviewees the freedom to provide detailed responses. It may generate ideas and sharing insights that would have been lost in the questionnaire, and it can be used to gather the data that would otherwise be very difficult to capture. In HCI research, listening to the users and understanding their concerns, requirements, preferences, feeling or attitudes is important. The direct discussions with the users may help to go deeper to generate ideas and useful data about their interaction with the system (Lazar et al., 2017). There are two forms of direct discussions with the users: *interviews* with individuals and *focus groups* involving multiple users at the same time. These two forms of data collection methods generate a subjective and qualitative data set. In this section, face-two-face interviews were utilised to capture students' perspectives about the NMAR learning approach.

7.3. Interview process

The last part of the lab experiment consisted of face-to-face interviews. This is the most effective way of digging deeply into users' perceptions of their experiences. Thirty-four students were interviewed, each interview lasted 10 to 16 minutes. All the interviews were recorded by using a digital recorder for the purpose of accuracy during the data analysis stage, and students were informed and consented to being recorded.

During the interviews a semi-structured, but flexible discussion guide was used (see Table 46). It was prepared to address six topics: the NMAR learning approach, self-regulation, motivation, comparison, improvement and intention to use. At the beginning of each interview, an initial small-talk of icebreakers, including thanks and appreciation for their time, which allowed them to feel at ease. This was followed by asking for general opinions about their experiences. During the interview, they were asked eight open-ended questions, which were more likely to prompt them to describe their experiences freely. Also, students were free to talk as much as they wanted. At the end, the interview was concluded by one generic question if they wished to add any further ideas related to their experiences.

Table 46: Interviews guide

NMAR	1. What is your overall or general opinion about the NMAR application?	
	2. What did you like in particular about the NMAR application?	
SRL	3. As student, how do you think is important learning independently in nursing clinical lab?	Why?
	4. Do you think that utilizing NMAR application will enhance your **self-regulated** learning?	Explain
Motivation	5. Which features do you consider useful that will **motivate** you to regulate your learning?	Why
comparison	6. Can you compare your new experience with your current learning method (without AR) in term of enhancing self-regulated learning?	
Negative	7. What are the **negative** features that need to be improved in NMAR learning approach?	Explain
Intention to use	8. Would you use the NMAR application if its released, in the future?	Why

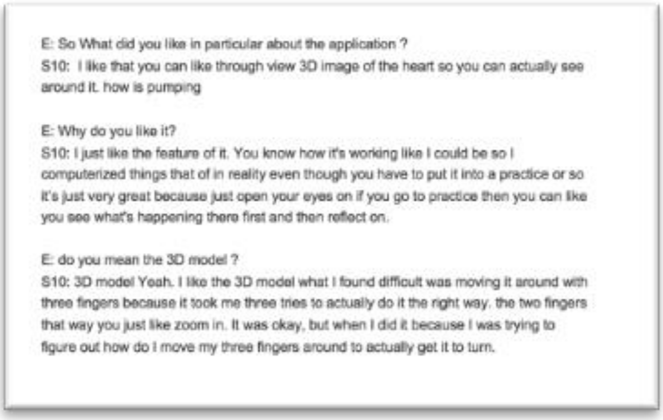
7.4. Qualitative data analysis

The goal of qualitative analysis is to turn the unstructured data found in texts into a detailed description about the important aspects of the considered problem (Lazar et al., 2017). Thematic analysis is the most common method for analysing qualitative data (Hanington & Bella, 2012). It was used to identify patterns and to explore the relationship between them in the students' interviews. The process of the analysis was iterative, involving many cycles. Indeed, thematic analysis is not a *linear* process of moving from one cycle to the next. Alternately, it is more *recursive* process, involving a constant moving back and forth across a data set as needed (Braun & Clarke, 2006). This research adopted a step-by-step guide to perform the thematic analysis as suggested by (Braun & Clarke, 2006), including 6 phases as follows.

Phase 1: Familiarising yourself with the data set

In this stage all the interview recordings were transcribed verbatim by using an audio transcription online services (Sonix), which generates highly accuracy text in a short time. Additionally, to increase the transcribing accuracy, the researcher listened to the recordings again while reading the generated transcripts. Then each transcript's file was assigned a number based on interviewee order, the first interviewee student has the number 1 and so on, the total number of files was 34 transcripts, the total duration of interview recordings was 320 minutes, and the total number of generated pages in Microsoft Word was 126 pages. The qualitative software NVivo was employed to code the data and to assist in the analysis phases.

The coding process started with reading and re-reading all the transcripts for the purpose of familiarisation with the depth and breadth of the data (example Figure 37).


E: So What did you like in particular about the application ?
S10: I like that you can like through view 3D image of the heart so you can actually see around it. how is pumping

E: Why do you like it?
S10: I just like the feature of it. You know how it's working like I could be so I computerized things that of in reality even though you have to put it into a practice or so it's just very great because just open your eyes on if you go to practice then you can like you see what's happening there first and then reflect on.

E: do you mean the 3D model ?
S10: 3D model Yeah. I like the 3D model what I found difficult was moving it around with three fingers because it took me three tries to actually do it the right way. the two fingers that way you just like zoom in. It was okay, but when I did it because I was trying to figure out how do I move my three fingers around to actually get it to turn.

Figure 37: Sample of the transcript

Phase 2: Generating initial codes

In this stage each transcript file was coded individually. The initial set of codes was guided by the interviews' questions, and additional codes were also generated from the data. Moreover, the coding methods followed the guidance offered in the coding manual for qualitative researchers (Saldana, 2016) . The total number of generated codes was 93 as an initial list.

Phase 3: Searching for themes

In this phase the codes were grouped, linked and sorted into potential themes, and gathered the data relevant to each potential theme gathered together. According to Braun and Clarke, (2006) using visual representation and a thematic map are helpful in exploring organising themes (example is given in Figure 38).

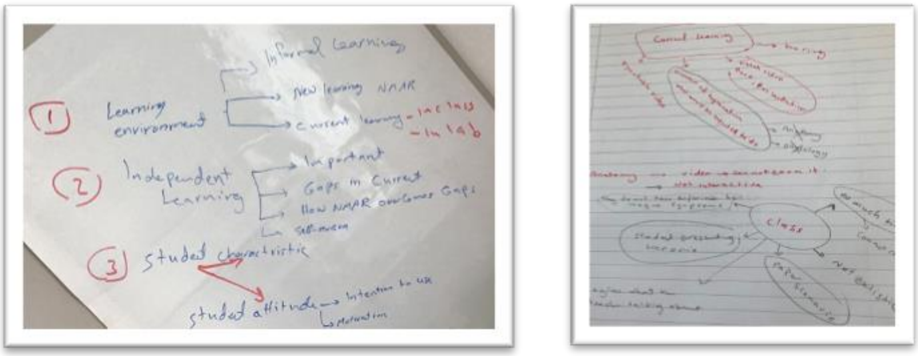


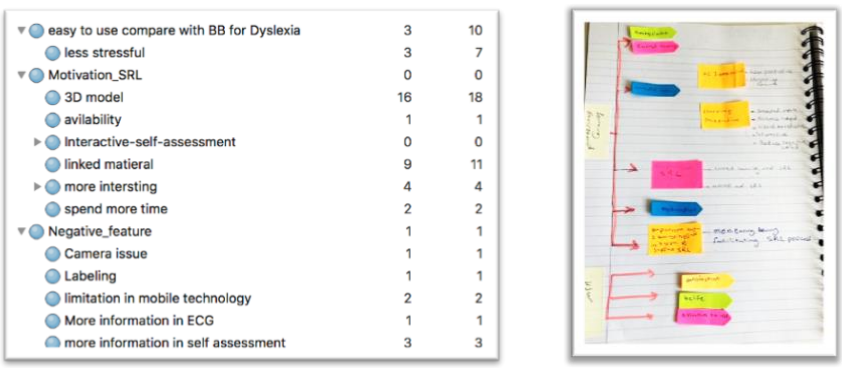
Figure 38: Thematic mind-map

Phase 4: Reviewing themes

This phase aimed to check if the themes work in relation to the generated codes in phase 1 as well as the entire data set. Themes might break down into sub-themes, others might coalesce into one theme. The process included two levels of reviewing and refining the themes by re-reading the entire data set. Level one involved considering the validity of each individual theme in relation to the data set. The second level was to code any additional data within the themes that had been missed in the earlier coding stages. At the end of this phase, the overall story of the data was clear.

Phase 5: Defining and naming the themes

This phase began when a satisfactory thematic map of the data was reached. "Define and refine themes" refers to identifying what aspect of the data each theme captures, as well as the storytelling of each theme. However, it is important to consider how it fits into the broader overall storytelling in relation to the research question. At the end of this phase all the themes and their sub-themes were identified and they were given their final names (Figure 39).



easy to use compare with BB for Dyslexia	3	10
less stressful	3	7
Motivation_SRL	0	0
3D model	16	18
avilability	1	1
Interactive-self-assessment	0	0
linked matieral	9	11
more intersting	4	4
spend more time	2	2
Negative_feature	1	1
Camera issue	1	1
Labeling	1	1
limitation in mobile technology	2	2
More information in ECG	1	1
more information in self assessment	3	3

Figure 39: Sample of the themes and sub-themes

Phase 6: Producing the report

The final stage of the analysis waswriting the details of the complicated story extracted from the data. As this is an investigative study, the analysis was performed by simply describing and reporting the themes, whilst exploring how the themes might be related, as well as mapping them into a diagram to facilitate their interpretation. The next section will discuss each theme in detail.

7.5. Thematic analysis main findings

The qualitative study intends to investigate students' perspectives between the current and the proposed NMAR learning approaches, in terms of facilitating SRL processes. Additionally, it intends to compare their preferable approach in motivating them to be more active learners. However, user experience research is looking to an individual interacting with a system as well as their perception resulting from that interaction. Accordingly, the main two themes of the analysis were the learning environment which is the system, and students who are the user. After the key coding items were identified, they were categorised into themes or sub-themes to represent the possible responses to **RQ3**.

Visualising the qualitative data provides the reader with the ability of seeing the author's meaning in more ways than just textually. Its suggested to be uncomplicated as possible and balance between the important information and minimum details (Verdinelli & Scagnoli, 2013). Consequently, Figure 40 below illustrates the theme structure generated from the analysis of students' interviews with the aim of achieving **OB12.** The analysis adopted a mixture of emergent coding and *a priori* coding during the process of identifying the key concepts. Most of the themes were identified through emergent coding. In contrast, the SRL processes theme and HCI perspective were derived from their existing theories.

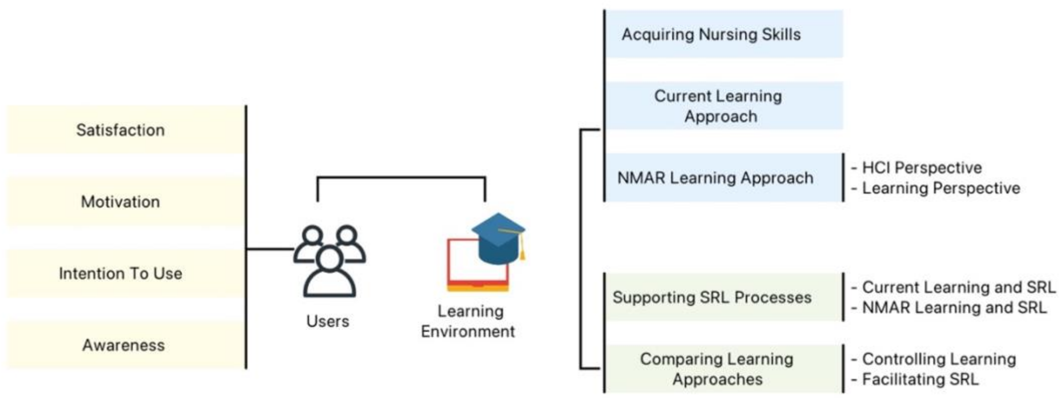


Figure 40: The identified themes structure

7.6. Learning environment

A tree map is a diagram that represents hierarchical data as a set of nested rectangles of differing sizes. The tree map below Figure 41 compares the interviewees' comments of NMAR and current learning approaches. The node with a large number of coding references would be display as a large rectangle. It can be noticed that most of the students found that NMAR features support their self-regulated learning.

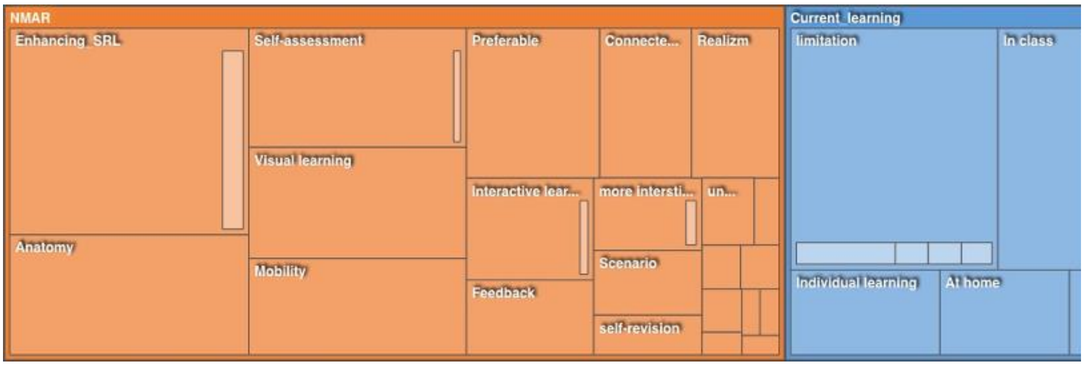


Figure 41: Tree map

More details about the nodes of both learning approaches will be discussed later in this chapter. However, before we present our analysis, it is better to understand how the nursing students are acquiring their clinical skills.

7.6.1. Acquiring nursing clinical skills

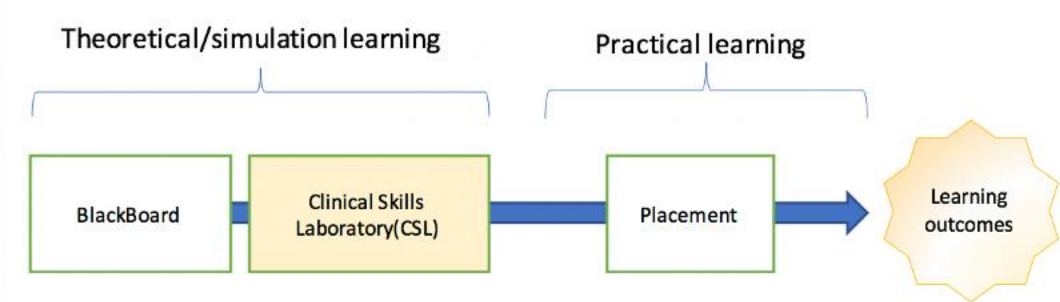


Figure 42: clinical skills Learning process

The complexity of acquiring clinical skills is due to the long learning process. The diagram in Figure 42 illustrates that it has three phases: in the first one students learn the anatomy and physiology as fundamentals in separate classes before attending the second phase, which is the Clinical Skills Laboratory (CSL), which is commonly known as a "skills lab". Students have to be prepared with required skills for their third phase which is the placement, when they deal with a real patients in a hospital. The goal of the CSL is to create a low-risk learning environment for nursing students to develop their clinical skills needed in the placement, as well as to develop their skills to practice safely and effectively as professional nurses:

"Now at the moment, we've got the theory which is self-study which you do on your own time and we've got the practical when you come into the university [skills lab]" [Std_13].

In the CSL, students learn by solving different real-life patients' scenarios and using manikins, focusing on linking theory to practice. This process helps them to practice clinical skills before using them in their placement. Moreover, it helps to ensure that they acquire the necessary techniques and are accurately assessed prior to practicing on a real patients. Therefore, remembering and understanding anatomy and physiology are necessary in scenario-based learning of skills lab:

*"You have to understand the **anatomy** and **physiology** to look after patients because it just enhances your **practice**. So it makes you a better practitioner if your knowledge is poor you can be struggled. All you have to know is what's really happening with the patient, **when you have that clear in your mind**, it makes your job so much easier" [Std_31].*

Consequently, the clinical skills learning environment is vital to achieve the clinical learning outcomes and enhance nursing students' competence in a safe place. This study is focusing on the CSL phase within the learning process.

7.6.2. Current learning approach

During the skills lab, students learn with different learning activities such as "*reading [the scenario] from a paper ..., being told what's going on*" [Std_20] or students act the scenario. They are normally "divided into smaller groups" [Std_17]. Table 47 shows a brief overview of the skills lab activities.

Table 47: Skills lab activities

Learning activities	**Sample of students' comments**
Written scenario with a manikin	"In a current lab, we just use like a paper scenario, so we read through it and we have to assess the patient" [Std_16]; "A student of nursing you speak to a dummy you have a dummy which has nothing moved" [Std_14].

Teacher explains a scenario	"In the lab, … we are having the lecturer telling us all the correct ways … and all the guidelines and everything and then of course showing us how it should be performed and which way is correct and all the regulations and then having the practice on a manikin" [Std_17].
Teacher gives feedback	"Usually when we do get something wrong, we have to wait a while to know that we've done something wrong" [Std_26].
Assessment	"The examiner telling you what the symptoms are, but you can't physically see them" [Std_13].

Student [Std_17] summarised the common learning activities in the skills lab and student [Std_12] added that it is better to do extra work independently at home as a nurse student as follows:

"If we've got now clinical skills, of course, you have to **read on** then if you've got some scenarios you can **watch them** as well. But there are some scenarios where the people **actual people that they are presenting this scenario**. So one person is a patient ,someone is like a nurse whatever it is, but also you've got **written scenarios** and but this is just about the situation and about the illness which the patient already I've got so and to know more about physiology and anatomy and illness you have to just go through the **Blackboard** and the other things. which You **had previously** like for example heart anatomy and physiology" [Std_17];

"You need to do extra work not just depending on the classroom to put more effort on your learning especially as a nursing student … it's good to do your own more independent learning because it helps to go deeper" [Std_12].

Additionally, due to the duration of the class "there's not much time for people to really have time to come up with teaching you everything … everybody learns differently so people catch up when the teacher is teaching and some people go back to kind of grab it bit by bit to understand it" [Std_4]. Especially with the anatomy and physiology parts, "there are lots of reading sources" [Std_18].

7.6.3. NMAR learning approach

This section analyses the interview data from HCI and learning perspectives.

7.6.3.1. HCI perspective

The focus of HCI is generally about the interaction between an individual and a system. When researching user experience, simply concluding that the system is usable is insufficient, what really matters is *how* the users interact with the system as well as their thoughts and feelings with respect to their entire interaction.

To better understand the users, we should mention here the design perspective including the four key elements discussed in chapter 6. Table 48 below details NMAR features under each of these categories. Then we identified the users' thoughts and feelings that were related to the system features. Figure 43 illustrates the themes which emerged from the analysis.

Table 48: Design perspective

Content	Presentational style	Functionality	Interactional style
o Heart anatomy o pathophysiology o Patient scenario including : 1. Patient's information 2. Patient's symptoms 3. Monitor's parameters 4. Patient's 3D heart 5. Patient's Electrocardiogram ECG	o Simple interface o Authentic design of 3 sections o Visual information 1. 3D heart 2. Video 3. Image o Text	o Rotated finger o Zooming o Self-assessment o Instant feedback o Showing the correct answer o Calculating the score in percentage o Interactive patient scenario	Mobile application

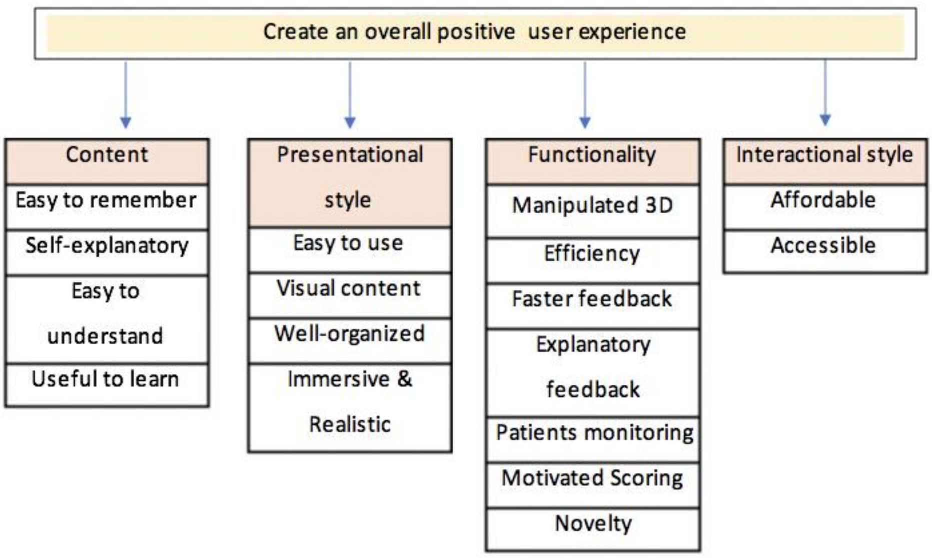


Figure 43: Participants' perspectives

Positive comments

The majority of the students expressed positive feelings and thoughts about NMAR learning approach, such as "*I loved it*"; "*it is more fun*"; "*definitely recommend it*"; "*it's very nice, It's very organized*"; "*It's knowledgeable*"; "*I've never seen that done before*"; "*I've never worked with technology like this*"; "*It's amazing*".

They found the content "very simple"; "explained clearly" and "self-explanatory", as one student said "the jewelry aspect of it shall I say it's basic so it's more understandable" [Std_8] and other added "it just puts it all into the right context for you" [Std_28].

Additionally, the presentational style of the content "makes everything a bit more realistic"; "It's really impressive it's a good job"; student [Std_13] expressed the effect of NMAR presentational style to enhance her learning:

"It basically explained everything like the stages. This is a situation [heart failure] and this is his observations [symptoms]. So the way they have tables everything it makes the sentences explanatory…So it makes you really assessing the patient. It's enhance you to come to a diagnosis" [Std_13].

A number of positive comments were related to the interaction with the content or supporting patient scenarios.

"**A good feature** is being able to manipulate 3D model and actually visualize it to what you want to see it. I think that's a quite good to use" [Std_21]; "**I like the fact** that you could move it around" [Std_24]; "showing heart in the monitor **is good to monitor patients** in other words" [Std_34]; "a live function really to see what your patients doing, I just thought **it was brilliant**" [Std_20].

Moreover, using a mobile application as the interactional style added additional positive features to NMAR learning approach, for instance accessibility: "[students] *could access at home for [their] learning and preparation*" [Std_17]. Students also said:

"Wherever you are, you can access, **that's a great idea** actually be able to do that" [Std_10];

"We use our phones quite a lot and **you can spend that time actually learning** and whenever you want like you can be in bed and you can be learning by yourself" [Std_26];

"If you are **learning yourself**, you know how much time you've got and it almost lends itself to be able to do your learning anywhere… **So the mobility of it is very good** " [Std_31].

Affordability is another positive feature of using mobile application, student [Std_14] commented that "*with the use of your finger, you don't even need any instrument and you are not going to pay for your finger*", she explained her positive feeling with NMAR by saying "***I strongly agree with the application*** *be that you can literally see everything going on and*

It reminds you exactly what is being explained to you easy to remember ... reminds you of everything you've studied by explaining to you to be much easier" [Std_14].

Negative comments

Despite the positive findings for the NMAR learning approach, each work has its limitations. Accordingly, students also made some of negative comments such as "*could have been clearer*"; "*could be a little bit improved*"; "*I got a little bit confused*". Their criticisms can best be treated under three headings: technology reliability; usability issues and suggestions.

Technology reliability

Students were concerned about being dependent on the technology, in terms of its availability and battery life.

"**What if the device is not working** and you so much reliant on it, and it's no working and you've got an emergency, what do you do? So I think availability of the device and making sure that it's always working and there's always extra in case something happens" [Std_22];

"If you are going to be using the application of the instrument, which fully charged then if each class finished **you need to plug it to charge** before another class come in" [Std_14].

Usability

Most of the negative comments were related to usability issues, especially when they interacted with 3D model or did the assessment. For example "when you move away from the marker, [the 3D model] disappears off the screen", the student suggested that "it would be ideal once you moved could maybe have it for timed in for a minute so that you could have a proper play" [Std_5].

In addition, students were more familiar with using two fingers than three, while interacting with a 3D model. In NMAR they used two fingers for zooming and three for rotating which "*is quite difficult at first [they] don't get it*" [Std_10]. However, one student suggested using two fingers for both types of interaction like the smartphone does:

"I would have preferred just use two fingers in everything whether to rotate depending on what you want, you can use like your phone where you want to zoom or rotate don't need to use the three fingers , **two fingers can do everything depend to how you want to do it**" [Std_14].

The coding colour for selecting the correct and incorrect answers was another issue reported by the students:

"When you click to the next one, the green colour you click on the first one goes white, why? so maybe if you could click on it and it stays green and you click sudden, you know, which ones you've actually chosen" [Std_9].

One of the participants said that the coding colour schema of the self-assessment seems to have an impact on students' attention to reading the feedback. In NMAR there was a usability mistake, as one of the correct answers was supposed to be green, but it appeared in red, and this mistake prevented her from reading the correct feedback, and accordingly affected her test result on the second attempt, causing some confusion: "*when I **clicked the correct** answer it **appears in red** so I just thought I didn't really pay attention to read them, just so it's incorrect answer*" [Std_17].

Suggestions

A few participants requested a training session, especially to demonstrate the interaction with a 3D model [Std_6]; [Std_10; [Std_12]; [Std_13]; [Std_14]; [Std_19].

Moreover, three participants suggested having more information and detailed explanations in the feedback section, which is most beneficial for first-year students "*because I'm a first-year student ... I need more explanation*" [Std_6]; [Std_20]; [Std_3].

Two students also suggested having "*like an area of the queries*" or "*online discussion board*" that can be used if "*the app cannot give you the answer*" [Std_31]; [Std_5].

7.6.3.2. Learning perspective

The crucial aim of CSL is to support students in the acquisition of the clinical skills by providing them with a simulation environment with opportunity to integrate their theory with practice before their placement and to learn from their mistakes without risk of harming real patients. Thus, the two themes were identified about NMAR here seem to be consistent with the aim of CSL in terms of linking theory to practice and enhancing independence. However, three additional NMAR learning aspects themes emerged from the analysis, which are visual and realistic learning, interactive, engaging and enjoyment learning, reduce cognitive load.

Connecting theory to practice

The novelty feature of NMAR is connecting theory to practice in one place with an easy access. It refers to having the anatomy and pathophysiology, which are the theory parts, and the practice, which are the scenario and the assessment. Students described the content of NMAR as "*connecting all together between the theory and the practice*" [Std_18]; "*It's like you've got your theory and your practical in once*" [Std_3]. So, "*you've got all associated together or connected so you can just go through the physiology and anatomy of the heart then you can see all the procedure*" [Std_17]. Student [Std_30] explained the usefulness of having all connected resources in one place, compared to the current learning method, by saying:

"I think the combination of them all being in one place because I could probably go on the internet to find an image of a heart **like spend an hours** okay, find the things separately but **having them all in one place** was the thing for me that made it most interesting. Yeah it was easy because **they were all there** and it was useful".

Enhance independency

With NMAR "you don't have to be in the class to know how things work and you can learn by yourself as well" [Std_11], and it allows the student to "go on and do it independently" [Std_28] without the "need to start asking anymore; [they] just get along than [they] just carry on and do what is required" [Std_22]. "Even without tutorial [they] can understand in detail, [they] can do study alone without the help of any lecturer" [Std_7]. The reason for independence could be the realism and the interactive self-assessment as students [4] and [23] explained:

"I think [patient's scenario] is like practical, so when you see it, you can be able to go on your own to find out what is this **because it's written particularly** … it's very directly it is very practical" [Std_4];

"I liked a lot that you could choose what you would do and it will tell you that incorrect you need to think again, **makes you think yourself** rather than someone else to say" [Std_23].

Students believe in the importance of monitoring their learning. They reported that "self-assessment is really important when learning clinical skills" [Std_11], and "having a confirmation coming, it's very important in the self-learning" [Std_19], because student will know "which areas [they] need to improve on" [Std_18].

Therefore, the interactive self-assessment mechanism of NMAR grants students the ability to correct their mistakes and monitor their learning:

"You learn from your **own mistakes**, basically and understood why, because if it didn't give me the actually correct answers, I will not know what's right and trying to guessing the other options" [Std_13];

"when you did it even know if you didn't get it at the first time **you can do it again** and then you know that okay, so you remember" [Std_9].

Student [Std_12] mentioned that self-assessment in clinical lab supports the students' preparation for their placement by saying:

"It's quite good because it would help me understand what to do, when doing clinical practice and during placement as well. As it is import to get that feedback up to actually try and **if you fail then you know what you need to learn** and if you pass then you know, if you learn them or not" [Std_12].

Visual and realistic learning

The visualisation of NMAR's content eases understanding and memorising. "[*Students] learn faster more with visual things*" [Std_2], and NMAR "*makes learning easier to understand because [they] can see visually*" [Std_6]. Students reported that they prefer visual learning to reading books:

"I actually got more out of that five ten minutes than I have from reading books for hours and hours and hours" [Std_20];

"You can actually see it's better than just seen on paper" [Std_28];

"It will be easy to see something I can relate to and understand more that if somebody telling me something it's very difficult" [Std_10].

An interesting comment came from student [Std_14] who described NMAR as blindness removing:

"For you something you don't understand it's like you are blind towards that thing … use **this application removes the blackness** out of you makes you to see … it makes you to see, it removes your blindness" [Std_14].

Beside the visual content of NMAR, students found it "*more realistic*"; "*makes everything a bit more realistic*" and makes it a "*more realistic approach to learning*". The realism of the virtual patient enhances the students' understanding as well as their independent learning:

"The way I saw the symptoms, I can sort of like visualize it and I can see it next time, **If it does happen to another patient I can recognize it**" [Std_26];

"This one feels like you are dealing with the patient directly. So how it made it looks real **you feel like you are interact with real** and with somebody" [Std_6];

"It will enhance myself learning … because **it's like dealing with patient directly**" [Std_14];

"I quite enjoy doing that because **it's like being on the warred**" [Std_28].

Interactive, engaging and enjoyable learning

Students also described the NMAR learning approach as "it's different, you [are] more involved, it's not you're just sat listening or watching", it is "more interactive and engaging", "the interactive bit of it, is more interesting way of learning", "it makes it to be more interesting to learn, it doesn't look boring".

Some students felt that the interactivity with the content created a sense of playing games:

"The application is more engaging to me, so **cannot feel like I'm learning**" [Std_22];

"It's like animated and **you can play with it**" [Std_26];

"I enjoyed all of them honest all of them I watched the app the first part twice.. I engaged a lot more because … **it gives you a different learning experience**" [Std_28];

"I think it's kind of a little bit of a good game as **well** so it makes it more fun" [Std_20].

Although students described different learning aspects of NMAR, one of them summarised the common aspects identified from the data set such as visual, interactive, engaging, easy to remember and support independent learning:

"I like the kind of **linked things** so I felt like I was learning a lot more because I was **looking** at some I was **seeing** and reading some **theory** and I was also **interacting** with the data which was increasing how much **I engaged** and I like that **it tested me** at the end as well. But I also like that I went through without having **to bother anybody** to say or can you just explain this to me feel like I will **remember** it more because of the different aspects" [Std_30].

Reduce cognitive load

Cognitive load simply refers to the used amount of working memory resources. Thus the majority of the participants mentioned that they are "*visual learners" and they "learn faster more with visual things*" [Std_2]. Also, using visual content "*makes learning easier to understand*". One student argued that "*watching video is really sticking to my mind really quickly*" [Std_8]. Other student agreed by saying "*the 3D model ... you can imagine it easier and you can memorize it better*" [Std_27].

Although most of the students' comments relating to the cognitive load were "easy to remember", two of them clearly expressed that NMAR reduce their cognitive load:

"Minimal the stress ... [because] you don't have to start memorizing it you can use it see it on your own ... it reduces the stress of **mental health**" [Std_22];

"It provides for you the self-assessment part shows you everything supposed to need to solve this problem... see them you don't **need to crack your brain load**" [Std_14].

There are several possible explanation for this result; for instance, from the Cognitive Theory of Multimedia Learning, Mayer (2005) stated that "*people learn more deeply from words and pictures than from words alone*". Thus NMAR offers a multimedia learning environment including different types of media resources such as text, image, 3D and video, in order to facilitate understanding of the concept. Furthermore, the result of a recent study about AR in science reading and cognitive load, demonstrates the positive impact of AR on multimedia learning situations as well as on reducing student's cognitive load (Lai et al., 2019). This result is in line with a previous study which used AR in English learning. The result showed that students who used the AR application have a low level of cognitive load (Küçük et al., 2014). Moreover, the study suggests that as a result of AR imposing a relatively low cognitive load on the students, it can be adopted efficiently into education curricula.

7.6.4. Supporting self-regulated learning

This section analyses how the current and NMAR learning approaches facilitate SRL processes.

7.6.4.1. Current learning and SRL

Within the process of clinical skills acquisition, independent learning is an essential process for two reasons. Firstly, learning anatomy and physiology for each organ are prerequisite subjects, students have to take them before starting their clinical skills classes. Moreover, the clinical skills learning process starts from home, students are "*given scenarios on paper and watching* *videos at home then come into practice them in a clinical skills lab*" [Std_20]. They have access to that scenarios through the Blackboard system but they "*can't really access like physiology and anatomy*" [Std_17]. So, for the anatomy physiology of that scenario, they "*have to go and do [their] own research*" [Std_20]. Due to the huge amount of information with less directed learning process one of the students reported that she struggled with finding the necessary information:

"I'm still having trouble navigating it because all the things come up you have access to all the other courses and Material so you really can just find the wrong stuff and get things completely wrong" [Std_5].

The second reason is the class duration, students "don't get enough time in the lab because it's quite resource-intensive" [Std_30]. During the class "the responsibility is on the teachers" [Std_30] who "explain all the goals through the presentation" [Std_17] then "come to explain … what [students are going] to do and they ask them to repeat what they've done" [Std_22].

However, due to the number of students and time restriction some students "feel like teachers rush on teaching [them] and they don't really get to do anything practically" [Std_19]. Additionally, when they "do get something wrong with, [they] have to wait a while to know that [they] have done something wrong" [Std_26]. Moreover, "not everything students come across about the patient that might have been taught in the classroom" [Std_26]. For example, when a student works with a real patients and looks after them, but she realizes that she does not have enough knowledge to understand what is going on, she has to "then go work in her own time to see what's wrong with them" [Std_24].

Although the university allows the students to use the lab, two participants reported that it does not support their independent learning:

"You don't always get in clinical skills unless you have an actor on the bed showing the symptoms it showed you the scenario" [Std_22];

"You are more likely to do it with the other, they say to us that the skills labs you can go on and in whatever you want. But what do we actually do when we get in here? **we're just stand there** … Like I don't know what should we do? You know, but if there's something to do then you're more likely to come and do it" [Std_13].

Two opposing views emerged from the data. Some participants criticised the teacher-centred learning approach during the class, arguing that students are learning differently: "*people are sometimes quicker at picking things up than others, [it makes] sometimes embarrassment*" [Std_20], for those who do not really understand. Also, they feel like they are "*being compared against other students*" [Std_21] or are nervous.

"I used to study the current approach is where there is a manikin is, a supervisors beside you the moment you say something wrong, they'll just look at you and say no. It's like think about another treatment you will be more nervous, you know, you don't know what to do when to answer" [Std_27].

Additionally, they pointed out that "relying on other people for feedback" [Std_21], makes them wait for someone who "tells what's right and what's actually wrong … [but] in the class … everyone is busy in that room experiencing things" [Std_11].

Other participants argue that "the teacher is still very important coming to a class and tell us what is going on … because in a clinical lab you need like a physical evidence that you know the scenario" [Std_15]. The given advice helped them to correct their mistakes. "Normally … the lecture explains all the goals through the presentation and explains and give [them] an example because usually the lecture is the qualified nurse and got some specialties and stuff like that" [Std_17], at the end they "learn with teacher and colleagues as well, and get feedback from both" [Std_11].

In summary, the results shows that teacher-centred approach is the learning method used during the skills lab. However, students use "*very lengthy*" and undirected learning methods after class when they work at their own pace.

The table below Table 49 describes how the current nursing students learn independently from the SRL perspective. It indicates that when the students learn independently by using Blackboard resources, it is difficult for them to control their learning as a result of the absence of self-assessment and feedback during their learning process. Student [Std_15] reported that more awareness is needed of how to regulate their learning. Other students showed their awareness of extra work needed, but the current approach is less motivating to them: "*the current learning is not very motivating*" [Std_29].

Table 49:The current learning from the SRL perspective

SRL	themes	Example of students' comments
Awareness	Needed	• "It's more actually giving awareness if you're aware of what to do then, you know, what come and look for when you're coming to the class" [Std_15].
	Aware	• It's good also to do your own research your extra deep learning because there's not much time during the class" [Std_12].
Goal setting	By a student	• "We have to watch videos on Blackboard for your pathophysiology in the anatomy physiology of it, but it's based on you doing that learning" [Std_20].
Task strategies	Self- searching	• "I still did my own research, but it probably took longer" [Std_24]; • "You have to go and do your own research. its time consuming. Very lengthy like hours and hours and hours and then if you do hours understand it" [Std_20]; • "Rather than just read books and say oh I've read some books and did something I can prove. I went on the e-learning NHS e-learning courses" [Std_5].
Self-evaluation	No self-assessment	• "With our normal one, you just get everything put on blackboard. So you go through the PowerPoints and you do reading" [Std_18]; • "When read some things, I'm going to have to re-read it to make sure I've read it Right" [Std_18].
Feedback	No feedback	• "At the moment we're doing things that we don't know if we do it right or wrong" [Std_23].
Motivation	Less	• "But reading a textbook it does bore me" [Std_16]; • "The current learning is it's not very motivating" [Std_29].

7.6.4.2. NMAR learning and SRL

Table 50 summarises students' perspective within the SRL processes. It shows that students are aware that NMAR's features may enhance their independent learning and boost their confidence. Additionally, through its mobility feature they "*can even get home and practice it and it will bring about more motivation for [them] to practice*" [Std_2], "*It gives [them] the opportunity to repeat as well so that's great because while [they are] repeating [they] learn as well*" [Std_17]. Also, they showed that they will be able to use it during the class with less help sought from the teacher.

Table 50: NMAR learning from the SRL perspective

SRL	Themes	Sample of Students' comments
Awareness	Aware	• "It's quite easy **learn independently supporting** because you learn things the way that is perfect for you. So and the good thing is that if you have a variety of things of how to learn is much more effective when you learning by yourself, so, you know, what works for you and how you'll understand things a lot better" [Std_11]; • "It would just help me retain it and help me learn it better and feel **more confident**" [Std_24]; • "It told you that how much you know about the topic which is more **convenient** than using the notes that you've made" [Std_25]; • "This will **boost your confidence** and boost yourself like which it's the right decision to take it for the patient" [Std_27]; • "I'm able to plan my own learning" [Std_29].
Goal setting	BY NMAR Which is "learning objectives", but the students activate it when they use it	• "With this using it this way, you're much more self-regulated because it's you deciding what you want to do, and when" [Std_3]; • "You have to make things happen by yourselves and make decisions of what you going to do by yourself" [Std_34].

Task strategies	At home	• "It's so explanatory as well … it is adjustable … you could just sit with it and learn more even at home not necessarily in the class you can really understand what is it all about" [Std_3]; • "I watched everything you can do to help this person without contacting even the doctor you can know if you are right or not" [Std_2].
	In class	• "Used independently don't need to be asking lots of questions that people around you all the time to do it by yourself. You don't need a group of people there like the 3D images with so much but alone in that way even the monitory is more realistic as well" [Std_34].
Self-evaluation	By NMAR	• "I think the most feature is the scenario feature because like you will be more able to have confidence for yourself and you **can diagnose and check the symptoms without a supervisor**" [Std_27].
Feedback	By NMAR	• "It's kind of giving you an idea of what you should do in that scenario" [Std_23]; • "You can sort of like look back at it and you wouldn't have to chase someone for information and to explain something to you" [Std_26]. • "When if I'm alone for example at home and with this app the app tells me what I want to know and if I think I don't understand it right. I'll have to go back it can tell me as many times as I want" [Std_7].
Motivation	More	• "You can even get home and practice it and it will bring about more motivation for you to practice because you happy too" [Std_2]; • "With this I get regulated more and activate the regulation more" [Std_32]; • "It makes self-learning to be very interested … that motivating me … is accurate it is visual everything should be able to learn how to do things."[Std_4].

7.6.5. Comparing the two learning approaches

This section compares the current and NMAR learning approach in terms of students' ability to monitor their learning and how each approach supports SRL processes.

7.6.5.1. Monitoring and controlling independent learning

The feedback principle is perceived as vital within the SRL cycle, as it allows the students to monitor their learning and correct themselves:

"If you cap the results afterwards so you can check and then you never have to wait for the teacher to say oh you're doing it right or wrong I think **having a confirmation coming It's very important in the self-learning**" [Std_19].

The table below describes the different learning methods between the class and home when learning clinical skills including: patients' scenarios, symptoms and feedback. For example, in the class, the teacher explains the scenario and gives feedback, and students are "*just looking at the manikin and imagining what is inside that clot*" [Std_22], but the "*students don't have that flexibility*" [Std_33] and experience to imagine the symptoms, they "*can't physically see it … [they] can action quicker when [they] see it*" [Std_13]. However, the only way to see the real symptoms is during the placement when they deal with a real patient in the hospital:

"[In the skills lab] when you are reading the scenario … it is really just being read on a piece of paper. You can physically see how it look like when you're in the placement" [Std_21].

However, if the students learn at home, they do not receive feedback because "there's no one next to you can explain to or just help you so kind of left alone and if you don't really understand anything you just going to stay like that" [Std_23].

In contrast, by using NMAR students "*don't have to be in the class to know, how things work and [they] can learn by [themselves] as well*" [Std_11]. They also can track their learning by getting the feedback instantly, they do not have to "*come back in a week's time or couple weeks' time to do it*" [Std_16] and get the feedback. Moreover, students "*don't feel like [they are] being tested but yet [they are] still gaining a lot from it*" [Std_21]:

"Because usually when we do get something wrong with **we have to wait a while** to know that we've done something wrong and **you cannot sort of identify that straight away** whereas with the app you can know straight away and that's where you went wrong so you can change it after to track yourself" [Std_26].

Also, NMAR enables students to repeat the scenario if they did not understand it in the class:

"You can go back on the situation and scenario you're end and go over that again and again as many times as you need **because if it is a lecture based when the lectures done and it's finished**. like in [NMAR], I could have gone over the video if I didn't understand it on the symptoms or even the 3D image of the heart and the video about the heart as well the disease we can repeat it as many times as you want. So until you understand it basically" [Std_13].

The findings in Table 51 illustrate that with NMAR students can easily control their learning compared to the current approach. The mechanism of NMAR interactive self-assessment including the virtual patient, instant feedback and scoring calculation can facilitate students' independent learning, and motivate them to be active learners "*the fail result motivates me to I want to get 100 so it makes you to try to get 100*" [Std_14].

Table 51: Easier to control the learning with NMAR than the current approach

		Blackboard	Clinical skills lab Simulation experience	Placement Real experience	
Current	Scenario	Written paper +self-research	Teacher explaining + dummy manikin	Real patient	**Difficult to control**
	Symptoms	Imagining	Imagining	Real	
	Feedback	No	Teacher	Supervisor	
NMAR	Scenario	Connected material with virtual patient	Virtual patient + manikin	Real patient	**Easy to control**
	Symptoms	Simulated	Simulated	Real	
	Feedback	Instant	Instant	Supervisor	

7.6.5.2. Facilitating the SRL processes

Table 52 below compares the current and NMAR approaches in terms of facilitating the SRL processes. It shows that although the current learning supports students to work on their own and provides them with resources through the Blackboard system, it is undirected with lack of self-assessment and of instant feedback. Accordingly, students face difficulty in controlling their learning. These limitations may discourage them, by reducing their ability to be independent learners and not always seeking help from their teachers:

*"When you don't understand what you are learning becomes very difficult because you **get stuck and you don't have anyone to help you father, So you waste time** then" [Std_22].*

Table 52: Comparing the two learning methods with SRL

SRL	Current	NMAR
Awareness	x	Student aware
Goal setting	Student	NMAR
Tasks strategies	Blackboard + Self-research	NMAR
Assessment	x	Self-assessment
Feedback	x	Instant feedback
Monitoring	Difficult	Easy
Motivation	Less	More

Moreover, the lack of students' motivation with the current learning method can also be due to its characteristics such as lack of interactivity and realism:

"The current learning is not very motivating because it's not that interactive and It's not close to reality" [Std_29]; "if it is really real it was enjoyable" [Std_4].

Finally, integrating technology effectively within the learning process could overcome the above limitations:

"It's nice to have feedback at the end of it and I could see that I'd learned something … **more motivated**. So like I wonder what else I could learn" [Std_30].

One student added that the NMAR interactive assessment affected her strength in self-learning: "[Self-assessment] is a good function, **I'm not very good** at self-assessment but NMAR enable me to gained strength in that area" [Std_1].

7.7. Users

This section discusses in detail the identified themes from the data set, which are related to the students (users). The diagram in Figure 44 shows four main themes and their sub-themes. We counted the students' preferences in the three main themes: awareness; motivation;

intention to use. This can be useful in providing insight into their needs as well as their perspectives of different aspects of NMAR.

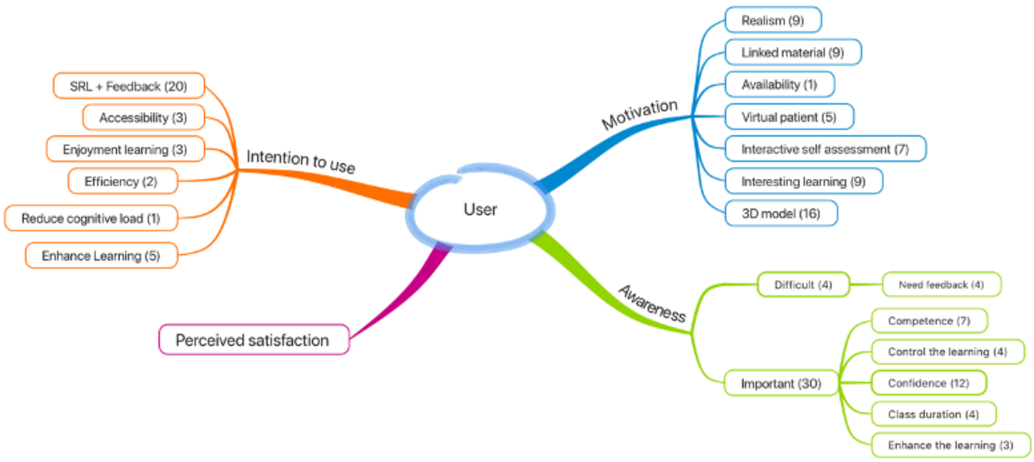


Figure 44: Users' characteristics

7.7.1. Awareness

Participants were asked about the importance of learning independently in a skills lab, and two different views were identified. The majority of the users (88%) believed it is important, whereas 12% of them reported it to be difficult.

Several different reasons were identified from the first group who believed it is important, such as "*the class duration is not enough*" [Std_31] Additionally, independent learning helps students to control their learning as a result of "*everyone learns differently*" [Std_18], with independent learning they "*learn the way that is perfect for*" them [Std_29], and they can "*repeat as many times as [they] need*" [Std_23]. Thus, they "*will not forget the information*" [Std_2].

The main reason was reported by 19 participants out of 34, who agreed that independent learning is a boost to their confidence and competence. For example, "*confidence can increase*" [Std_6] because "*It prepares you for the practice*" [Std_24], also, "*it's going to help you in the long term*" [Std_28]. As nursing students "*saving people's lives, ... that is the most important part of our learning*" [Std_17] and "*into the practice, you are going to be independent*" [Std_34], "*dealing with real patients and you're expected to know ... as if you miss your clinical skills, you're not going to know*" [Std_20] how to help the patients.

Before explaining these findings, we need to define two terms used throughout the analysis: competence and confidence. We distinguish between them as follows: nursing clinical **competence** refers to students' ability to solve the patient scenarios successfully or efficiently, whilst **confidence** means students' beliefs about their clinical competence.

Learning clinical skills is treated as a developmental process, where repeated practice helps students to gain confidence and competence. The importance of confidence in the context of the clinical skills lab comes from the learning outcomes which are measured in terms of clinical competence.

However, a small number of the respondents were against the independent learning in a skills lab, arguing that teacher's feedback is needed:

"To be honest, it's difficult" [Std_23], "self-directed it's not that easy in a clinical lab … teacher demonstrating is important" [Std_15], students "will get stuck" [Std_22] without help or feedback, and "when you learn independently don't very often get feedback from some people" [Std_1].

The possible explanation for these results may be their level of self-efficacy.

According to Panadero et al. (2017a) self-efficacy refers to the student's belief about their personal capabilities to perform a task and achieve the established goals. Those four students showed a low level of self-efficacy. Student [Std_1] explained that, because of her lack of experience, the teachers' feedback is important. However, other students showed less confidence:

"The teacher is still very important coming to the class and tell us what is going on" [Std_15]; "When you don't understand what you are learning, becomes very difficult because you get stuck and you don't have anyone to help you further" [Std_22]; "It's always good to have a teacher because you can come up with strange questions" [Std_23].

To sum up, students with low self-efficacy might be led to believe that the tasks are harder than they actually are. However, enhancing their confidence is not a luxury option, it is essential for a future nursing career, the reason is:

"We're going to be making decisions by ourselves, or not going to be relying on anyone to correct and make decisions for us" [Std_26].

7.7.2. Motivation

Despite the fact that 4 students reported that independent learning is difficult during a skills lab, all of them agreed that the NMAR learning approach will enhance self-regulated learning and motivate them to utilise it as an effective learning tool. Seven different motivating aspects of NMAR were identified from the data set, as some of the students stated more than one aspect. The list of motivating aspects are realism, virtual patient, easy to access, interactive self-assessment, interesting learning, and connecting the theory with practice. The interactive 3D model and visual content were the highest motivating aspects reported by the participants.

7.7.3. Perceived satisfaction

In the field of HCI, user satisfaction can be defined as the "subjective sum of interactive experiences", and it is generally visualised as the expression of affection obtained from interaction (Liaw & Huang, 2013).

The analysis of the interviews reveals that most of the participants were satisfied with NMAR as a learning approach. Their satisfaction was not only because it has the confirmation which is "very important in the self-learning" [Std_19], but also, because they were dissatisfied with some current learning activities by feeling bored or awkward:

- "When you have an actor you feel a bit **awkward**" [Std_22];
- "I got **bored** when I read books when I'm in class" [Std_3];
- "It is really easy to use so I'm not going searching for papers or research, which I **hate doing**" [Std_24];
- "It will always hard for me to imagine the anatomy like when they gave us the normal model followed model is **very hard to imagine** it" [Std_27];
- "When you reading sometimes you get a **bit reading blind** … you've got to keep looking up things … **you lose your train** of thought and you lose what you're looking at in the first place. So you **get distracted** by something else that catches your interest" [Std_28].

Students who were satisfied more with NMAR criticised the long period between the theory and practice in the current approach:

"If you learn something you're not putting into practice until you've gotten on the hospital or someone else is talking to you about it you do forget a lot of things" [Std_28].

NMAR connects theory to practice, so students can remember more information:

"It helped you try and remember what you just learn so you was like trying to bring back the knowledge even though you'd rather watch the video and looked at the 3D model you was trying to bring back all that information that you just learn straight away It wasn't just a let's learn it and come back in a week's time or couple weeks' time to do it you was doing it straight away." [Std_16].

Some of the senior students expressed their satisfaction with NMAR because it is expected for them to be in the hospital for a full day, NMAR will help them to prepare for their placement easily. It can be a self-revision tool as "on the spot training":

"I can use it on my phone I could take it with me If I'm on placement I can use it if I'm on my break or rather than carrying lots of books around. It's got all the information there" [Std_18].

Moreover, the results of our previous investigative study showed that time restriction is one of the major issues in preventing students from attending clinical labs. It could be student's timetable or class duration time. One of the senior students confirmed this issue by complaining "*It's very seldom that we get the opportunity to be in the skills lab … I'm half way* *with year three, but I've only had one so far this year which I don't think is enough ... I don't think there's been enough time*" [Std_24].

Indeed, she went so far to express her anxiety:

"I am in the third year now and it's getting to crunch time. It's getting to **scary time** and in six months, I'll be expected to know all these things and I feel like a lot of it I obviously do know but a lot of it I feel like we could not have been taught it" [Std_24].

In other words, acquiring clinical skills is a challenging process, it requires students to do extra work and preparation at home by "lots of reading sources". Technology such as NMAR can be beneficial in facilitating their learning and reducing their anxious feeling:

"We've already studied the heart and stuff on AMP, but there was some knowledge that **I did not know** like the morphine injection so **I picked up** that while I was watching the videos" [Std_16].

Additionally, working with group in the class could negatively affect students who feel as if they are being judged, and using NMAR may overcome this issue:

"Without that feeling of being nervous and anxious feel like you're being judged" [Std_21].

Unexpected results were reported from non-English speaking students, they were more satisfied with NMAR's virtual patients than the current "patients" as a result of English accent barrier. They reported that NMAR helped them to understand the patient's scenario clearly:

"I think [self-assessment] is adequate for me I found it so straightforward so explanatory, **the English** is not that difficult, you can **really understand**" [Std_3].

Another participant added:

"It was really helping me like sometimes you hear some things and especially **local patients**, which may not be very clear and you **might not understand** what they are saying" [Std_4].

Table 53 below summarises participants' thoughts on how they distinguish between NMAR and current learning.

Table 53: Participants' thoughts

Current	NMAR
Boring	Not boring
Not engaging	Engaging
More searching	Connected theories to practice
Lots of reading	Visual learning
Not immersive, not real	Immersive and real
Need someone to explain	Reduce the load of seeking help
Feeling awkward with patient's actor	Virtual patient
Students do not have the flexibility to imagine the symptom	Students see the real symptom, hear the patient's voice and read the patient's monitor.
Not directed learning	Directed learning
Difficult to control learning	Easy to control learning

7.7.4. Intention to use

All the participants showed their intention to use NMAR if it is released in the future. Their purposes behind the intention were diverse. Over half of the participants (20) indicated that they will use the application to enhance their self-regulated learning, especially outside the classroom. The reset of the participants reported that their intention to use NMAR for other purposes like enhancing their learning in general, due to it being easy to access, reducing the time for searching, and stimulating enjoyable learning. Some students asked for specific time or "*want to ask if you can send it to me to use and try it at home*" [Std_14].

One individual stated that she would like it to be released sooner because this kind of learning approach will solve her transportation issue, she used to study clinical skills at home instead of attending the lab sessions:

"I want it to myself I get like two and a half hour bus travel to get here. So I **can't always get here** ... it means for me that I could do my clinical skills without having to travel all the way to be here" [Std_21].

This idea is in line with some of the written comments in our investigative study, and students for instance said:

"I am meeting real patients on placement, scenarios just **aren't as good for** learning as meeting real people" [Investigative_std_67]; "I **prefer dealing with the real patients** in placement" [Investigative_std_101]; "I don't have time as I am focusing on assignments, exams or **placement**" [Investigative_std_50].

It is somewhat surprising that some students may rely more on Blackboard resources for placement preparation than attending skills labs. The noticeable comments draw our attention to further investigation on how the insufficient realism of the manikin discourages students from attending the lab, especially for senior students. For example, a comment of one interviewee supported this idea by saying in the lab "*someone just tells us [the patients' symptoms], we never see it which **for me is rubbish***" [Std_33].

7.8. Discussion

As a result of the explosion and rapid development of technologies, there is increasing interest in self-regulation and self-regulated learning research. This development introduces new learning activities and makes it accessible, as well as creates an opportunity to develop a highly sophisticated technology-enhanced learning environment.

The study findings of Zhao (2016) showed how environmental determinants are the key role in shaping the SRL process in e-learning, and that SRL processes can be directed and organised by the learning environment. Our analysis and findings support this claim that the learning environment characteristics that shape SRL processes influence students' ability to be active learners. The results (in section 7.6.5) indicate that the current learning approach provides students with learning resources through the Blackboard system, in order to facilitate their independent learning. However, as a result of its undirected learning, students are facing difficulty in monitoring their learning. The NMAR learning approach can overcome this limitation, by developing a learning environment with an interactive self-assessment mechanism. These findings are also supported by a peer review study into self-regulated learning in a technology-enhanced learning environment. The study showed that a technology-enhanced environment offered more opportunities for interaction, feedback and self-monitoring, receiving students' higher ratings in respect to facilitating SRL processes (Steffens, 2006).

Moreover, the innovative approaches of monitoring students' learning and providing feedback, is a way to encourage their motivation and activate their self-regulated skills (Barber et al., 2011). Our findings are in line with this idea as well as with a study that stated that interactive self-assessment tools that engage the students in quizzes involving feedback, challenge them to actively be self-regulated learners (Petty, 2013).

In other words, AR mobile technology produces many advantages in supporting independent learning, it facilitates access to the material and mobilises the learning environment. Additionally, the interactive learning environment can motivate passive students to be active learners. Utilising NMAR that facilitates SRL processes could develop gradually students' self-regulated skills. The findings show that the innovative way of NMAR self-assessment including scenarios, quizzes, instant feedback, and result's scores, might motivate them to activate their SRL skills. The immersive learning and the realism of scenarios such as seeing the patient's symptoms, hearing their voice, reading their ECG, and monitoring parameters, motivate some students to be self-regulated learners (section 7.7.2 Motivation). This finding corroborates the findings of previous work in this field (Vaughn et al., 2016), where the author adopted a Google Glass as AR tool to present a scenario in the skills lab, and the results found that the realism of the technology contributed to independent problem solving and motivation.

In accordance with facilitating nursing clinical skills acquisition outside the lab, a previous literature review study has demonstrated the need for directed learning away from practice and limited class time, and an effective technology-enhanced environment can play a part in achieving that. The study found that interactive self-regulated learning tools have been shown to have benefit in self-directed learning. However, it is not attracting all learners and their engagement can be variable (Petty, 2013).

Consequently, students' characteristics is a factor that cannot be neglected. Students' beliefs, awareness, learning styles, self-efficacy, experience, and other personal characteristics, influence their motivation and ability to be active learners. For example, students with lack of experience may be less confident in clinical skills practice. Furthermore, our findings in this chapter show that the majority of students are aware that independent learning is important in acquiring clinical skills. Additionally, the NMAR interactive learning environment which facilitated the SRL processes motivates them to be active learners. However, a few students reported it is difficult to learn independently especially during class time. It is worth looking more deeper into those students, and Table 54 below summarises their key answers. The results in the table show, despite their belief about independent learning, they agreed that NMAR facilitates SRL. For example, student [Std_15] intended to use NMAR to enhance her SRL outside the class time, this result indicates that a student is motivated to be an active learner if the learning environment supports this, while the other students intended to use NMAR to enhance their learning. The possible explanation may be lack of awareness, they may not be aware how to regulate their ideas. This result is limited and further research is needed to investigate the effect of students' characteristics to activate their SRL skills.

Table 54: Low-level motivated independent learners

Std	NMAR enhances SRL	Motivating feature	Intention to use
[Std_1]	Yes	Realism	"it would enhance your learning"
[Std_15]	"Definitely"	Accessibility	"It's an easy way to self-direct yourself."
[Std_22]	Yes	Visual content	"it makes learning easier for me"
[Std_23]	Yes	Visual content	"I prefer this better than books"

Generally speaking, our findings reveal that students have a positive attitude towards the NMAR learning approach. They found it more motivating and easy to control their learning in comparison to the current approach. Additionally, the underlying reason for students showing a positive attitude may be the fact that they come across different multimedia learning materials, compared to the current approach, and interact with the content.

Other findings reveal that some students may face difficulty in regulating their learning, or not realise **how** they should regulate it, and using technology could solve this issue. This finding is confirmed by a student's [Std_30]'s comments:

"I would never really thought about the need to have self-regulated In the lab ... so I think sometimes we don't get enough time in the lab because it's quite resource-intensive. So it's absolutely where there's an option for students to work independently" [Std_30].

On the other hand, NMAR can be used in the skills lab or at home. In the lab, utilising NMAR as a learning resource should not eliminate the teacher's role from the learning process; however, it should enable them to become a greater part of the entire learning environment in supporting students. During the lab activities, teachers are not the centre of the learning experience, their role is facilitating students' learning and directing them to be more independent learners.

7.9. Summary

The goal of this chapter was to highlight the key findings generated from the qualitative data. Participants were interviewed about their AR experience in the skills lab, and thematic analysis was performed to analyse their interviews. The analysis identified two main themes: learning environmental characteristics and students' characteristics. It aimed to compare students' perspectives in the current and NMAR learning environments. The findings indicated that students showed positive perspectives towards the NMAR learning approach, compared to the current learning in terms of facilitating SRL skills. The outcomes contributed to answering **RQ6** and therefore achieving **OB12**.

CHAPTER 8

8. CONCLUSION AND FUTURE WORK

8.1. Introduction

The previous chapters have shown that the research objectives have been successfully achieved. The main aim of this research was to investigate the feasibility of AR features in facilitating independent learning in nursing education.

This chapter outlines the key findings drawn from this research and summarises its contribution to the field. Additionally, it explains the challenges and limitations of the thesis as a whole and suggests further direction for future work.

8.2. Discuss the main findings

Nowadays, the growing power of personal computers and mobile devices allows conventional educational environments such as schools and universities to apply AR.

The ability of AR to allow students to be immersed in a realistic experience has attracted educators to use this creative way of learning. Recent research has shown a positive impact of AR on education by making the educational processes more active and influential. Researchers from different disciplines have adopted AR when teaching students. As mentioned in the literature review in chapter 2, there are massive benefits that students can gain from AR; for instance, AR is an authentic, interactive, visual and engaging learning tool that motivates students to learn. It is easy to access material in "real-time spot inquiries". Most of the studies reported that AR is a motivational learning strategy that enhances students' learning and supports knowledge acquisition and retention. As academic achievement is hugely affected by students' motivation, it is obvious why it is considered the most in the literature (Arici et al., 2019). AR was also found to promote self-learning and enhance independence.

Moreover, AR has been utilised in many cases within the healthcare sector. For instance, in a nursing context, there are several potentials for adopting AR, such as saving time, visual and individual tools, supporting simulations and reducing anxiety (Wüller et al., 2019). Even though several studies have stated that AR enhances independent learning and supports shifting to a student-centred learning approach (chapter 2 section 2.4), they have not described how the AR system had been designed to achieve that.

The main aim of this research is to bridge this gap in the literature and proof-of-concept of the feasibility of adopting AR in facilitating independent learning in the nursing context. The following research hypothesis lays the basis of the research topic and defines the main focus of this thesis.

H: AR has a positive role in facilitating the SRL process for nursing students?

In order to support this hypothesis or not, a further six research questions were developed to be more precise within the research process. They have been addressed through three research design phases (problem identification, solution design, evaluation), as a design science research approach was applied as an overarching research methodology in this work. The next section will discuss how these research questions have been answered.

RQ1: How can AR features be integrated with SRL theory?

This research question aimed to cover the pedagogical aspect of the research. From the pedagogical point of view, terms such as self-learning, independent learning, learner control, or self-management can be translated into SRL theory. According to Zhao (2016), environment characteristics play an essential role in shaping the self-regulated process in an e-learning environment.

In nursing education, the curriculum relies heavily on conventional teacher-centred approaches. Researchers challenged nursing educators to implement student-centred learning approaches (Murphy et al., 2011). However, problem-based learning is promising as a pedagogy of integration when applied to the gathering of both internal (class-based) and external (real-world-based) knowledge to solve a problem (Mary et al., 2005). As the problem is presented at the beginning of the learning process, before other curricular inputs, students engage in aspects of self-directed and lifelong learning, taking greater responsibility for their own learning. Studies show that improving self-regulated skills leads to improved problem-solving learning skills (Kramarski & Gutman, 2006; Raaijmakers et al., 2018). A study in nursing education indicated that students could be more active in developing their self-regulated skills when they use problem-based learning (Nguyen et al., 2016).

The question was addressed in chapter 4 by adopting the theoretical model of the relationship between PBL and SRL of English and Kitsantas (2013), and modified it by replacing the teacher's role in a face-to-face classroom with an interactive MAR environment. The answer established the initial theoretical framework for integrating AR in nursing education by following SRL strategy.

RQ2: To what extent is independently acquiring clinical nursing skills supported in the current approach?

RQ3: To what extent do nursing students intend to foster their independent learning?

These two questions investigated the students' perspectives about their current learning activities in acquiring clinical skills and AR technology. An exploratory online questionnaire was distributed to nursing students at The University of Salford. One hundred and eight valid responses were received. The questionnaire had two sections: the first section addressed **RQ2** by exploring the current learning activities, aiming to understand how the current approach supports independent learning as well as to identify any challenges and limitations (relevance). The second section addressed **RQ3** by determining the students' willingness to foster their independent learning by using MAR.

The descriptive statistical analysis of the collected data is presented in chapter 5. The findings of the first section revealed that the learning activities in the current approach rely heavily on the teacher-centred approach during the lab. At the same time, students use written scenarios in the class and outside the class by accessing the Blackboard system. The outcomes showed that the current learning environment is less supportive of independent learning due to many environmental or personal obstacles such as lack of feedback, accessibility issues, lack of realism of manikins in clinical labs, difficulty with controlling learning and there is a need to facilitate nursing clinical skills acquisition outside the lab. However, the analysis highlighted that the majority of students agreed that independent learning is important in acquiring clinical skills to increase their confidence and competence.

Moreover, the analysis of the second section, which answered **RQ3**, revealed that the majority of the students would appreciate having a new AR learning environment to enhance their independent learning in acquiring clinical skills, indicating that they are willing to be active learners once the learning environment supports it.

These insights from the investigative analysis shed light on the importance of developing a new learning approach that incorporates a new technology as well as overcomes the environmental obstacles of the current approach.

Accordingly, answering **RQ1, RQ2**, and **RQ3** has resulted in supporting the development of the proposed NMAR learning platform.

RQ4: Is the developed nursing mobile AR platform simple to use?

This question was addressed in two stages: development of the prototype NMAR platform and evaluation of its sections.

Stage one involved designing the learning activities that were fulfilling the SRL cycle in the theoretical framework as well as creating the platform on the mobile device. The AR virtual patient with interactive self-assessment was the novel aspect to overcome the lack of feedback in the current approach when the students access the learning resources of the Blackboard. The prototype was validated in terms of suitability of the learning content by nursing educators to ensure that the learning activities were meeting the learning objectives. Also, a pilot test was carried prior to the main experiment. The process of developing and validating the proposed NMAR learning platform was discussed in chapter 6.

Stage two evaluated the students' experience in general and the proposed NMAR aspects in terms of usability in particular by adopting 5Es usability dimensions. A lab experiment was conducted with 34 nursing students at the nursing clinical skills lab at the University of Salford. The quantitative and qualitative outcomes generated from the 5Es questionnaire were analysed to answer this question. The quantitative data analysis indicated that the students were satisfied with the use of the NMAR platform as a learning tool. They found that the NMAR sections (anatomy, pathophysiology, patient's scenario, self-assessment) effective, efficient, engaging and easy to use. Although the students were not trained to use NMAR before the experiment, all the participants completed the whole experiment tasks successfully, explaining that students were able to activate their independent learning if a usable learning environment was provided to them with features supporting their independent learning. Additionally, their familiarity with using the mobile application may play a vital role in explaining this result.

Moreover, the qualitative analysis confirmed the quantitative result that students had a joyful experience, and they were satisfied with the NMAR features in terms of effectiveness, efficiency and engagement with few usability issues reported (see chapter 8 section 8.3). Therefore, answering **RQ4** showed that students had positive user experience overall within the NMAR sections.

RQ5: To what extent does the NMAR self-assessment mechanism affect students' interactions with the platform?

This question was addressed with the objective data obtained from 33 screen recordings, aiming to investigate the user behaviour while interacting with the NMAR platform. The analysis highlighted that most of the students repeated their self-assessment in order to increase their grades. However, all the students who failed their first attempt repeated their tests at least once. The reason could be that "pass/fail" grading mechanism used in NMAR fosters the intrinsic motivation of the students and increases their motivation to learn and pass (Melrose, 2017). This result confirmed by the nursing student during the interview she stated that

"the fail result motivates me to I want to get 100, so it makes you try to get 100" [Std_14].

The findings also indicated that students had different behaviours when they assessed themselves with interactive self-assessment. Although the correct answers were given after the first attempt, some students failed or did not obtain 100% on the second, third or fourth attempts. This finding is consistent with the literature that students pay different amounts of attention to the given feedback (Eberlein et al., 2011; Hattie & Timperley, 2007; Van Der Kleij et al., 2012). Students' willingness and ability to actually use the feedback plays an essential role in effective learning from the feedback.

Therefore, answering **RQ5** showed positive student behaviours towards NMAR interactive assessment (see chapter 8, section 8.2). The qualitative analysis in chapter 9 also supported these findings; students reported that the interactive self-assessment was one of the factors motivating them to adopt NMAR learning approach. This is in line with a study on healthcare education that stated that an interactive technology-enhanced SRL tool has a positive impact on learners' satisfaction and users were interested in being active learners and participating in their own learning in the form of independent knowledge acquisition (Petty, 2013).

This kind of technology-enhanced learning approach is ideal for nursing students with limited opportunity to be engaged in a direct face-to-face class. Additionally, the interactive self-assessment supports nursing students to reduce the medication errors to provide safer care to the real patient. It allows them to pursue areas that need to be improved in their learning. The degree of confidence that learners have to correct their responses can affect their ability to invest effort into dealing with feedback information (Hattie & Timperley, 2007). This finding may be somewhat limited to only one scenario. Longitudinal research is required to confirm the positive behaviour towards the interactive self-assessment.

RQ6: To what extent does the NMAR approach facilitate independent learning in comparison to the current learning approach?

This question investigated the students' perceived experience and their perceived usefulness of the two learning approaches. The current learning approach and the proposed NMAR learning approach in terms of supporting their independent learning. Addressing this question involved two sections.

Section one addressed the usefulness through quantitative data obtained from two questionnaires related to each approach. The questionnaire consisted of seven items that were used to evaluate the usefulness of the current and the proposed NMAR approach in acquiring clinical skills independently.

The data analysis highlighted that there is a difference between the students' perceived usefulness in regard to evaluating the two learning approaches. Furthermore, evidence of significant differences in perceived usefulness between the current and NMAR approaches was found via the paired T-test. To obtain a more accurate result, the Wilcoxon Signed Rank test and boxplots visualise method were used. It was clearly found that students reported a greater degree of perceived usefulness in regard to NMAR approach than they did in regard to the current approach (see chapter 8).

Section two addressed students' perceived experience via qualitative data obtained from post interviews about their experience after utilising the NMAR platform. The interviews were analysed using the thematic analysis technique. The findings of the qualitative approach indicated that students had a positive experience using the NMAR platform. Students were more satisfied with NMAR than the current approach in terms of supporting independent learning, and all of them agreed that the NMAR learning approach might enhance self-regulated learning and motivate them to utilise it as an effective learning tool, more detail is presented in chapter 9.

On the basis of the above discussion, Table 55 summarised the key findings of each aspect in the evaluation process. Evaluating the platform, understanding the users and comparing the current and proposed learning approaches together provide a more in-depth insight into the comprehensive user experience with NMAR. The aggregated findings shed light on the positive role of AR technology in facilitating independent learning when acquiring clinical skills. This overall positive user experience might influence the students and motivate them to activate their role to become self-regulated learners. These results support the research hypothesis that AR has a positive role in facilitating the SRL process for nursing students. The study also hopes to have contributed in one way or another in proving the feasibility of adopting AR technology in facilitating independent learning. Figure 45 presents the proposed AR learning approach that overcomes the current learning environmental obstacles.

Table 55: Summarised the key findings of the evaluation phase

Evaluation aspects	Current environmental obstacles	Quantitative results (chapter 8)	Qualitative result (chapter 9)	Literature	Note
Students' behaviour with self-assessment mechanism	No feedback mechanism on the Blackboard resources. Difficult to control learning without teacher feedback.	All the students who failed their first attempt repeated their tests at least once.	"The fail result motivates me to I want to get 100, so it makes you try to get 100" [Std_14].	"Pass/fail" grading mechanism fosters the intrinsic motivation of the students and increases their motivation to learn and pass (Melrose, 2017).	Positive
NMAR platform	Overcome the environmental obstacles of the current approach in terms of supporting independent learning.	Simple to use and effective learning tool.	The majority of the students expressed positive feelings and thoughts about the NMAR learning approach (e.g. they prefer its visual content to reading text, it is like a real patient).	AR has been used in nursing education to provide a more **authentic learning** experience than a manikin can provide. It holds the promise of improving the realism of the simulation lab, and students have reported that practising in a real experience environment enhances their motivation (Vaughn et al., 2016).	Positive
Comparing two learning approaches	-	There are statistically significant differences in perceived usefulness scores between the current and NMAR approaches.	NMAR facilitates the SRL process to a greater extent than does the current approach	Students were motivated to adopt NMAR to facilitate their learning. As Solvik and Struksnes (2018) claimed, "it is the student's responsibility to practice the procedures before internship...students' responsibility to be prepared for the internship."	Positive
Students' perception	-	NMAR was the preferable approach.	All the participants expressed their intention to use NMAR if it is released in the future.	Vaughn et al. (2016) adopted Google Glass as an AR tool to present a scenario in the skills lab, and the results found that the realism of the technology contributed to independent problem solving and motivation.	Positive

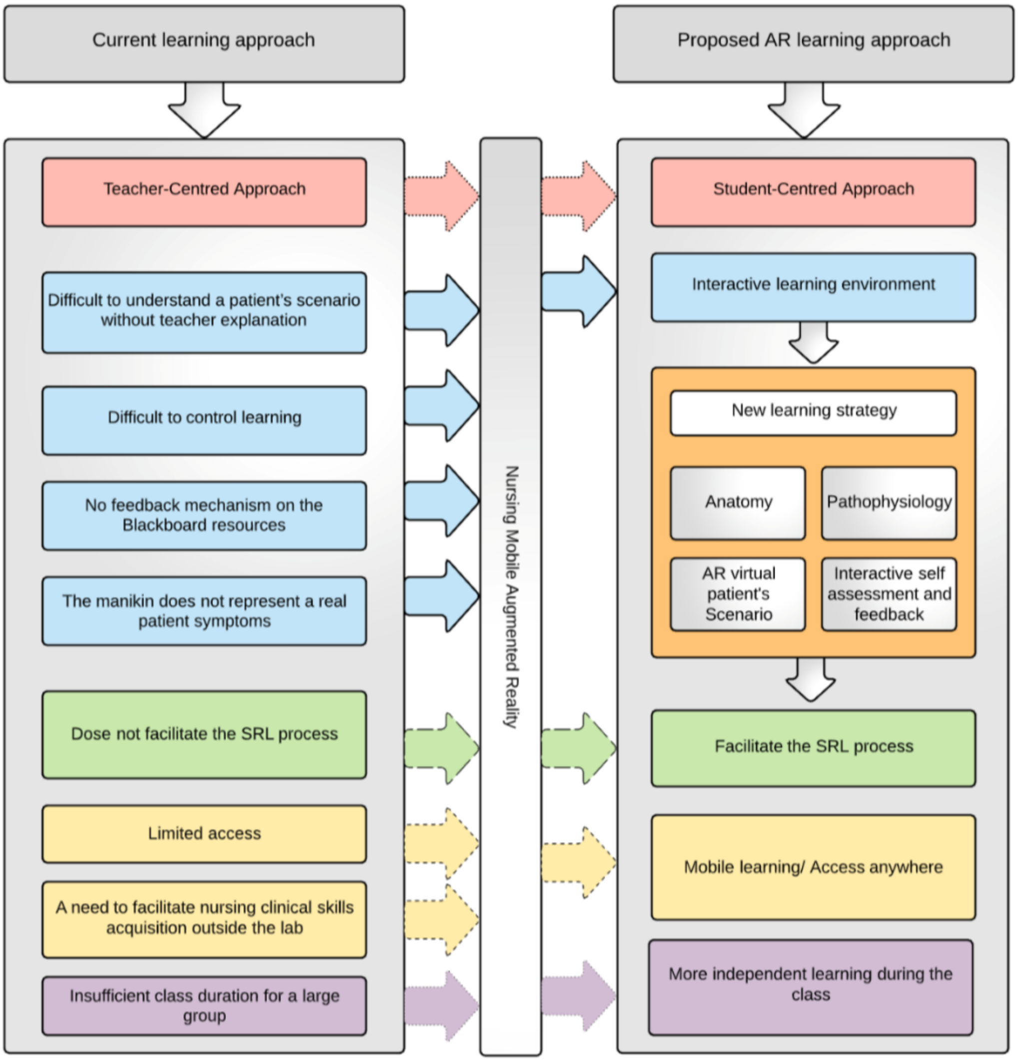


Figure 45: AR learning approach framework

8.3. The novelty of the NMAR platform

The NMAR platform was developed with three main novelty aspects. In the literature, most of the studies utilised AR in nursing either for teaching the theoretical concept (such as anatomy and pathophysiology) or in the practice lab (for visualising the patients' symptoms on a dummy manikin) (see chapter 2 section 2.5).

The first novelty feature of NMAR is about connecting the theory to practice in one place with easy access. The platform has the anatomy and pathophysiology, which are the theory parts, as well as the practice, which is the scenario and the assessment.

The second novelty aspect of NMAR is the realism of the patient's scenario, the scenario is not only limited to visualising real patient symptoms but also other related information such as patient's history and patient's real electrocardiogram (ECG) monitor.

The third novelty aspect of NMAR is adding interactive self-assessments with instant feedback; those features have been added to allow the students to control their learning easily and learn from their mistakes.

All three novelty features of NMAR have been deployed to overcome the limitations of the current learning approach in terms of supporting independent learning. Our investigative study (chapter 3) showed that the current learning environment is less supportive of independent learning due to many obstacles, such as lack of feedback, accessibility issues, and lack of realism of manikins in clinical labs. However, learning with NMAR introduces a new learning strategy, aiming to enhance students' independent learning. Utilising NMAR allows students the freedom to discover the solution of the patient' scenario independently and activate their learning.

8.4. Research implication

Learning clinical skills is a developmental process, and repeated practice promotes students' confidence and competence. The learning environment that can achieve rapid success in increasing clinical skills leads to greater confidence. A student's being an active learner in this context is important (Garrett et al., 2018). Hence, AR mobile technology produces many advantages in supporting active nursing learners. Our findings are evidence that AR seems to offer a positive contribution to a technology-enhanced learning environment that facilitates SRL processes in acquiring clinical skills.

Moreover, most of the universities which adopt clinical skills labs consider their facilitation of nursing students' clinical preparation. They make the transition to real-life nursing experience as smoothly as possible. However, according to Solvik and Struksnes (2018), most of the students did not perceive that the procedure conducted at the university is how it is conducted in clinical practice. Thus utilising AR immersive learning with a virtual patient can be a possible solution in bridging the realism gap between the skills lab in the university and the practice in the hospital.

In addition, within the context of the CSL, where outcomes are measured in terms of clinical competence, the challenge for educators is to maintain a fine balance between giving instruction and promoting inquiry, so that efficient and effective skills acquisition occurs in a short-time (Docherty et al., 2005). Therefore, our findings are in agreement with Garrett et al. (2018), who suggested that AR can build capacity in the lab session, as having the AR resources available on mobile devices and at the bedside in the lab, may reduce the learner's frustration of not getting immediate support from the lab supervisor. Furthermore, a teacher who adopts

AR learning technology facilitating SRL processes in the skills lab can play an active role in directing the students and facilitating their learning, rather than being the centre of the learning experience.

Our findings also partially contribute to the SRL literature in terms of designing the learning environment. Researchers claim that self-regulatory processes are teachable and can increase students' motivation and achievement (English & Kitsantas, 2013; Kramarski & Gutman, 2006; Raaijmakers et al., 2018).

However, the most important task for instructional designers and educators is to develop effective learning environments that encourage students to become active, autonomous, and self-regulated learners. Our findings have gone some way towards understanding the positive role of AR in facilitating SRL. People who intend to create an AR learning platform that supports SRL in acquiring clinical skills can use our design perspective in chapter 6 as an initial step of the early design stage.

The COVID-19 pandemic has raised a new implication. The reason is that the current nursing curricula rely heavily on conventional teacher-centred approaches to student learning. For instance, in clinical skills acquisition, the student-centred approach is compromised of lecturers providing information and demonstrating activities in a traditional, teacher-centred manner, where students are passive recipients with limited practice under direct supervision. However, the COVID-19 pandemic motivates many universities to unexpectedly and comprehensively adopt distance learning, and it accelerates the need to shift to a student-centred approach when the students' playing an active role is necessary. AR can fulfil this mission by providing students with a scenario-based learning environment that facilitates nursing learning during such a situation when the students cannot be physically present, and they can safely stay while continuing their learning.

Finally, going back to a reference which believed that student-centred learning with AR technology could be an important new movement for education (Diegmann et al., 2015), our findings provide some support for this claim that AR is a positive contribution to supporting the SRL approach by enabling the students to explore knowledge independently. Similarly, this result is in line with another study that stated "*AR technology supported independence, as students navigated to the AR trigger locations to explore and learn at their own pace, this freed the teacher to act as facilitator*" (Kamarainen et al., 2013). However, a careful design of the learning activities should be considered in order to achieve the learning objectives in the AR learning environment.

In the end, it is clear that AR can potentially provide a unique learning experience by bridging the gap between the virtual and the real world, utilising the latest technology in learning can be more attractive to digital native students.

8.5. Research contribution

This research investigates the positive impact of utilising new technology AR in acquiring clinical skills needed in nursing education. Also, it helps to shift from conventional teacher-centred learning into student-centred learning.

Thus, the findings of this research contribute to proving the feasibility of using AR technology in the educational process. The mobility features of MAR could play a positive role in providing better user experience for enhancing students' individual learning. The findings establish that AR has the potential to facilitate the SRL process during acquiring clinical skills as well as enhance independent learning. AR gives the learners a chance to have facilitated access to the learning materials and mobilises the learning environment anytime via widely accepted devices, which enable flexibility of learning.

Moreover, mobile learning using AR offers convenience and brings the learning environment to the learners, which is vital in learning a complex concept such as human anatomy. The convenient features of NMAR assist in understanding the patient's scenario as a knowledge that can be frequently revised, the students do not have to be limited to view the physical human anatomy on the basis of laboratory availability. According to "learning by doing" theories, repetition in learning the skills can enhance the level of learning outcomes (Solvik & Struksnes, 2018). Furthermore, NMAR facilitates understanding of the patient's scenario by enhancing the realism and visualising the ideas while acquiring clinical skills. Moreover, the research findings contribute to the literature and are dedicated to the feasibility of AR features in the context of the nursing learning environment.

Also, the findings of our research offer empirical evidence on the positive role of the AR interactive learning environment in facilitating independent learning that might motivate passive students to become active learners. Utilising the AR learning platform that facilitates the SRL process could develop students' self-regulated skills.

Accordingly, this research contributes to the information systems field; specifically, AR in the learning environment. It bridges the gap between the AR technology and an independent pedagogical approach by establishing an initial theoretical framework for integrating AR in nursing education by following the SRL strategy.

Additionally, this research contributes to existing knowledge in AR in health education by providing the current state of the research on this topic. Also, it has identified relevant aspects which required further investigating in order to identify the benefits of the AR technology to improve the healthcare learning process.

Finally, the research findings are expected to help nursing educators and policymakers in understanding the feasibility of adopting AR technology in facilitating SRL to support nursing education inside and outside the class time.

8.6. Research limitations and challenges

Similar to any research, the study is not free from limitations. This section explains the limitations and challenges which might affect the interpretations of the main findings and, accordingly, need to be taken into consideration.

The first limitation relates to the study sample consisting of just 34 nursing students from one university, thus the small sample size restricts the generalisation of the findings. Additionally, the sample was limited to the context of the UK, a different cultural background of participants may impact the way they perform and experience learning with the help of technology. The main challenge affecting the sample size of the study was the difficulty in recruiting students for a one-hour lab experiment during the data collection period.

The second limitation regards the content, as the platform was developed with only one subject, which is heart anatomy, and one patient scenario of heart disease. The obtained results were mainly dependent on that content; therefore, a different learning context may lead to varying perceptions, behaviours and effects.

The third limitation is related to the Apple operating system. The platform can only be used on the researcher's iPad, to control the effect of one screen size. Moreover, it has not been made available online in the Apple store or Android store. So, the device used was not the students' own device, which may lead to usability and familiarity issues.

The fourth limitation is that the majority of the students were not familiar with a 3D model and most of them had not used it before. Thus, the novelty of AR technology might introduce a sense of fresh enjoyment that could influence the students' perceptions about the NMAR learning approach.

The fifth limitation is related to the evaluation, as using the SRL scale and measuring students SRL skills, can be achieved by developing a large-scale project on the AR platform including different nursing scenarios. Then students can utilise the system for a while before filling the SRL instrument or being used for a longitudinal study. However, in our case, using a small prototype system with only one scenario produced invalid data. Thus we cannot measure students' SRL skills. Measuring the educational perspective of the NMAR platform will be the next phase and our future work.

Finally, AR technology is still in the developing phase, and the main technical challenges of research in the AR field is the rapid development of hardware and software with a lack of available resources. Extra effort has been added during the research to solve compatibility issues whenever a new update was released. The development of NMAR platform was started before Apple ARkit was introduced. Utilising such AR platform for iOS devices could affect the development process and reduce effort.

8.7. Future work and recommendations

The presented research has significantly advanced the knowledge in a technology-enhanced learning environment in facilitating acquisition of clinical skills independently. The findings contribute to the understanding of the positive role of AR in facilitating the SRL process in nursing education. The findings imply that the NMAR learning approach enhances the learning materials and facilitates independent learning inside and outside the lab session. Moreover, it maximises the benefits of the student-centred learning approach with new technology during the lab session. However, due to time and fund constraints, there are some concerns that could impact this research, in this final section of the thesis, many recommendations that are considered to be worthy of future research are summarised as follows:

- This research has focused mainly on the environmental learning characteristic and proposed a solution for overcoming the current environmental obstacles. However, the students' individual characteristics and their personal obstacles require further investigation in future research.
- Conducting NMAR learning approach research through a real experiment with a fully developed platform to evaluate the proposed theoretical framework in chapter 4, covering the educational aspects of the NMAR platform is recommended. Moreover, investigating students' experience with NMAR over a long period may reduce the innovation effect amongst the participants.
- Expanding the work by testing the NMAR approach on other human organs and patient scenarios may reveal more AR benefits in the nursing learning environment.
- This research has adopted the lens of HCI in evaluating the NMAR approach, another lens of evaluation can also be used in future to evaluate other aspects of NMAR.
- It is recommended that this research be applied using a large sample size or utilising a different research approach to evaluate the students' experience in order to validate the current findings.

In conclusion, the research findings contribute to the AR literature on the potential of AR technology to facilitate independent learning and bridging the gap between AR and SRL learning theory. Furthermore, academia can use the proposed NMAR learning approach as relevant groundwork to initiate other related studies, which might help to fill the gap in the AR learning area.

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10. APPENDIX

10.1. The University of Warwick Ethical approval

WARWICK
THE UNIVERSITY OF WARWICK

PRIVATE
Mrs Ebtehal Quqandi
Computer Science
University of Warwick
Coventry
CV4 7AL

17 September 2018

Dear Mrs E Quqandi

Study Title and BSREC Reference: *Investigating students' satisfaction with mobile Augmented Reality in assisting individual self-learning* REGO-2018-2193

Thank you for submitting the revisions to the above-named study to the University of Warwick's Biomedical and Scientific Research Ethics Sub-Committee for approval.

I am pleased to confirm that approval is granted.

In undertaking your study, you are required to comply with the University of Warwick's *Research Data Management Policy*, details of which may be found on the Research and Impact Services' webpages, under "Codes of Practice & Policies" » "Research Code of Practice" » "Data & Records" » "Research Data Management Policy", at: http://www2.warwick.ac.uk/services/ris/research_integrity/code_of_practice_and_policies/research_code_of_practice/datacollection_retention/research_data_mgt_policy

You are also required to comply with the University of Warwick's *Information Classification and Handling Procedure*, details of which may be found on the University's Governance webpages, under "Governance" » "Information Security" » "Information Classification and Handling Procedure", at:
http://www2.warwick.ac.uk/services/gov/informationsecurity/handling.
Investigators should familiarise themselves with the classifications of information defined therein, and the requirements for the storage and transportation of information within the different classifications:

Information Classifications:
http://www2.warwick.ac.uk/services/gov/informationsecurity/handling/classifications
Handling Electronic Information:
http://www2.warwick.ac.uk/services/gov/informationsecurity/handling/electronic/
Handling Paper or other media
http://www2.warwick.ac.uk/services/gov/informationsecurity/handling/paper/.

Please also be aware that BSREC grants **ethical approval** for studies. **The seeking and obtaining of *all* other necessary approvals is the responsibility of the investigator.**

These other approvals may include, but are not limited to:

www.warwick.ac.uk

1. Any necessary agreements, approvals, or permissions required in order to comply with the University of Warwick's Financial Regulations and Procedures.
2. Any necessary approval or permission required in order to comply with the University of Warwick's Quality Management System and Standard Operating Procedures for the governance, acquisition, storage, use, and disposal of human samples for research.
3. All relevant University, Faculty, and Divisional/Departmental approvals, if an employee or student of the University of Warwick.
4. Approval from the applicant's academic supervisor and course/module leader (as appropriate), if a student of the University of Warwick.
5. NHS Trust R&D Management Approval, for research studies undertaken in NHS Trusts.
6. NHS Trust Clinical Audit Approval, for clinical audit studies undertaken in NHS Trusts.
7. Approval from Departmental or Divisional Heads, as required under local procedures, within Health and Social Care organisations hosting the study.
8. Local ethical approval for studies undertaken overseas, or in other HE institutions in the UK.
9. Approval from Heads (or delegates thereof) of UK Medical Schools, for studies involving medical students as participants.
10. Permission from Warwick Medical School to access medical students or medical student data for research or evaluation purposes.
11. NHS Trust Caldicott Guardian Approval, for studies where identifiable data is being transferred outside of the direct clinical care team. Individual NHS Trust procedures vary in their implementation of Caldicott guidance, and local guidance must be sought.
12. Any other approval required by the institution hosting the study, or by the applicant's employer.

There is no requirement to supply documentary evidence of any of the above to BSREC, but applicants should hold such evidence in their Study Master File for University of Warwick auditing and monitoring purposes. You may be required to supply evidence of any necessary approvals to other University functions, e.g. The Finance Office, Research & Impact Services (RIS), or your Department/School.

May I take this opportunity to wish you success with your study, and to remind you that any Substantial Amendments to your study require approval from BSREC before they may be implemented.

Yours sincerely

[redacted]

Dr David Ellard
Chair
Biomedical and Scientific
Research Ethics Sub-Committee

Biomedical and Scientific
Research Ethics Sub-Committee
Research & Impact Services
University of Warwick
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http://www2.warwick.ac.uk/services/ris/research_integrity/researchethicscommittees/biomed

10.2. The University of Salford Ethical approval

University of Salford MANCHESTER

Research, Innovation and Academic Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
University of Salford
M5 4WT

T +44(0)161 295 2280

www.salford.ac.uk/

4 September 2017

Dear Melanie,

RE: ETHICS APPLICATION–HSR1617-152–'To examine the effect that using different levels of simulation (including virtual reality) during Basic Life Support training, has on the confidence and competence of student nurses.'

Based on the information you provided I am pleased to inform you that application HSR1617-152 has been approved.

If there are any changes to the project and/or its methodology, then please inform the Panel as soon as possible by contacting Health-ResearchEthics@salford.ac.uk

Yours sincerely,

[redacted]

Sue McAndrew
Chair of the Research Ethics Panel

10.3. Investigative study online questionnaire (chapter 3)

Investigative Study in Nursing Clinical Skills at Salford University

Thank you for agreeing to take part in this survey. I'm PHD student and conducting research to evaluate the importance of students' Self-Regulation learning skills in nursing clinical skills at Salford University. Self-Regulated learning has described as an active learning where students are taking responsibility of their learning by setting goals and monitoring their progress and self-evaluating their performance. I would like to hear about your current clinical skills practices and your view on how it could be better supported independent learning. Please be assured that your responses are strictly confidential and will only be used for research purposes - the survey is anonymous. Individual participation will not be Identified in the analysis as only aggregated results will be analyzed and presented.

The survey will take about 5 minutes to complete. For the majority of questions please simply tick one or more options as appropriate

*Completing the questionnaire constitutes your consent to participate.

If you need more details, please contact me
Ebtehal Quqandi
Email : E.quqandi@warwick.ac.uk

Investigative Study in Nursing Clinical Skills at Salford University

* Required

Section 1 : Demographic Data

1. Gender *

- ◯ Male
- ◯ Female
- ◯ Prefer not to say

2. Age *

- ◯ 18-21
- ◯ 22-25
- ◯ 26-30
- ◯ Above 30

3. Student level *

- ◯ Year 1
- ◯ Year 2
- ◯ Year 3 or 4
- ◯ Postgraduate

Are you nursing student at Manchester Salford university *

- ◯ Yes
- ◯ No

Investigative Study in Nursing Clinical Skills at Salford University

* Required

Section 2: Self- Regulated Learning

It is the process in which a student learns independently, with or without the teacher assisting. Self-Regulated learning is active learning where students take responsibility for their learning by setting goals, monitoring their progress and self-evaluating their performance.

4. As a student, how important is learning independently in a nursing clinical skills lab? *

- ◯ Very important
- ◯ Important
- ◯ Neutral
- ◯ Not very important
- ◯ Not important at all

5. How often do you practice a patient's scenario individually "without a teacher assisting" in a clinical skills lab? *

- ◯ Frequently
- ◯ Occasionally
- ◯ Never

if you have answered Never in this question, please state why

Your answer

6. What is the main learning method used for practicing a patient's scenario in a clinical skills lab? (Tick all that apply) if (other) please specify *

- [ ] Teacher explains the patient scenario
- [ ] Scenario has been written on paper
- [ ] Scenarios are accessed from an online resource
- [ ] Other: ____________

7. Are you able to practice patients' scenarios outside a clinical skills lab? *

- ○ Yes
- ○ No

8. What do you think the factors are that prevent you from practicing nursing clinical skills independently? (Tick all that apply) if (other) please specify *

- [ ] Difficult to understand a patient's scenario without teacher explanation
- [ ] The manikin does not represent real patient symptoms
- [ ] I do not have enough experience to create the clear mental image needed for a simulated scenario
- [ ] Lake of motivation to work independently
- [ ] More interactive environment is needed between the patient's scenario, the manikin and the patient's monitor
- [ ] Other: ____________

9. Which of the following are likely to motivate you to adopt self-learning in a clinical skills lab? (Tick all that apply) if (other) please specify *

- [ ] Independent learning which forces me to use my critical thinking
- [ ] Solving the patient scenario independently increases my confidence and competence in basic nursing clinical skills
- [ ] The lab supervisor is busy with helping other students
- [ ] Other: ____________________

10. Have you ever used a 3D model while learning human anatomy ? *

- ○ Yes
- ○ No
- ○ Maybe

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Investigative Study in Nursing Clinical Skills at Salford University

* Required

Section 3 : Augmented Reality (AR)

AR creates virtual extra layers on physical objects. It allows the bringing of digital information into the real environment by blending those two worlds together. Snapchat is a well-known application using AR

11. Consider the phrase "Augmented Reality". Which of the following most accurately describes your prior knowledge of Augmented Reality? *

- ◯ I have never heard of it.
- ◯ I have heard of it but I don't really know what it means.
- ◯ I have some idea what this means, but I am not too clear.
- ◯ I have a clear idea what this means and can explain it.

12. Which of the following Augmented Reality applications have you used before (Tick all that apply) if (other) please specify

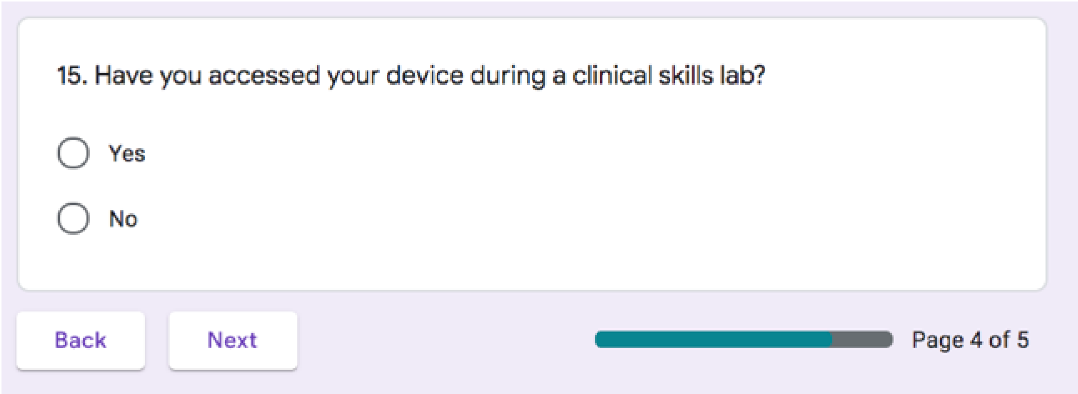
- [ ] Snapchat
- [ ] Pokemon to GO
- [ ] Aurasma
- [ ] AR GPS navigation
- [ ] Google Translate camera
- [ ] IKEA AR Catalogue
- [ ] I have never used any AR application
- [ ] Other: ____________________

13. I use Augmented Reality applications for the following (Tick all that apply) if (other) please specify

- [ ] Entertainment
- [ ] Shopping
- [ ] Educational purposes
- [ ] Map navigation
- [ ] I do not use any
- [ ] Other: ____________________

14. Which of the following devices do you carry during a clinical skills lab? (Tick all that apply) if (other) please specify

- [ ] Smartphone
- [ ] Laptop
- [ ] Tablet
- [ ] Smart glass
- [ ] Other: ____________________


15. Have you accessed your device during a clinical skills lab?

- Yes
- No

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Section 4: Future expectations from current nursing clinical skill practicing

16. Would you appreciate using a new application on your smart device to enhance your self-learning in clinical skills lab? *

◯ Yes

◯ No

17.a If yes, then please rate how important these features would be in a Augmented Reality application in order to enhance your self- learning?

	Very Important	Important	Neutral	Not Important	Not Important at all
Access learning resources when and where I need	◯	◯	◯	◯	◯
Ease of use	◯	◯	◯	◯	◯
Enjoyable tool	◯	◯	◯	◯	◯
Interactive learning environment between manikin, scenario and monitor	◯	◯	◯	◯	◯
Represents real patient symptoms	◯	◯	◯	◯	◯
Having the resources available "at the bedside" when you are in the clinical lab	◯	◯	◯	◯	◯

17.b If No, then can you tell us why?

Your answer

18. What are your favorite media which help you when learning human anatomy? (Tick all that apply)

- [ ] Interactive 3D model
- [ ] Video
- [ ] Image
- [ ] Text

10.4. Lab experiment's questionnaires (chapter 6)

Questionnaire (A)

Student reference No ___

Section 1 : Demographic Information

1.Gender	o Male	o Female	o Other	
2.Age	o 18-21	o 22-25	o 26-30	Above 30
3.Student level	o Year 1	o Year 2	o Year 3 or 4	o Postgraduate

Smart Device Experience

4.How much time (hours) do you spend using a smart device per day?

Less than hour	2	3	4	5	6	7	8	9	More than 10 hours

Section 2: Current learning method in the clinical lab

The current learning method means the approach that student uses to learn clinical skills and patient's scenario. It could be teacher-explained, paper-written, student groups or online resources.

5.Based on your clinical learning experience, please indicate the degree to which you agree or disagree with the following statements.

	Statement	Strongly Agree	Agree	Neutral	disagree	Strongly Disagree
1	The current learning method helps me to create the clear mental image for the patient's symptoms.					
2	The current learning method helps me to access the clinical learning resources anytime and anywhere.					
3	The current learning method helps me to be self-reliable.					
4	The current learning method helps me to understand patient's scenario more quickly.					
5	The current learning method helps to improve my learning performance.					
6	The current learning method helps me learn effectively.					
7	Overall, the current learning method is useful.					

Questionnaire (B)

Student reference No ___

Based on your recent experience with the **NMAR application**, please indicate the degree to which you agree or disagree with the following statements.

	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	NMAR helps me to create the clear mental image for the patient's symptoms.					
2	NMAR helps me to access the clinical learning resources anytime and anywhere.					
3	NMAR helps me to be self-reliable.					
4	NMAR helps me to understand patient's scenario more quickly.					
5	NMAR helps to improve my learning performance.					
6	NMAR helps me learn effectively.					
7	Overall, NMAR app is useful.					

- How much did you get in the self-assessment? ___ %
- Did you repeat your self-assessment? Yes No
  If yes, how many time? ____

Questionnaire (C)

Student reference No ___

Based on your recent experience with the **NMAR application**, please indicate the degree to which you agree or disagree with the following statements.

1. **Evaluate the NMAR's features**

1-Anatomy	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My tasks for this section were fully completed.					
I completed the tasks without much effort.					
I liked the way in which the NMAR supported the tasks.					
This section was difficult to complete.					
I started using this section without any tutorial.					
2-Pathophysiology	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My tasks for this section were fully completed.					
I completed the tasks without much effort.					
I liked the way in which the NMAR supported the tasks.					
This section was difficult to complete.					
I started using this section without any tutorial.					
3-Patient's scenario	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My tasks for this section were fully completed.					
I completed the tasks without much effort.					
I liked the way in which the NMAR supported the tasks.					
This section was difficult to complete.					
I started using this section without any tutorial.					

4-Self-Assessment	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My tasks for this section were fully completed.					
I completed the tasks without much effort.					
I liked the way in which the NMAR supported the tasks.					
This section was difficult to complete.					
I started using this section without any tutorial.					

Comparing between current method and the NMAR	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I prefer using NMAR to enhance my self-regulated learning.					
I prefer using the current learning approach to enhance my self-regulated learning.					

Do you have any comment on the NMAR compared to the current learning method?

____

Any comments or suggestions

____

10.5. Consent form of the interviews

WARWICK
THE UNIVERSITY OF WARWICK

CONSENT FORM

Student reference No ___

Title of Project: Investigating students' satisfaction with mobile AR to assist individual self-learning

Name of Researcher(s): Ebtehal Quqandi and Prof.Mike Joy

Please initial all boxes

1. I confirm that I have read and understand the information sheet dated **on June 2019** for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time before filling the questionnaire without giving any reason, education, or legal rights being affected. ☐
3. I agree that my voice will recorded for research purposes. ☐
4. I agree to take part in the above study. ☐
5. I understand that my real name will not be used in any reported research outputs (e.g. thesis conference, presentations, papers and articles). ☐

____________	____________	
Date	Signature	
Name of Person taking consent	Date	Signature

10.6. Cardiovascular Written Scenario

Jim Thomson

60yr old lorry driver

Previous medical history

Hypercholesterolaemia (high cholesterol levels)

https://www.youtube.com/watch?v=PbfuLpXoI5g

Presentation

Woke at 6am with chest pain and shortness of breath. His wife rang for an ambulance

On admission to Accident and Emergency

Airway- talking in short sentences (appears grey in colour, clammy, sweating and facial grimacing due to the chest pain

Breathing- respiratory rate 24 breaths per minute, shallow breathing, equal chest expansion. Oxygen levels Sao290% (Sao2 increase to 95% if Oxygen applied)

Circulation- pulse 130 beats per minute, feels thread (reduced to 90 beats per minute when pain relief supplied); blood pressure 100/70, capillary refil time 3 seconds

Skin cold and clammy (face pale grey colour and peripheral cool and clammy)

ECG= shows ischaemia blockage in LAD artery (atherosclerosis -could show build up due to cholesterol on the LAD artery)

Pain score 6/10 moderate pain (could show facial expressions grimacing to indicate pain) pain reduces to 0/10 following morphine injection and patient appears relaxe

Various Youtube videos below that could be used to show the inside of the artery and some could be used for the students to click on :

Very important vedio : https://www.youtube.com/watch?v=QlIguanpKic&t=167s

Wellcome Trust, Atheroma in the artery: https://www.youtube.com/watch?v=Ps_54TQsv0c

Aterosclerosis, Heart Disease: https://www.youtube.com/watch?v=SO2E10yy87c

What is atherosclerosis? https://www.youtube.com/watch?v=zfAqC1oPbkw

Development of atherosclerosis:https://www.youtube.com/watch?v=Kbz70treoSI

Cardiovascular system in under 10 minutes:https://www.youtube.com/watch?v=_lgd03h3te8

How the heart works 3D video:https://www.youtube.com/watch?v=oHMmtqKgs50

This type of thing on the video below could be useful for selecting the correct equipment for example the ECG machine, morphine for pain relief, blood pressure equipment etc

Holograms: https://www.youtube.com/watch?v=FSpAo_ZWPIs

This video below shows a man grimacing and in pain having a heart attack:

Johns heart attack video https://www.youtube.com/watch?v=sR4cVqnWV9Q

10.7. Irrelevant interesting findings

Interesting outcomes have been identified from the interviews data set. Although they are not relevant to answering our research questions, it is worth mentioning them here. The outcomes could propose new ideas for future research in the field of AR, healthcare and formal/informal education.

Teaching children

- " I've got children at home so I could sit at home and show the children [using NMAR]. This is a heart and so I like that part of it more [3D model of the heart]" [Std_16];
- "My kids would love it because they're so interested in things like that [3D model]. You can teach kids" [Std_20];

- “I will use it and encourage friends and my kids to use it” [Std_7].

Common and uncommon illnesses AR application

Developing an application for specific diseases could be used in the hospital with the doctors, or in the university with the teacher.

- “You can do it for all the different systems and common illnesses, maybe not so common illnesses that you've not generally come across. So that you look for the indications when you're out in practice having it. I think hospitals would use it” [Std_20].

Access patients remotely by using smartphones

- “From your mobile phone as a medical practitioner you can easily have access to the patient in your office in your room, it will save you a lot of time” [Std_2].

Patient’s understanding of their disease

- “Even to be able to save people's life ... those who do not want to use it in educational setting they can use it, in helping people to recover before taking them to a hospital and I need to have the patient to even understand what is wrong with himself because in some cases I can say in some hospitals the patient and indeed the patient’s nurses doctors, there is no good communication system, the patient will just be asking them their diagnosis, but it doesn't know what is going on. But with this application the patient will be able to know what is going on with him , whether it's heart or which is kidney or any part of the body the person will quickly understand” [Std_2].

Teacher calling off sick

- “If one lecturer is calling off sick the [other] lecturer can use it for two classes. So for each person is having whatever they need to use. They carry on whatever they're doing while the lecturer can see what is learnt in that class” [Std_14].