Brief Summary

All details are below, it has to be ***min 20 pages, exc. images and refs***. If interested can you send over a 1-page proposal via email to me by **24th November 2021**, that would be ideal giving a brief overview of the chapter.

For the full chapter the following must be adhered to:

1. ***Minimum 20 pages long, 1.5 spacing, excluding images and references, Font size 12, Times New Roman***
2. References in the Harvard style, with in-text written stations (not numbering)
3. The Basic Style reference system is to be used (refer to the Key Style document attached, p9.)
4. The final chapter should be sent in word doc format to myself at Paul.Rea@glasgow.ac.uk
5. Images should be labelled throughout as Fig 1, Fig 2 etc
6. Send over the images as separate TIFF or JPEG files saved as Fig 1, Fig 2 etc
7. Abstract is required at the start, with up to 6 key words
8. The Consent to Publish should be returned when submitting the final chapter, which will be advised about in due course
9. I would need to receive everything by **31st January 2022**, including names, affiliations and contact email addresses of all authors. Let me know if that timing works, and we have a small amount of wiggle room with these dates.
10. Finally, enjoy and happy to answer any questions along the way! When published, the contact author will receive a complimentary physical copy of the book.

Any other editing/formatting question should be answered here:

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Title of Chapter:

"Learning About Skin Breakdown" – Design, Development and Evaluation of An Augmented Reality Application to Inform about Pressure Ulcers (sores) and Moisture Lesions

Matthieu Poyade - School of Simulation and Visualisation, The Glasgow School of Art, Glasgow, UK – m.poyade@gsa.ac.uk
Claire Eaglesham - School of Simulation and Visualisation, The Glasgow School of Art, Glasgow, UK – c.eaglesham@gsa.ac.uk
Barrie Wilson – Scottish Social Services Council – Dundee, UK - barrie.wilson@sssc.uk.com
George Burton – Scottish Social Services Council – Dundee, UK - george.burton@sssc.uk.com
Keith Quinn – Scottish Social Services Council – Dundee, UK - keith.quinn@sssc.uk.com

Abstract

The identification, treatment and management of pressure ulcers and moisture lesions present a huge challenge to health and social care, and the individuals who suffer from them. Despite some progress in reducing the incidence of pressure ulcers in recent years, many Scottish support workers giving direct care are not always aware of skin changes until the ulcers have become established. With many pressure ulcers being preventable, raising awareness of the causes and indicators of pressure ulcers amongst care and support workers is critical to enable early detection and improve the quality of life and outcomes for individuals being supported. This chapter presents an innovative collaboration between the Glasgow School of Art's School of Simulation and Visualisation and the Scottish Social Services Council (SSSC) to develop a mobile application which aims to address this learning need. A consultation with 7 individuals with relevant expertise helped to define the specific features, functions and content topics the application needed to include. The application was storyboarded and developed using Unity, building upon the requirements analysis outcomes which provided a unified description and depiction of the application's functionalities.

The application, branded as "Learning About Skin Breakdown", is compatible with iOS and Android mobile platforms. It adopts a simple, depurated and user-friendly design to provide relevant interactive information about risk factors, signs and symptoms, as well as skin breakdown management techniques. Using Augmented Reality, the application can be used as a learning tool to inform care and support workers about skin breakdown using both visual and text-based content overlaid onto the real world.

The application was tested in a single session with a cohort of 19 individuals with experience in care and/or care management. User testing aimed to explore several aspects of the application, including (1) the effectiveness to support knowledge development and acquisition; (2) the sense of engagement and motivation experienced by users; (3) the usability and user experience; and (4) the generated cognitive load. In order to provide a robust user evaluation and reliable outcomes, standardised and/or well-established methods of measurement were selected.

User testing outcomes reported a significant increase in users' knowledge about skin ulcers after using the application, suggesting a high short-term learning effect. The different usability and motivation constructs were unanimously rated high, suggesting strong usefulness, ease of use, ease of learning, confidence, relevance of content and user's

satisfaction. Finally, low cognitive load measures outcomes suggested the application content and instructional design did not undermine the learning process.

Keywords

Skin Breakdown, Augmented Reality, Mobile Application, Android, iOS

Introduction

Pressure ulcers consists of localised lesions to the skin and underlying tissues, primarily caused by constant contact with the epidermis. These are typically experienced by individuals confined in bed or wheelchair and can gradually develop on body areas such as heels, elbow, hips, base of the spin, which are typically put under pressure. Early symptoms of pressure ulcers are often described as skin patch discoloration that may feel warm, spongy or hard, and may become painful or itchy, but can rapidly develop into more severe conditions such as open wounds or blisters, which can potentially affect from the superficial layer of the epidermis towards muscular and bone tissues (NHS).

The identification, treatment and management of pressure ulcers presents a huge challenge within health and social care, as well as to the individuals who suffer from them (Niezgoda & Mendez-Eastman, 2006). The cost of pressure ulcers for both patients and healthcare providers is already significant(Dealey et al., 2012; Demarré et al., 2015), and likely to increase with an aging population. The beneficial cost of prevention, which takes many forms, has been highlighted when compared with the cost of standard care (Padula et al., 2011; Moore et al., 2013; Demarré et al., 2015). There is a need for cost-effective measures to reduce the incidence of pressure ulcers (Dealey et al., 2012). Despite some progress in reducing the incidence of pressure ulcers in recent years, many support workers giving direct care are not always aware of skin changes until the ulcers have become established (Aguwa et al., 2012). With many pressure ulcers being preventable, raising awareness of the causes and indicators of pressure ulcers amongst care and support workers is critical to enable early detection and improve the quality of life and outcomes for individuals being supported (Mitchell, 2018).

Setting up conventional didactic training programmes at a national scale which empower the early detection of pressure ulcers symptoms would likely increase workload on the National Healthcare Service and the professional body of care and support workers, both which are already experiencing greater strain due to the global pandemic. The feasibility of such programmes could also be limited due to the logistical challenges associated with reach an unequally distributed population of care and support workers across a country and organising training activities and information sessions at dedicated times and locations, particularly with the added challenge of the Covid19 pandemic.

The emphasis in formal learning programmes has been on teaching concepts and facts, in an abstract and decontextualised form: i.e. students experience the teaching of these concepts, facts and theories in the classroom and are expected to transfer them to the practice setting at a later date. The problem with this is that, in general, this abstract knowledge is not retrievable in real-life, problem-solving contexts, because this approach ignores the interdependence of situation and cognition (Herrington, 2006). It has been acknowledged that learners struggle to assimilate information out of any context of demand that can’t be tied to their direct experience (Foreman, 2004). Research has highlighted concerns about the effective transfer of learning from the classroom to the workplace and suggests that learning for the workplace is best when it is designed in the context of actual workplace problems and delivered in that workplace context (Smith, 2003). Webster-Wright (2009) shares this viewpoint, and highlights that delivering learning divorced from its application reinforces the divide between theory and practice. Learning carried out in the context in which it is meant to be used, as close to the point of its application as possible, increases knowledge retention of that learning and therefore its effectiveness. This learning and teaching approach is commonly referred as 'Situated Learning' or ‘situated cognition’ (Smith, 2003, p 62), and established that learning will be most successful when it takes place in the culture and context in which it is expected to be applied.

The huge uptake and general availability of mobile devices such as smartphones and tablets, and mobile data broadband has the potential to support the power of situated learning by allowing the development of immersive and engaging learning experiences which reflect the real-world problems faced by employee (Dede, 2005). The effectiveness of learning activities which provide augmented digital information overlaid upon real-life experience can be significantly improved by making them readily accessible in real-world situations. It is now much easier to deliver engaging learning materials to learners in and outside workplace settings potentially facilitating ubiquitous learning (Kinshuk, 2012). It also provides a means of enabling spaced and self-paced repetition as a means of creating enduring learning and potentially reduce the Ebbinghaus ‘forgetting curve effect’ (1885) (Ebbinghaus, 2013) which describes the loss of retained information as time elapses from the point at which this information was acquired, to the time it is being applied, without reinforcement (O’Neil et Rivera, 2012). Effectively, research has highlighted that a frequent refresher of learning can reactivate the initial learning and increase student retention, combatting the knowledge decay as described by Ebbinghaus (Custer, 2010, Pusic et al, 2012).

Equipped with high-resolution cameras and high graphical rendering capabilities, modern mobile devices are capable of displaying digitally produced content overlaid onto a real-time screen capture of the real world, and thus augment real-life experience. This is typically referred as Augmented Reality (Azuma, 1997), an emerging technology, as identified by many, with a strong potential to transform education (Kiryakova et al., 2018; Resnyansky et al., 2018; Schuteral et al., 2021), and clinical practice (Orciuoli et al., 2020; Vinci et al., 2020) among other applications. Indeed, research has highlighted that Augmented Reality has the potential to foster conceptual understanding (Ibanez & Kloos, 2018) , increase motivation (Buchner et al., 2018, Anuar et al., 2021), and positively encourage autonomous learning in nursing education (Rodriguez-Abad et al., 2021). Augmented Reality has been successfully implemented in the form of a Clinical Decision Support System for assessing pressure ulcer severity, however this system does not aim to develop fundamental skills for caring for pressure ulcers Orciuoli et al., 2020).

With the advent of mobile health, a wealth of applications are now available to support improved management of various health conditions (Koepp et al., 2020). Despite highlighted shortcomings such as price, language limitations, usability and design challenges among others (Koepp et al., 2020), interactive mobile applications applied to heath condition management offer opportunities to provide more engaging self-paced learning experiences. In turn, this can build upon the benefits of the situated learning approach, to help raising awareness about identification, treatment and management of pressure ulcers among care and support workers. Koepp et al. (2020) have reported that several mobile applications for pressure ulcers are currently available. Each addressing one or several of the challenges typically faced by care and support workers such as identification, classification, evaluation, prevention, and treatment. However, there is only a very limited number of applications for pressure ulcers management that have been supported by methodological and evaluative research. Thus, there is a clear need for further research which focuses on collaborative and co-creative processes to produce user-centred content design, developmental approaches and evaluation building upon established methodologies (Koepp et al., 2020).

This chapter presents a collaboration between the Glasgow School of Art's School of Simulation and Visualisation and the Scottish Social Services Council, which led to the co-design and development of a smartphone application to address the learning needs of care and support workers across Scotland. Using Augmented Reality, this freely available application

compatible with Android and iOS platforms, can be used as a learning tool to inform about pressure ulcers using both visual and text-based content. The final version of the application was tested with a group of potential users to assess the value of such learning tool within a care giving context. Using standardised and well-established approaches, the acquisition of knowledge about pressure ulcers and care procedures, usability and user-experience, motivation and generated cognitive load were measured.

Materials and Methods

Apparatus

This section presents the material that has been used throughout this research. The development of the mobile application was performed on a Dell Z440 PC Workstation. An Apple Mac workstation was used for generating the XCode files and test the deployment of the application to an iOS mobile device. An Android Samsung Galaxy S7 phone and an iPhone 6 Plus were used to test the application throughout the development process. The software packages that have been used are presented in Table 1.

Table 1. List of Software & Packages

Software	Manufacturer	Process
Adobe Photoshop	Adobe System (https://www.adobe.com/uk/products/photoshop.html)	Mood board 2D asset creation
3ds Max 2019	Autodesk (https://www.autodesk.co.uk/products/3ds-max/overview)	3D Modelling Animation
MudBox	Autodesk (https://www.autodesk.com/products/mudbox/overview)	3D Texturing Retopology

Unity 2019.2.9f1	Unity (https://unity.com/)	Development Interaction Implementation
Microsoft Visio 2016	Amazon Web Services (AWS) (https://aws.amazon.com/polly)	Analysis of Requirements Software Design
AR foundation	Unity (https://unity.com/unity/features/arfoundation)	Unified Interface to AR development
AR Core	Google (https://developers.google.com/ar/develop/unity-arf/getting-started-extensions)	AR subsystem for Android devices
AR Kit	Apple (https://developer.apple.com/augmented-reality/arkit/)	AR subsystem for iOS devices

Production Workflow

The research and development activities undertaken for the implementation and deployment of the mobile application to raise awareness about skin breakdown among care works were completed in accordance with collaborative design principles and development framework presented below (Fig. 1).

Design of the application

Co-Design Work

Figure 1. Research and Development Activities Workflow

A co-design workshop was organised to consult individuals with relevant expertise in the care sector to further define the specific features, functions and content topics the application would need to include in order to meet the initial specification of this collaborative project. Participants were provided with a participant information sheet and asked to sign a consent form before the workshop to ensure they were fully informed and willing to take part in this project. The workshop, which lasted for two hours, aimed to generate discussion about the challenges and opportunities of current ways of working and the design and use of smartphone applications as learning tools. It utilised a Voice of the Customer (Aguwa et al., 2012) approach to gather participants' thoughts, knowledge and interests, and analytical techniques to help foresee an optimum user experience of the application.

Seven participants from the social care sector, attended the workshop, generating a wealth of data, information and design direction. Following the workshop this data was documented, analysed and synthesised to produce fundamental project themes, which aimed to provide guidance throughout the design and development process; content topics as the key pieces of information, both visual and text based, which the application will need to contain in order to inform and raise awareness about of the causes and indicators of pressure ulcers amongst care and support workers; and visual design principles which defined the core aesthetic of the application user interface.

Four fundamental project themes were defined: Approach, Accessibility, Communication and Support for Best Practice. These themes describe the high level specifications of the application as expected by participants. Approach describes the potential of the application to empower users to detect pressure ulcers at early stages, but also to provide information that support care and support workers training development and build confidence. Accessibility specifies the ease of reach and inclusiveness of the application and the information it provides. In other words, information must be accessible to all, including informal carers. Communication describes the way the information is intended to be managed by users and between users and social care services. The content of the application must be clear, concise and jargon-free, but also remains easily shared between care workers, service providers and service users. Finally, the application must support best practice meaning that it must inform the user to take preventable measures against pressure ulcer formation, and build further support, trust and working relationship between care workers, service providers, their affiliates and relatives.

Content topics provided the core structure of the navigation interface for users to access key information within the application (Fig. 2).

Figure 2. Content topics identified during the co-design workshop

The Visual design principles defined during the co-design workshop define at high level the most prominent interaction, navigation and graphical features of the application. Overall, all participants concur that the navigation interface must remain consistent between screens. The interface must be customisable to allow users to configure the text size, contrast and notifications. The graphical design must build upon eye catching iconology that are easy to understand.

These outcomes will input into the next stages of the design of the application: the requirement analysis and the application wireframe.

Requirement & Functional Analysis

Building upon the wealth of information from the co-design workshop, a requirement analysis was conducted. This consisted of generating a standardised description of the application functionalities and system properties using a software engineering system modelling nomenclature - System Modelling Language (SysML). A table of requirement is provided in Appendix I.

Figure 3. Use cases identified from the collected requirements

Later, a series of functional Use Cases (Fig. 3) was identified to gather the previously described requirements into functional blocks. A full description of each Use Case was constructed using a standardized and unified modelling nomenclature – Unified Modelling Language (UML) (Table 2). This included details of the pre and post conditions of use for each Use Case, and inform about the functioning of the application.

Table 2. Use Cases Description

Use Case Name	Description	Pre-Conditions	Narration	Post-Conditions
Interact with Content	This use case enables the user to interact with the application's content on their smart mobile device	The user has installed and launched the application on their smart mobile device	The user will be able to interact with the application's content (for example user interface elements) by using touching the smart mobile device's screen with one finger. These interactions will be intuitive and trigger actions within the application allowing the user to access and control the application's content	The user can now complete the action they have selected to complete
Navigate Content	This use case enables the user to move between the various sections of the application	The user has installed and launched the application on their smart mobile device	The user will be able to identify which section of the application they are currently in, identify the other sections and move to a different page or section as required. This will be facilitated by a navigation bar displayed on each screen, the main menu screen and page information displayed to the user	The user can now review the section or content they have selected to review
Display Content	This use case enables the user to view the application's content	The user has selected to view the application's content through the main menu interface	The user will be able to view the application's content by displaying the relevant topic or section the user has selected to view (following Interacting with content and Navigating content). The content topics accessible to the user will be inform (the causes of pressure ulcers, grades and impact), identify (at risk individuals, verbal indicators, pressure ulcer locations, factors and their development over time), manage (preventative measures and treatment) and refer (next actions, tools to use, referrals and additional training)	The user can now review the section or content they have selected to review

Use Case Name	Description	Pre-Conditions	Narration	Post-Conditions
Execute Design Principles	This use case enables the user to experience the content as intended by the application's design	The user is reviewing the application's content	Throughout the application the content will be presented clearly to the user, use simple language and design elements and be easy to understand. These key design principles are in place to ensure the user's experience of the application is simple yet effective	The user can now experience the content as intended by the application's design
Contextualise Content	This use case enables the user to contextualise the application and its content as being produced by the Scottish Social Services Council as a learning tool	The user is reviewing the application's content	Throughout the application, from first launching it to each section of content, the user will be presented with consistent visual cues (such as font, branding and logos) and written information (such as acknowledgements) which will communicate the owners and intended use of the application and its content	The user can now identify the owner and creators of the application and all the content held within it
Set Up System	This use case ensures that the application's content runs correctly when operated by the user	The user has downloaded the correct version of the application for their compatible smart mobile device	The user will be able operate all the application's functionality (for example the augmented reality functionality) and access all the content within the application	The user can now operate the application and all of its functions as intended by the application's design
See AR Content	This use case enables the user to view the application's augmented reality content	The user has provided permission for the application to access the device's camera and has selected to use the application's augmented reality functionality	The user will be able to view and interact with content within the augmented reality functionality of the application	The user can now experience the application's augmented reality content as intended by the application's design

Use Case Name	Description	Pre-Conditions	Narration	Post-Conditions
Instruct User	This use case enables the user to be presented with operating instructions for the application's augmented reality functionality	1) The user is using the augmented reality functionality for the first time	1) When the user launches the application's reality functionality for the first time they will be presented with instructions which outline how to use the application's augmented reality functionality	The user can now operate the augmented reality functionality as intended by the application's design
		2) The user has selected to use the application's augmented reality functionality, and they have used it before	2) When the user launches the application's augmented reality functionality after they have used it before, they will have the option of skipping or reviewing the augmented reality operating instructions	
Personalise Content	This use case enables the user to control the application's content on their smart mobile device	The user has accessed the main menu of the application	The user will be able to control aspects of the application's content (for example, font size and contrast) by selecting the corresponding user interface element, which is triggered using the touch sensors on the smart mobile device's screen	The user is now presented with the application's content in the way they have chosen

A Use Case diagram was then created (Fig. 4) to provides a high level visual representation of the functional design and interactions between the components and functionalities of the application.

Figure 4. Use Case Diagram which provide a high level representation of the functioning of the application.

Storyboard and Moodboard

Building upon the analysis of functional requirements and system specifications, the interface design of the application has been formulated and discussed with the digital learning team at the Scottish Social Services Council. That design presented a "wireframe" version of the application (Fig. 5). This consisted of a storyboard which presented, in visual format, the user journey through the application and its content, the structure and layout of each screen and user interface elements, a description of the functions and actions available to the user and finally the relationship between the various sections of the application. Additionally, the design proposal was accompanied with a mood-board which presented the rationale for the application interface colours and content fonts (Fig. 6). Storyboard and Moodboard were developed using Adobe Photoshop.

Figure 5. Storyboard of the application: A proposal of wireframe design of the interface

Figure 6. Application Mood-board.

Development

The application was built on Unity 2019.2, a ground-breaking game engine platform considered by many as a standard technology for the development of real-time interactive content. In a first instance, a "test" project was built to assess the suitability of various Unity compatible AR SDKs against the requirements of the project (Appendix I). AR Foundation, a newly released (at the time) package, was selected as it facilitated cross-platform AR development independently of the building environments. Effectively, AR Foundation

provides a layer of abstraction to lower level platform dependent AR SDKs as AR Kit (iOS) and AR Core (Android), offering a unified development interface on Unity. AR Foundation supported marker and marker-less (plane-based) detection and registration, with the latter being chosen as the most appropriate to satisfy requirements defined during the consultation workshops.

Other software was used to create additional assets for the application. 2D Logos and UI elements were created using Adobe Photoshop, adhering to the Scottish Social Services Council branding and style guides as presented in Fig. 6. Photoshop was also used to refine the medical images which feature in the app. All images were provided by the Scottish Social Services Council and the National Health Service Scotland.

The 3D models which feature in the AR function of the application were created and/or modified and animated using 3DS Max. In addition, Autodesk Mudbox was also used to refine the texture of the humanoid 3D model.

Results

A mobile application compatible with Android and iOS, was developed to help care workers identify potential skin breakdown, and understand the risk factors associated with pressure ulcers and moisture lesions. The application enables support and care workers to access crucial and relevant information about pressure ulcers and moisture lesions directly from their place of work, or more generally any place they feel comfortable to do so. The application features a custom user interface which gives users access to informative content provided as text and supported by graphical material provided by the Scottish Social Services Council (Fig. 7).

Figure 7. Interface of the Learning About Skin Breakdown Application

The application was also designed and developed with an inclusive mindset, encompassing functionalities to facilitate access to users who experience visual limitations. Functionalities such as contrast and font size alterations are two inclusive features that users can access from the setting menu (Fig. 8).

Figure 8. Settings of the application to support inclusion among users

The application includes an AR feature which enables enhanced interaction and navigation at the location of care (Fig. 9). This feature allows the display of graphical information about the different stages of advancement of skin lesions on virtual panels located on user-defined spots on the AR-detected ground plane. The AR feature also provides a 3D indication of the common placement of skin lesions on the body, using a digital avatar that be displayed in both standing and sitting positions.

Figure 9. AR feature of the application

Finally, as part of the strategy for enhanced digital learning at the Scottish Social Services Council, user learning activities can be monitored and notifications can be sent to users to remind them to complete specific sections within the application.

Evaluation

User-testing was conducted to assess the effectiveness of the application to raise awareness about identification, treatment and management of pressure ulcers among care and support workers. This testing explored several aspects of the use of the application, including knowledge development and acquisition; its usability and the resulting user experience; the motivational and engagement aspect of the proposed instructional design; and the generated cognitive load among users.

Participants

19 individuals (F = 18; M = 1) (M = 42.105; σ = 14.027) with experience in care and/or care management volunteered to take part into the experiment (7 care workers, 9 care managers, 3 learning and development specialists). Participants reported to be frequent users of computers (M = 4.211; σ = 1.182) and mobile technologies ((M = 4.526; σ = 1.172), although they acknowledged to have little experience with video games on both types of technologies, respectively (M = 2.211; σ = 1.357) and (M = 2.632; σ = 1.571). In addition, all participants reported to be unexperienced about AR (M = 1.579; σ = 1.121). For logistical reasons,

participants were distributed into two groups. Each group went through a workshop which exposed them to similar experimental treatment. Workshops took place at the Scottish Social Services Care facilities on the same day.

Procedure

A face to face, testing workshop was identified as the most appropriate approach as it would allow the project team to control the experiment environment and observe users interacting with the application, as well as being available to engage with users to answer queries or collect ad hoc feedback regarding the application.

Participants were first provided with a participant information sheet which explained the objectives of the study, the experimental procedure and their rights as participants. They were then asked to sign a consent form in which they acknowledged they have been fully informed and were willing to take part to the experiment.

Workshops ran for two hours each and started with participants completing a pre-test questionnaire which captured demographics data, information technology habits and use, and initial skin breakdown knowledge.

Participants were then provided with an Android tablet each, on which the application has been previously installed, and an experimental procedure document that identified the sections of the application they were required to explore. Participants worked through the experimental procedure at their own pace and workshop facilitators were available for additional support when required.

Once a participant completed the experimental procedure, they returned the tablet and were required to fill in a post-test questionnaire. This questionnaire assessed skin breakdown knowledge recalling similar questions as the pre-test questionnaire, and assessed the application usability and user experience, motivation and engagement, and cognitive load. In addition, participants were invited to provide any additional comments they thought to be relevant to help to the understanding of how the application could better support skin breakdown care.

Data Analysis

In order to provide robust conclusions about the application, standardised and/or well-established questionnaires and methodologies were used. The different measures of the experiment were explored using the following methods:

- Knowledge acquisition about Skin Breakdown – A quasi-experimental approach was adopted in order to contrast participants' knowledge before and after using the application. A series of statements are provided to participants in both the pre-test and post-test questionnaires. Correct answers to each statement were quantified as one point whereas erroneous answers correspond to a zero point score. Points were summed up, and that sum was translated into a percentage, in order to provide a score which attested for skin breakdown knowledge before and after using the application. Knowledge acquisition was quantified as the difference of score reported by pre-test and post-test questionnaires.
- Usability was measured using the well-established Usefulness, Satisfaction, and Ease of use (USE) Questionnaire (Lund, 2001). This questionnaire consists of 30 usability items which assess four dimension of the tested product (1) Usefulness, (2) Satisfaction, (3) Ease of Learning and (4) Ease of Use. The questionnaire is constructed as seven-point Likert rating scales and participants were asked to rate their agreement with the statements, ranging from strongly disagree to strongly agree. Statements ratings were summed up per dimension for each participants and then averaged in order to provide an overview of each participant's perception for each dimension. In addition, participants were asked a series of open questions to explore what they most liked/disliked, would change or refine.
- User Motivation and Engagement, supported by the instructional design, were explored building upon the Attention, Relevance, Confidence, and Satisfaction (ARCS) Model of Motivational Design used by the Instructional Materials Motivation Survey (IMMS) (Hauze & Marshall, 2020). The survey consists of 36 rated items using a 7-point Likert Scale. The scale allows participants to express their agreements with each statements providing ratings from Very untrue to Very true. However, recent research has constructively discussed the IMMS and proposed a Reduced IMMS version (RIMMS) (Loorbach et al., 2015) which has revealed to be an equally robust and reliable method of assessment of user motivation and engagement. RIMMS consists of only 12 items from IMMS, and uses similar Likert scale. The

RIMMS has been used to survey the motivational aspect of the instructional design of the application.

- The cognitive load generated by the application was explored building upon previous research (Molina et al., 2013) which investigated the suitability of mobile devices to provide teaching material in alignment with instructional design principles and facilitate access to effective learning. Molina et al. (2013) built upon the Cognitive Load Theory (CLT) (Sweller, 2005) to measure the cognitive load generated by a mobile learning application. They devised a 5-point Likert Scale questionnaire where 1 means strongly disagree and 5 means strongly agree. The questionnaire was composed of three statements which aim to inform about the task demand, and thus indicate the intrinsic load (*"The Learn section activity was difficult"; "The Learn content was difficult for me"; "The Learn section activity required a lot of mental activity / effort"*); and two other statements (*"I have made an effort in order to visualise the content of the app (navigation and scroll)"; "It was difficult to learn from the content using this app"*) to look at the demand caused by the mobile interface itself, and thus inform about the extraneous load.

Ethics

The experimental procedure along with all associated documentation (personal information sheet, consent form and questionnaires) received ethical approval from the Research and Enterprise Office at the Glasgow School of Art.

Experimental Results

Knowledge Acquisition and Development

Participants answered to a series of questions before and after completing the experimental procedure. The discrepancies between participants' responses before and after completing the experimental procedure highlighted the impact of the application on their confidence of knowledge, and effective knowledge acquisition after using the application (Table 3). A Non-parametric statistical analysis using a Wilcoxon signed Rank test reported there were very significant differences between participants answers before and after using the application ($Z = -3.72, p < 0.001$), suggesting a high learning effect (Fig. 10). Similarly, significant differences were reported about participants' confidence of knowledge before and after using the application ($Z = -2.36, p < 0.05$).

However, despite such encouraging results, the increases of participants' confidences regarding their knowledge about skin breakdown and their knowledge acquisition before and after using the application was not significantly correlated (Spearman correlation: $r(17) = -0.42; p = 0.745$).

Table 3. Knowledge acquisition and knowledge confidence - pre-test vs. post-test

	Pre-Test		Post-Test	
	M	**σ**	**M**	**σ**
Confidence of Knowledge	**64.211**	**18.353**	**76.842**	**19.164**
What is the difference between a pressure sore, a moisture lesion and a combination lesion?	40.351	39.408	70.175	36.675
There are 3 causes of pressure sores, can you list them?	28.07	29.945	43.86	33.431
How many grades of pressure sore are there?	26.316	45.241	84.211	37.463
Can you name 2 factors that put someone at risk of developing pressure sores?	52.632	38.993	78.947	25.363
Moisture lesions can form as a result of four different types of moisture, can you list two of them?	50	44.096	89.474	26.765
What does IRD stand for?	0	0	68.421	47.757
Indicate on the image the various locations where skin breakdown wounds most likely develop	31.203	14.327	56.767	13.775
Knowledge Acquisition	**32.653**	**30.287**	**70.265**	**31.604**

Figure 10. Average calculated knowledge acquisition throughout the experimental procedure

Usability and User Experience

Participants were asked to answer a series of questions from the USE questionnaire, in order to assess the perceived usability of the application. The questionnaire builds a definition of usability and user experience upon four constructs which were rated using a 7-point Likert scale ranging from strongly disagree to strongly agree.

Overall, participants appeared to be satisfied about their experience using the application ($M = 5.396, \sigma = 1.069$). They found it easy to use ($M = 5.506, \sigma = 0.911$), with a fairly moderate

learning curve (*M = 5.618, σ = 0.918*). Finally, they felt the application to be useful to support care activities related to skin breakdown (*M = 5.313, σ = 0.938*) (**Figure 7**).

In addition, Participants were also asked to answer to three simple open questions: (1) "*what did you most like?",* (2) "*what did you most dislike?*", and (3) "*what would you change?*". Participants reported statements that were supportive of the USE Questionnaire outcomes. They enjoyed most the Informative and stated it has all relevant content (9); they most like the Easy to use / simplicity (8), Usefulness for care givers (4), its clarity of use and easy language (2), the AR functionality (2), the visual design (2), the enjoyment (2) and the engagement (1) the application generates. In contrast, they reported to feel the need for more practice to use the application correctly (3), and 3 participants reported to have difficulties using the AR features. Other negative aspects have been suggested, although these were marginal. Finally, further changes have been reported in a marginal way: Addition of further diagnostic or patient information (1), Make the AR avatar appear straight away (1), Remove AR features (1).

Figure 11. Usability testing outcomes.

Motivation

Participants' motivation was measured using the four constructs proposed by the RIMMS (Loorbach et al., 2015), Attention, Relevance, Confidence and Satisfaction. RIMMS is constructed upon a 5-point Likert scale with which participants confirmed their agreement with a series of statements.

Overall, participants reported to experience high motivation unanimously providing ratings located in the upper range of the scale for all four factors; Attention (*M = 4.281, σ = 0.669*); Relevance (*M = 4.246, σ = 0.8.67*); Confidence (*M = 4.105, σ = 0.667*); Satisfaction (*M = 4.123, σ = 0.739*) (***Figure 8***); Further discussion with participants highlighted that an overwhelming majority would be happy to download this application onto their personal mobile device to support their work-related learning (*M = 4.053, σ = 1.223*).

Figure 12. RIMMS questionnaire outcomes.

Cognitive Load

Participants answered a series of questions that aimed to explore two types of cognitive load: the intrinsic load (which refers to the complexity of learning certain content that depends exclusively on the actual content to study and not of the presentation format or device used) and the extraneous load (depending on instructional design, that negatively interferes with the learning process). Measures were constructed upon a 5-point Likert scale which ranged from strongly disagree to strongly agree.

Overall, participants reported low intrinsic ($M = 2.035, \sigma = 0.693$) and extraneous ($M = 2.433, \sigma = 0.691$) cognitive load when using the application despite the confirmed effectiveness of the application to support knowledge acquisition and development.

Discussion

This research resulted in a mobile application which aims to raise awareness about the causes and indicators of pressure ulcers amongst care and support workers. There already exist many mobile applications for pressure ulcers although little research has been completed to support the validity of these applications for their specific purpose (Koepp et al., 2020). Furthermore, it has been highlighted the needs for a more methodological approach to application development in order to allow research reproducibility (Koepp et al., 2020). By providing a thorough description of the technical aspects of the design and development processes, this chapter can contribute towards filling this specific gap.

The mobile application was designed in accordance with a series of criteria, functional features and system requirements defined at the beginning of the research by several stakeholders from the social care industry in Scotland. These were gathered using the Voice of the Customer approach (Aguwa et al., 2012), a well-established methodology for capturing users' needs and expectations in market research. Actively involving the stakeholders at early stages of the design process proved to be a useful approach to produce an effective user-centred application design. Understanding the needs of end users was a crucial step towards the production of a storyboard, and subsequent graphical user interface which reflected users' initial expectations. Initial needs and expectations were translated into a series of requirements that informed the software design of the application, in the form of functionalities that describe the functioning of the application and the interaction with the user. Requirement analysis outcomes served as a roadmap throughout the different stages of development of the application, from alpha, beta to camera-ready version, ensuring the

implemented functionalities and features satisfied the initial specifications and requirements. Standardised software engineering methodologies, SysML and UML, were used. These methodologies are considered powerful software engineering methods which can provide insights into the finest functional and user-interaction details of the application. This aspect of the research can be critically appraised. Effectively, while being supported by the graphical representation of the application interface provided by the storyboard, further details into the functioning of the application could have been provided. The short timescale of the research limited the extent of software engineering design activities.

Building upon initial users' specifications, the application provides a simplistic iconic design which reuses the colour palette of the Scottish Social Services Council, with an intuitive drag and click touch interaction paradigm. Despite endeavours to maximise the reach of the application, by releasing build versions for Android and IOS system, the use of AR Core and AR Kit as subsystems to AR Foundation was one of the limitations of the application. Effectively, due to performance requirements, AR Core and AR Kit present limited compatibility with mobile devices using their respective manufacturer operating system, making it unsuitable for older models of Android and iOS devices.

Overall, the proposed methodical approach to design and development has been demonstrated to be fruitful ensuring the completion of design and implementation objectives within a five-month period.
Koepp et al. (2020) also highlighted the need for user-testing to affirm the validity of mobile applications for pressure ulcers. They reviewed various applications designed for different purposes. In some cases, these applications used image processing algorithms to analyse pressure ulcer in lieu of relying on human expertise (Poon & Friesen, 2015; Tibes, 2015; Faux et al., 2016). In contrast, our application does not have any image processing and neither diagnosis or analysis capability, but rather focuses on the knowledge development and consolidation about pressure sores and moisture lesions, among support and care workers.

In this research, several aspects of the application were explored, including (1) its effectiveness to support knowledge development and acquisition; (2) the sense of engagement and motivation experienced by users; (3) the usability and user experience; and (4) the generated cognitive load.

Overall, user-testing on knowledge gained resulted to be overwhelmingly encouraging. Participants demonstrated significant gain of knowledge and increase in confidence in their knowledge after using the mobile application. A Spearman correlation analysis showed the absence of correlation between these two variables. This suggests that a gain of knowledge was not automatically reflected as an equivalent increase in confidence of knowledge. This can be explained by the fact that one participants rated his/her confidence to the maximum before and after using the application; five others reported no changes in their confidence of knowledge, while one stated a loss of confidence in his/her knowledge, despite they all improve their knowledge about pressure ulcers. Anecdotally, the one who reported a loss of confidence in his/her knowledge, resulted to be the one gaining more knowledge. It is fair to hypothesize that involving more participants would potentially lead to highlight clearer trend between the variation of confidence of knowledge and knowledge acquisition.

Usability testing results were more moderately encouraging. Overall, participants somewhat agreed with the statements that informed about the usefulness, ease of use, ease of learning and satisfaction. This suggests the mobile application has a good level of usability. Despite not being a fully standardised tool, in this study, as in others (Machado et al., 2016), the USE questionnaire has proven to be a robust instrument to determine the usability of our mobile application, despite the absence of an quantitative assessment benchmark as with the System Usability Scale (Brooke, 2013), but also to provide a glance at the user experience. The open questions at the end of the USE questionnaire resulted extremely valuable for us, and they provided information about what users appreciated and disliked and this feedback was incorporated into the final refinement stage of the development. It appeared that the simplicity, ease of use and usefulness of the application was acclaimed, although few reported experiencing difficulties when using the AR features of the application, possibly needing more practice outside the experimental controlled environment. During a conversation with participants outside of the experiment context, half of participants expressed their interest for including more information about patient handling procedures, and almost half mentioned they would be interested in similar application focused on dementia.

The evaluation of the participants' motivation was conducted using the RIMMS (Loorbach et al., 2015), and outcomes were overwhelmingly encouraging. Overall, participants reported high levels of motivation, expressing beyond good ratings for the four constructs assessed by

the RIMMS. These results suggest that the instructional material provided through the application contribute to maintain the user's attention, confidence, perception of relevance and satisfaction at high level. Measure outcomes for the satisfaction construct are in alignment with the findings from the USE questionnaire.

Finally, two types of cognitive load were measured: the intrinsic load and the extraneous load through a short questionnaire. Overall, results were encouraging. Participants reported little intrinsic cognitive load, which suggest that the content of the application did not contribute to increase the complexity of learning; and little extraneous load, which suggest that the instructional design did not constrain learning. This forms the basis of a very powerful argument in favour of the application – being able to acquire and nurture knowledge about skin breakdown while maintaining low cognitive load. These results are also coherent with the outcomes reported through the USE questionnaire, more particularly outcomes for the Ease of Use and Ease of Learning constructs.

Conclusion

This chapter presents a methodological and technological framework for the development of a mobile application which aims to raise awareness and help users to acquire knowledge about pressure ulcers. The delivery of the specific knowledge builds upon the approach of situated learning in which learning is believed to be most successful if it takes place in the culture and context in which it is expected to be applied. Using Augmented Reality features, the application allows overlaying digital content onto the real world, creating more engaging means for the users to interact within the real world context.

Evaluation has shown the mobile application to be highly usable, and able to generate a satisfactory and motivation learning experience. The application supports the acquisition of knowledge about skin breakdown in a significant manner, and generate little cognitive load for the user. Further testing involving a wider pool of participants would result useful to confirm these trends.

Acknowledgements

We would like to thank the Care Inspectorate, NHS Tayside, NHS Forth Valley, NHS Lothian and Health Improvement Scotland, Hillcrest Futures, Balhousie Care Group Dundee City Council, Sense Scotland, for their involvement in this research.

References

See Attached file

Appendix I

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
1	**Target Platform**	**The application must be able to be run on the most popular smartphone platforms**	**To be able to share the application to as many users as possible, the application must be able to run on the most popular platforms**	**This will be satisfied when it's children requirements are satisfied**	**Compulsory**
1.1	iOS	The application must be compatible with the iOS operating system, version 11 to 12.3.1	iOS is one of the most popular operating systems for mobile devices and has been specifically requested by the project funders as the target platform. Note: ARKit requires min iOS 11 to function	The application will be tested on an iPhone 6 S Plus available at SimVis and also on an iPad available, both which are currently running on iOS 12.0	Compulsory
1.2	Android	The application must be compatible with the Android operating system, version 8.1 (Oreo) to 9 (Pie)	Android is another popular operating system for mobile devices and to increase the target user base the project funders have requested this as an optional, additional target platform	The application will be tested on a Samsung Galaxy S7 and also Samsung tablet available here at SimVis which is currently running on Android version 8.0.0	Optional

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
1.3	App store	The final iOS application must be available in the SSSC account on the App store	In order to adhere to SSSC guidelines, all apps developed for the SSSC must be available in the SSSC account on the App store and Google Play.	The application's availability on the relevant platform will be confirmed by the project team following deployment	Compulsory
1.4	Google Play Availability	The final Android application must be available in the SSSC account on Google Play	In order to adhere to SSSC guidelines, all apps developed for the SSSC must be available in the SSSC account on iTunes and Google Play.	The application's availability on the relevant platform will be confirmed by the project team following deployment	Optional
2	**Target Technology**	**The application must be functional on smart mobile devices**	**To be able to share the application to as many users as possible, the application must be able to run on the most popular smart mobile devices**	**This will be satisfied when it's children requirements are satisfied**	**Compulsory**
2.1	Smartphone	The application must allow content to be displayed in a similar resolution to that of a smartphone	The application's content must be compatible with a standard smartphone screen (format, resolution and size (min 4 inches))	The application will be tested on both an iPhone 6 S Plus and Samsung Galaxy S7 smartphones	Compulsory
2.2	Tablet	The application must allow content to be displayed in a similar resolution to that of a tablet	The application's content must be compatible with a standard tablet screen (format, resolution and size)	The application will be tested on both an iPad model and Samsung tablet	Optional

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
2.3	Aspect ratio	The application's content must automatically adapt to different screen sizes	The application will be deployed to a variety of smart mobile devices, and therefore the content should automatically adjust to take account of different screen sizes	The application will be tested on an iPhone 6 S Plus, iPad, Samsung Galaxy S7 and also a Samsung tablet. Additional screen sizes will also be tested within the Unity Game engine editor	Compulsory
3	**Augmented Reality Libraries**	**The application must use the required augmented reality libraries so that the AR functionality is available for the user**	**In order to develop augmented reality functionality within the application, the use of augmented reality libraries within the Unity game engine is required.**	**This will be satisfied when it's children requirements are satisfied**	**Compulsory**

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
3.1	ARKit	The application's augmented reality component must be developed using ARKit	In order to deliver the augmented reality component to the application's primary target platform (iOS), the application will use the ARKit package available within the Unity game engine. This package is designed to deliver augmented reality functionality, such as surface detection, for smart mobile devices using the iOS operating system	The application's augmented reality functionality will be tested on an iPhone 6 S Plus available at SimVis and also on an iPad which is currently running on iOS 12.0	Compulsory
3.2	ARCore	The application's augmented reality component must be developed using ARCore	In order to deliver the augmented reality component to the application's secondary target platform (Android), the application will use the ARCore package available within the Unity game engine. This package is designed to deliver augmented reality functionality, such as surface detection, for smart mobile devices using the Android operating system	The application's augmented reality functionality will be tested on a Samsung Galaxy S7 and also a Samsung tablet available at SimVis which is currently running on Android version 8.0.0	Optional

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
3.3	ARFoundation	The application's augmented reality component must be developed using ARFoundation	In order to deliver the augmented reality component to both of the application's target platforms (iOS and Android), the application will use the ARFoundation package available within the Unity game engine. This package is designed for use alongside ARKit and ARCore to deliver cross platform augmented reality functionality, such as surface detection, for smart mobile devices	The application's augmented reality functionality will be tested on both an iPhone 6 S Plus and Samsung Galaxy S7 smartphones	Optional
4	**Branding**	**The application's content must adhere to the SSSC's branding guidelines**	**The design and content contained within the application will adhere to the SSSC's branding guidelines, specifically the use of logos, fonts, tone of voice and the colour palette outlines in the guidelines for digital content**	**This requirement will be considered satisfied following feedback from SSSC team**	**Compulsory**
4.1	Fonts	The application's text must be presented using the Verdana font	In order to adhere to the SSSC's branding guidelines, all the applications and their content must use the Verdana font. Title font will be Verdana bold. Second level font will be Verdana regular.	The application will use the required font and formatting throughout and this will be checked prior to final build	Compulsory
4.2	Title	The application must have a suitable title	So that the users can easily identify and recognise the application, the application must have a unique, appropriate title	The application's title will be agreed by key project stakeholders to ensure it is fit for purpose	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
4.3	Logo	The application must have an identifiable logo	So that the users can easily identify the application on their smart mobile device, the application must have a unique and eye-catching logo	The application's logo will appear on the smart mobile device when the application is installed, it will be easily identifiable and selecting it will launch the application	Compulsory
4.4	Identifiable	The design of the application must enable the user to easily identify it as a SSSC application	So that the users know the context and producer of the application (SSSC as opposed to Care Inspectorate or NHS), the design of the application, including branding, tone of voice, content and logos, must be consistent with other SSSC products, such as eBooks and the website.	The application's logo will appear on the smart mobile device when the application is installed and selecting it will launch the application	Compulsory
5	**Self-contained**	**The application must be fully self contained**	**The application must be fully self contained in that it should not require access to potentially sensitive user data or device functions in order to run. Nor should it be required to collect and/or share any user sensitive data.**	**The final version of the application will use an SDK which does not access, store or transmit usage or diagnostic information.**	**Compulsory**

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
5.1	Camera permission	The application must be granted access to the device's camera by the user before the augmented reality functionality is utilised	The user must have the ability to grant (or deny) the application permission to their device's camera before the augmented reality functionality is activated. This will be requested the first time the app is launched on the user's device.	This is in-built functionality for smartphone applications and will automatically request the user's permission when the application is launched the first time.	Compulsory
5.3	Application size	The final application build must be a suitable size so it will be able to be stored easily on the user's smart device	The build of the final version of the application must be 40M or below so that it will download to the user's smart device quickly, easily and without taking up too much internal storage space	The build of the final version of the application is equal to or below the target application size	Compulsory
6	**Navigation**	**The user must be able to easily navigate through the application's content to access the required reference material**	**The navigation of the application will be designed to be simple, consistent and using the fewest steps possible to achieve the desired outcome**	**This will be satisfied when it's children requirements are satisfied**	**Compulsory**
6.1	Main Menu	The application must present the user with a main menu screen at launch	When the application launches the user will have the option of selecting which aspect of the application they want to access based on their needs at the time (i.e. AR visual aspects or text based reference material)	The user will be presented with a main menu when the application launches	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
6.2	Index Page	The user must be able to return directly to the main index page from every screen	It must be possible to return directly to the main index page of the application from every screen to enable quick and easy navigation to screens covering different topic areas and functionality.	The user will be able to return to the main index page from every screen within the application	Compulsory
6.2.1	Navigation bar	The application will have a consistent navigation bar at the bottom of each screen	So that the user can easily move between screens and functionality (AR vs info) in the application, each screen must contain a navigation bar at the bottom of the screen which will be the same on each screen in the application	The navigation bar will enable the user to move between screens and will be consistent throughout each screen of the application	Compulsory
6.3	Page Information	The user must be informed about their progress through the content	Each page of the application will show the user where they are in the content, for example which section or page they are on to help them navigate the application's content. This information must appear in a consistent format throughout the application	The user will be able to identify their position within the application's content	Optional
7	**Application content**	**The application must provide informative content to the user to enable them to use it as a learning tool**	**In order for the application to fulfil the design goal of raising awareness of early indicators of pressure sores, the application must provide accurate and relevant information to the user, including acknowledgements for the authors/sources of the content**	**This will be satisfied when it's children requirements are satisfied**	**Compulsory**

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.1	Splashscreen	The application must open with a splashscreen showing the title of the application and logo of key contributing organisations	To ensure the key creators of the application are adequately highlighted, the application will launch with a title screen which shows the SSSC and GSA School of Simulation and Visualisation logos as well as the title of the application	The application will show the correct title and logo for each creator when it is launched	Compulsory
7.2	Acknowledgements	The application must contain an acknowledgements section	To ensure each contributor to the application is adequately acknowledged, the application will have an acknowledgments section which will contain a written thanks to the named individuals and organisations who have contributed towards the development of the functionality and content of the application, including their logos	The application will show written acknowledgments and logos for each contributing organisation	Compulsory
7.3	Disclaimer	The application must contain a disclaimer which will specific the limitations of the application's content to the user	In order to clarify the limitations of the application's content to the user, the application will contain a disclaimer which will outline that it is not to be used as a diagnostic tool, refers the user to their own policies and procedures and reminds the user they have a responsibility to report any concerns (quote code of practice 3.2?)	The application will contain a suitable disclaimer which is presented to the user	Compulsory
7.4	Anonymisation	The application's reference content must be fully anonymised	No patient or service user should be identifiable within the application's reference content, either images or written material used (note: stock marketing and communications images which show individuals are acceptable)	This requirement will be considered satisfied following feedback from subject matter experts	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.5	Adult support	The application's content must accurately portray adult support issues	The GSA team will liaise with subject experts within the project team regularly to ensure that adult support and protection scenarios / issues are portrayed accurately and realistically in any photographic or video content.	This requirement will be considered satisfied following feedback from subject matter experts	Compulsory
7.6	Distinct content sections	The application's AR functionality must be separate from the applications written content section	So that the application is easy to use and the information within it is presented in the most appropriate format the AR visual representations and written information will be organised into two different sections within the application	This requirement will be considered satisfied following the design of the application if the design documentation demonstrates that these will be held in different sections	Compulsory
7.7	Segmented content	The application must split the content into suitable subsections / segments	As cognitive load increases for every 100 words you put on a page the information contained in the application must be broken down into suitable subsections or segments. This means that specific learning goals or user problems can be addressed individually, reducing the cognitive load, increasing learning capabilities and allowing the user to access what they need.	This requirement will be considered satisfied following feedback from prototype testing with target user group	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.8	Targeted content	The application must contain content which is suitable for the target user group	The information contained in the application must reflect the level of expertise of the target user group as this can contribute to lowering the cognitive load	This requirement will be considered satisfied following feedback from prototype testing with target user group	Compulsory
7.8.1	Simple language	The application must use simple, jargon free language throughout the content	In order for the information to be accessible and understandable to as many users as possible, the language used throughout the application must be simple, clear and concise and avoid the use of medical and complex terminology	This requirement will be considered satisfied following feedback from prototype testing with target user group	Compulsory
7.9	Pressure Ulcer information	The application must contain reference material regarding pressure ulcers	In addition to the AR component, the application will also include reference material to enable users to access information about pressure ulcers when required. This content will be supplied by subject experts from the NHS and the Care Inspectorate and will enable users to learn about and identify the early indicators of pressure ulcers developing	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.9.1	Causes of pressure ulcers	The application must contain information regarding the causes of pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the causes of pressure ulcers (i.e. what is happening to the tissue)	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.2	Pressure ulcer development time	The application must contain information regarding the time it takes for a pressure ulcer to develop	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the time it takes for a pressure ulcer to develop	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.3	Pressure ulcer grades (description)	The application must contain information regarding the various grades of pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the various grades of pressure ulcers	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.9.4	Pressure ulcer impact	The application must contain information regarding the impact of pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the impact of pressure ulcers on the individuals who have them and the services they use	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.5	At risk individuals	The application must contain information regarding the individuals who are at risk of developing pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the individuals who are at risk of developing pressure ulcers	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.6	Pressure ulcer locations	The application must contain information regarding the most likely locations pressure ulcers develop	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the most likely locations pressure ulcers develop, for example using a diagram	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.9.7	Pressure ulcer factors	The application must contain information regarding the factors which may cause a pressure ulcer to develop or worsen	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the factors which may cause a pressure ulcer to develop or worsen. These may be environmental or medical	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.8	Verbal indicators	The application must contain information regarding the verbal indicators which may suggest a pressure ulcer is developing	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the type of verbal indicators which may suggest a pressure ulcer is developing. This could be something the service user may raise, or something raised by the service user's family	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.9	Preventative measures	The application must contain information regarding measures which help prevent pressure ulcers developing	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding measures which help prevent pressure ulcers developing. This must be presented in a "hints and tips" format and can include both environmental and medical factors	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.9.10	Treatment methods	The application must contain information regarding the methods used to treat pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the methods used to treat existing pressure ulcers. This must be presented in a "hints and tips" format and can include both environmental and medical factors	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.11	Next actions	The application must contain information regarding the next actions to take following the identification of a suspected pressure ulcer	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the next actions to take following the identification of a suspected pressure ulcer. This must outline the generic actions (i.e. share the information appropriately), signpost the user to their own organisation's procedures and policies and remind the user of their duty of care	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.12	Tools to use	The application must contain information regarding the tools which can be used to help identify or monitor pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding the tools which can be used to help identify or monitor pressure ulcers	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Optional

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.9.13	Referrals	The application must contain information regarding who to inform following the identification of a suspected pressure ulcer	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information regarding who to inform following the identification of a suspected pressure ulcer. This must also emphasise their duty of care to report any concerns.	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.9.14	Additional training	The application must contain information which signposts the user to additional training opportunities relating to pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain information which signposts the user to additional training opportunities relating to pressure ulcers	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.10	Integration of visual content	The application must integrate visual and textual information	The application should integrate visual and textual information, thereby reducing multiple sources of visual information (e.g. diagrams, labels and explanatory text) which divide the user's attention and increase cognitive load.	This requirement will be considered satisfied following feedback from prototype testing with target user group	Compulsory
7.11	Augmented Reality Functionality	The application must incorporate the use of augmented reality functionality to communicate content to the user	In order for the application to fulfil the design requirements of the brief, the application must incorporate the use of augmented reality	This will be satisfied when it's children requirements are satisfied	Compulsory

Learning About Skin Breakdown: Requirements					
ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.11.1	Image Overlay	The application must allow the overlay of digital images into the real world using augmented reality	The application will use augmented reality to overlay images of different stages of skin breakdown that will enable workers to learn about and identify the early indications of this using the camera on the user's smartphone	The user will be able to overlay images using the application's augmented reality functionality	Compulsory
7.11.1.1	Pressure ulcer grades (AR)	The application's AR functionality must show images of all grades of pressure ulcers	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain images showing the various grades of pressure ulcers	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.11.1.2	Wound progression	The application must enable the user to see the change in wound progression over time	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain images showing the way in which a pressure ulcer will develop over time	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Optional

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.11.1.3	Pressure ulcer locations (AR)	The application's AR functionality must show images of pressure ulcers on different parts of the body	To meet the project outcome of enabling users to learn about and identify the early indicators of pressure ulcers developing, the application must contain visualisations of pressure ulcers found on different parts of the body	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Optional
7.11.2	AR Instructions	The application's AR component must contain user instructions	When the user accesses the AR component of the application they must be presented with basic instructions outlining how to operate the AR functionality.	When the user enters the AR section of the application they are presented with a set of instructions which informs them how to use the AR functionality of the app	Compulsory
7.11.2.1	Skip AR Instructions	It must be possible to easily skip the AR instructions	It must be possible to easily skip the AR user instructions if they are already familiar with the app and the way it operates	When the AR instructions appear there will be a way for the user to easily close or skip the instructions	Compulsory

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
7.11.2.2	Availability of AR instructions	The user must be able to access the AR instructions at any point when they are using the AR functionality of the app	To ensure the user's know how to operate the AR functionality correctly, or in case they did not understand the instructions, the user must be able to access the AR instructions from anywhere within the AR section of the application	The user will be able to access the AR instructions from anywhere within the AR scene	Compulsory
7.12	Moisture Lesion information	The application must contain reference material regarding moisture lesions	In addition to the AR component, the application will also include reference material to enable users to access information about moisture lesions when required. This content will be supplied by subject experts from the NHS and the Care Inspectorate and will enable users to learn about and identify the early indicators of moisture lesions developing. This information will follow the same format as the pressure ulcer information (see 7.9.1 to 7.9.10 above)	The application will contain all the required reference material provided by the project partners in an appropriate format for the application	Compulsory
7.13	Glossary	The application must contain definitions for medical terminology	Due to the nature of the application's content, some medical terminology will be included. To ensure the user fully understands the content, a glossary/definition of key terms used in the application must be included, enabling the user to easily understand what each term means	The user will be able to view the definition of any medical terminology used within the application	Compulsory

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
8	**Usability**	**The application must be easy to use by all target users**	**The application must be easy to use by the target user group**	**This will be satisfied when it's children requirements are satisfied**	**Compulsory**
8.1	Intuitive	The application must be intuitive to use	The navigation and control of the application will be designed so it feels intuitive to the user and they can operate all the application's functionality without the use of written instructions	This requirement will be considered satisfied following feedback from prototype testing with target user group	Compulsory
8.2	Interaction	The user must be able to control the application by interacting with the smart mobile device screen	All of the application's controls will use the inbuilt touch detection functionality of smart mobile devices to allow the user to navigate through the application's content	The user will be able to control all of the application's functions and navigation by interacting with the smart mobile device screen	Compulsory

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
8.3	Clarity	The application's content must be easily readable for users	The application's content must be compatible with a standard smartphone screen (format, resolution and size (min 4 inches))	The application will be tested on an iPhone 6 S Plus, iPad, Samsung Galaxy S7 and also a Samsung tablet. Additional screen sizes will also be tested within the Unity Game engine editor	Compulsory
8.4	Accessibility	The application must incorporate accessibility considerations	The content and design of the application must be clear and simple enough so that most people can use it without needing to adapt it, while supporting those who do need to adapt things	The application will be tested using tools such as the "Accessibility Scanner" app (Available on Google Play) and Snook to assess how it meets accessibility guidelines	Compulsory
8.4.1	Scalable	The application's content must be scalable	So that all users can read the application's content, the pages and content must be scalable, allowing the reader to zoom in and out	The user is able to enlarge an object, image or piece of text	Optional

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
8.4.2	Adjustable font size	The application must allow the user to adjust the size of the content's font	The application's font size must be adjustable to ensure it is readable for all users	The user will have the ability to easily increase or decrease the size of the font in the application	Compulsory
8.4.3	Colour accessible descriptions	The application's instructions must not rely solely on colour descriptions	The application's instructions must not reply on colour descriptions such as "click the red button" as this replies on the user's ability to distinguish specific colours and may not know what button they need to press	Any instructions used within the application will be described in such a way that all users will be able to follow them	Compulsory
8.4.4	Finger gestures	The application must allow a user to perform all functions using only one finger	Some users may have limited dexterity or range of movement, which means it’s important that they do not have to use complex gestures that involve more than one finger to navigate the application.	The application will be checked to assess whether it’s possible to navigate using just one finger, including double-tapping to zoom in and out of the page and holding or hovering one finger on an object or element.	Compulsory

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
8.4.5	Colour contrast	The application's content must have a suitable contrast ratio	The application's content must have a contrast ratio between text and the background colour of at least 4.5:1 in order for any users with visual impairments to use the application. In addition the colour contrast between any buttons or navigational elements and the background must be at least 3:1 in these cases.	The application will be tested using tools such as the "Accessibility Scanner" app (Available on Google Play) and Snook to assess how it meets accessibility guidelines	Compulsory
8.4.6	Adjustable contrast	The application must allow the user to adjust the contrast settings	The application's contrast settings must be adjustable to ensure it is readable for all users, enabling them to switch between standard and high contrast	The user will have the ability to easily increase or decrease the contrast settings of the application	Compulsory
8.4.7	Automatic content	The application must not have any content which plays automatically	Any interactive, animation or video based elements of the application must be triggered to begin or stop easily by the user, they should not automatically play	Any interactive, animation or video based content will not play unless triggered by the user	Compulsory

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ID	**Req Name**	**Description**	**Rationale**	**Verification**	**Priority**
8.5	Notifications	The user must be able to receive customisable notifications about the application	In order to maintain ongoing learning and provide a refresher on learning content, the user must be able to receive customisable notifications about the application, for example reminders for them to review the content of the application or check their service users for early warning indicators of skin breakdown	The user can receive customisable notifications regarding the application and its content	Optional
8.6	Simple design	The application must use simple design elements	So that the application is clear and easy to use, the design should employ simple design elements, such as large, tile shaped buttons and simple backgrounds	This requirements will be considered satisfied following feedback from the users	Compulsory