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Improving User Experience and Communication of Digitally Enhanced Advanced Services (DEAS) Offers in Manufacturing Sector

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Abstract: Digitally enhanced advanced services (DEAS), offered currently by various industries, could be a challenging concept to comprehend for potential clients. This could result in limited interest in adopting (DEAS) or even understanding its true value with significant financial implications for the providers. Innovative ways to present and simplify complex information are provided by serious games and gamification, which simplify and engage users with intricate information in an enjoyable manner. Despite the use of serious games and gamification in other areas, only a few examples have been documented to convey servitization offers. This research explores the design and development of a serious game for the Howden Group, a real-world industry partner aiming to simplify and convey existing service agreement packages. The system was developed under the consultation of a focus group comprising five members of the industrial partner. The final system was evaluated by 30 participants from engineering and servitization disciplines who volunteered to test online the proposed system and discuss their user experience (UX) and future application requirements. The analysis of users' feedback presented encouraging results, with 90% confirming that they understood the DEAS concept and offers. To conclude, the paper presents a tentative plan for future work which will address the issues highlighted by users' feedback and enhance the positive aspects of similar applications.

Keywords: serious games; servitization; user experience; DEAS; gamification; metaverse

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1. Introduction

The evolution in computing, engineering and manufacturing enables the development of complex products that are continuously upgraded and optimised to improve their output and functionalities. Sustaining the high performance and output standards provided by such products requires an equally sophisticated process of maintenance that could be offered by the provision of advanced services. The complexity of both the products and the maintenance options could be a daunting task to communicate to the end-users/businesses that could limit their understanding of the benefits and value of the provided services. This is of concern both to the company providing the advance service and to the customer.

To alleviate this, a new paradigm of service provision has emerged in the form of digitally enhanced advanced services (DEAS), which are business models centered on delivering outcomes to customers as opposed to products [1]. To further support the DEAS concept, various studies have been conducted to explore innovative digital technologies for enhancing communication, education, and customer engagement in various complex fields [2–4]. One of the technologies employed aims to disseminate the information to potential clients and educate them simultaneously through a gamification method that could convey crucial information to the user in an enjoyable manner [5–7].

This paper presents an innovative application aiming to extend customer and business understanding of DEAS and educate them about its value through gamification and/or a serious game approach. To explore this, a collaborative project was undertaken in conjunction with a major engineering company (Howden Group Ltd., Renfrew, Scotland) which provides clients with industrial air and gas handling equipment [8,9]. The real-life products enable various sectors to improve their daily processes, from mine ventilation to wastewater treatment to heating and cooling [9]. The proposed research utilized the manufacturer's "service agreement", to investigate if this DEAS offer could be gamified or communicated through a serious game. The service agreement itself is an intricate document that provides the options of services that could maintain the uninterrupted speed and quality of production of the client businesses through several scenarios that could affect the above. However, the provision of such information and description of multifaceted scenarios can be a challenging task to explain to each business client. From this issue stemmed the following research question: *Can serious games convey complex DEAS information in a simplified, understandable and enjoyable manner to non-specialist users/clients?*

Serious games have been successful in various other industries and education [5–7]. The innovative element of this project aimed to ascertain whether these methods could be applied to enhance communication, education and customer engagement regarding advanced services by developing and applying these theories in a real-life, heavy industry case [8].

The paper describes the development of the serious game for the particular manufacturer's DEAS offers (Howden Group). During the development of the project, a focus group, comprising five specialists from the industry, supported, consulted and tested the different development stages of the game to ensure compliance with all the industry and client requirements. The final version was evaluated by 30 users relevant to the area of interest with the use of a qualitative method described in the following sections. In turn, the paper presents the evaluation data analysis and discusses the benefits and drawbacks of the proposed system. Finally, this work concludes with an overview of the project, the notable results and a tentative plan for upgrading the application based on the users' feedback. Based on the latter, a revised second version of the application will be evaluated with a larger cohort of users to improve the granularity of future results and inform similar future projects and applications in the DEAS domain.

2. Background

The term servitization refers to the transformation of selling manufactured goods/products to offer additional or alternative innovative and valuable services to its customers. Research related to servitization in manufacturing can be traced back to the late 1960s when Rolls-Royce introduced the "Power by the Hour" to support the production and maintenance of Viper engines [10]. This innovative product offered an engine and accessory replacement service on a fixed-cost-per-flying-hour basis. As a result, this enticed the manufacturer and operator as they only purchased engines that had a reliable and high-level performance. Rolls-Royce has maintained and developed this servitization offer, further embracing innovative digital technologies to offer a range of additional modern features to their products. In the 1980s, servitization research expanded in several industries affected by factors such as technological advancements, globalization and intense competition in the field [11,12]. As businesses have embraced the digital transformation over the past

few decades, it has become apparent that new strategies for the product stages had to be developed. To this end, advanced services were gradually offered for the replacement or enhancement of their products. Several successful leading examples of businesses embracing servitization have emerged in recent years. This includes Caterpillar's Cat® Product Link, a remote tracking and monitoring service offered with their products [13]. Alstom Transports also offers a range of advanced services for the railway industry, which include maintenance, support, modernization and parts and repairs [14]. Xerox, a company that initially manufactured photocopiers, has grown its business model to offer advanced services for business processes and management [15].

More recently, manufacturing companies are adopting the servitization strategy to provide advanced digital services to existing products. This provides fresh opportunities for the companies to expand their business models and increase their revenue and profits [16–20]. Previous studies have highlighted that the lack of perceived value by the customer can impact the adoption of such advanced services [11,21–23]. As such, the offer presented by the service provider should align with the customer's product expectations and concept of enhanced value. This paradigm shift from primarily trading a product to trading the output of the product and peripheral services is a challenging new concept for the traditional process of product provision. However, digital emerging technologies have the potential to assist the clients to understand the value of the outcome provided by the product, and consequently how DEAS can help them (the customer) perform better [1,24,25].

Constant technological advancements in engineering and computing are resulting in emerging interactive technologies. Virtual reality (VR), augmented reality (AR), serious games, 3D Simulations and HCI are just some of the innovative technologies that are redefining and aiding processes procedures across the world.

The concept of game-based learning predates digital video games and has evolved with time and technological advancement [26]. Video-game-based learning can be categorized into two main models, 'Gamification' and 'Serious Games', presented in detail in the following sections.

2.1. Gamification

Gamification is typically applied to content to promote the learning process by utilizing game mechanics and features to engage users [27,28]. The main functionality of gamification is to enhance the learning experience through interaction and engagement. Even though video game-based learning has seen success in many areas, there are only a few examples in the current literature of these learning techniques being used to convey the concept of servitization [29–33]. By adopting game-based learning methodologies, some of these studies demonstrated some success in bringing the benefits of servitization across to manufacturers.

Nevertheless, the methodology adopted has primarily been gamification of content rather than creating a serious game. Several studies highlighted the importance of the gamification concept and proposed possible theoretical models [29,34,35]. The transition of gamification from a theoretical to a practical level has not been explored or applied in real-life systems by the vast majority of studies. A limited number of examples managed to implement a gamification model with the highlight of a particular study that employed the gamification method for servitization based on a popular snake and ladders game [36,37]. However, the game developed was not a video game, but a board game designed to encourage players to reflect upon the significance of the stages of transformation as they pertain to servitization [33,36,37].

In other disciplines, gamification is an extensively utilised model, that could entice users to learn enjoyably, but it has certain limitations regarding its gameplay and simulation [38,39]. The use of game mechanics and other features that are commonly found in entertainment games can provide an engaging experience for its users, motivate them

to perform certain actions and has yielded positive outcomes as a marketing tactic for businesses [39].

Although this method might be particularly effective for marketing purposes, it does not always equate to being the best solution for teaching/training users or simulating a process. In general, the delivery of gamified content or material can be restricted to the delivery of content or material already available; as a result, the final output can only enhance the original delivery. Gamifying content is essentially building over an existing structure rather than designing something with optimum utility in mind. Hence, this can limit the play element of the game, restrict the ways how the content could be delivered to the user and bind the overall creativity. It can be suggested that one reason why the current literature demonstrates the majority of studies utilized gamification over serious games is that gamification is much simpler and cheaper to implement.

2.2. Serious Games

Alternatively, the serious games model embeds specific learning outcomes in the design of the game and the learning objectives are met through playing and/or completing the game. Such games are designed with a defined learning specification in mind and the game is developed keeping the learning goals at its core. The serious game model can empower the developers to design bespoke pedagogical processes and apply user-centered design (UCD) when making the educational game [40,41]. UCD methods allow game designers to incorporate end-user's needs into each design phase and develop the game iteratively. Serious games typically offer training and/or simulation as part of the gameplay [42]. There are only a limited number of studies that have adopted the serious game model when using game-based learning to convey servitization.

One of the first serious games related to servitization was developed to educate managers about the value of advanced services and their role in the supply chain [30,43]. The work concluded that the approach adopted was unsuccessful for teaching all the intended learning outcomes but managed to convey several important factors about servitization. Although the researchers were concerned with user age and gaming experience in relation to usability, they reported that neither factor correlated with usability. This could be attributed to the fact that the particular game focused more on educating/communicating the overall servitization concept than demonstrating a particular business offer. Moreover, the majority of preceding work has attempted to provide roleplaying simulation experiences, which are complicated to learn and play. Such games often require prolonged play, which can reduce player engagement.

A more recent study demonstrated that servitization options could be presented and taught successfully through the use of a serious game [44]. Specifically, the game was successful for education in the context of business transformation and service delivery to impart knowledge and build self-confidence amongst students. This serious game takes its inspiration from the traditional bicycle manufacturer GBI. Researchers used an imaginary scenario-based approach in the design of the game, by making the players run a pretend company. Based on their decisions, the player transforms the company from a product-driven business model into a service provider.

Most of the work concerning video-game-based learning and servitization has focused on emphasizing educating/conveying the overall servitization concept. Except for the study mentioned above, where an imaginary company was used to illustrate servitization in action, to the best of our knowledge, this is the only example illustrating a specific servitization offer for a real-world company.

Both methods, gamification and serious games have been employed in multiple other disciplines to convey information, simulate emergency situations and even raise awareness for major environmental or health issues [45–47].

This paper presents a prototype serious game developed out of the need of a real-world client (Howdens Group) to convey their 'service agreement' to customers and other stakeholders. An iterative game design methodology was adopted that featured User-

Centered Design (UCD) as described above. The real-world manufacturing client was engaged throughout the design and development to aid the developers' understanding of their servitization offer and the current limitations faced by them when communicating this to customers. The following sections present the overall design consideration, implementation process and the research methodology utilized.

3. Proposed Serious Game Application

Adhering to the above observations this work adopted the serious game model over gamification, making it possible for the game to be developed with a unique play experience centred on the manufacturer's DEAS offers. Moreover, this allowed experimentation with the dissemination of the content to be communicated and develop a well-suited game for the intended target audience which included both the employees and customers. An iterative game design process was applied to the proposed work to research, design, develop, and test a DEAS offer-based prototype game level. Figure 1 outlines the key phases of the research project. These phases included project definition, capture, brainstorming, game development and evaluation.

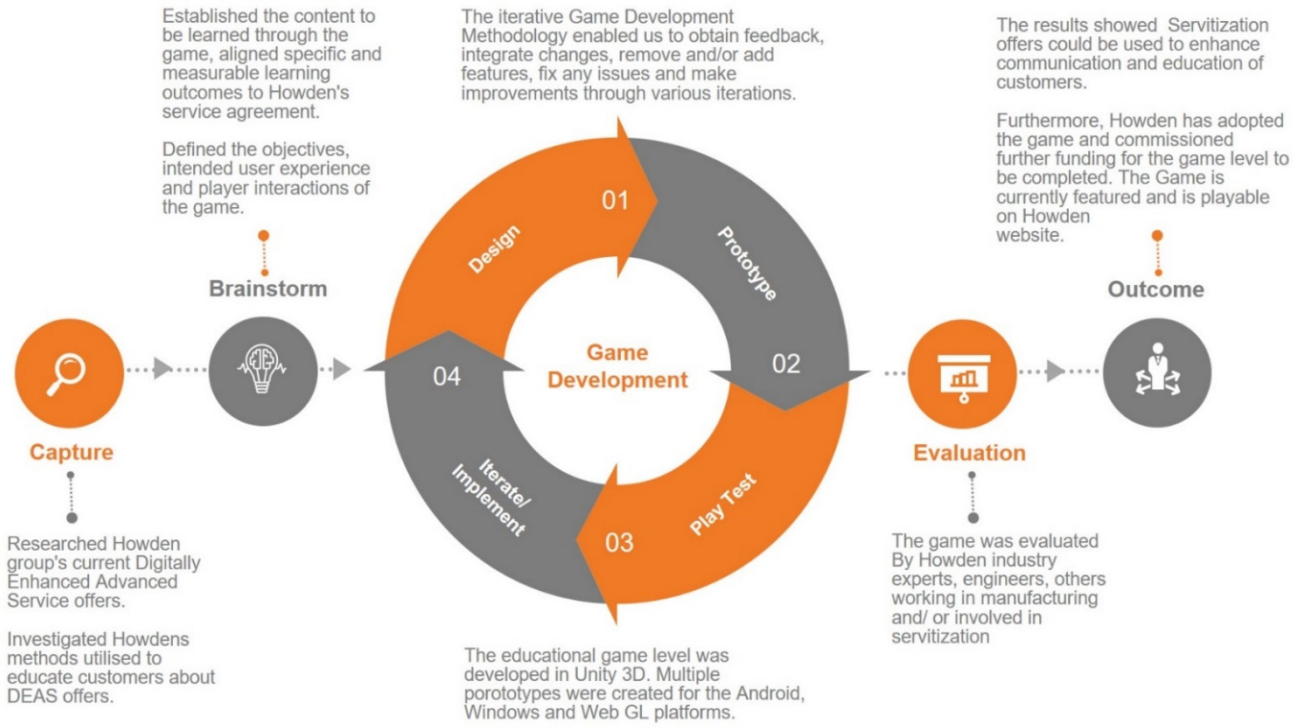


Figure 1. Schematic of the game development process.

4. System Development Process

4.1. Capture—Project Definition Phase

The primary goal of the first phase of the project was to understand the manufacturer's servitization offer and the challenges they faced as customers adopted their new advanced services.

A key part of this process was to interview individuals involved with servitization at manufacturers and to gather the necessary content (brochures, slides, marketing material) to aid the overall process. For this reason, a focus group was formed including five engineers from the Howden Industry involving two Senior Managers, and three engineers covering different stages of the manufacturing and servitization process (i.e., CAD engineer, Mechanical Engineer—Pumps/Hydraulics and Electrical Engineer).

The pump/hydraulics manufacturing area was selected after discussions with the Howden industry focus group as it was posing the largest obstacles in the conveyance

of information and benefits of servitization to existing and new customers. The lack of a special medium to present the above had a direct impact on the selection of such services by the manufacturer's clients resulting in a loss of significant potential income for both the manufacturer and the clients. This process identified key features of the service agreement that the Manufacturer wanted to prioritize in the game. One of the key features was 'Uptime', which is a remote monitoring service offered on their products.

Capture phase findings identified key considerations and requirements:

- Simplicity in Gameplay: This research identified a high probability that the target group of players may not play video games often and may find complex gameplay/interaction and sophisticated mechanics difficult to learn in the timeframe available. The complexity of the game may hinder user engagement and uptake. To engage the end-users, the prototype game followed a 'Pick and Play' approach, this included simple controls and no steep learning curve for the players.
- Fun, Engaging and Educational Gameplay: The learning content had to be embedded in the gameplay whilst fun and learning was balanced to achieve an optimal playing and learning experience (OPLE). This phase of the research also identified and prioritized elements of the manufacturer's DEAS offer that were deemed essential to be communicated through a serious game rather than gamification. As a result of implementing a serious game approach, the educational goals of the DEAS offer could be designed into the formation of the game.
- Game Play needs to show the offer in action: The gameplay was required to present to the full extent the key elements of the service agreement (DEAS Offer) and help players understand its benefits. To ensure that the player understands and uses the manufacturer's services effectively in the game, the information to be learnt had to be simplified and presented experientially. Unlockable upgrades and power-up features within the game enabled the player to learn through experience and highlight how practical the services are. The aforementioned features were incorporated as unlockable features and forced the players to learn through experience, highlighting the practical application of the services. In addition, these features aided player progression and achievement by gradually introducing benefits related to the service so they could learn how to effectively use them and improve their score.

4.2. Brainstorm Phase and Initial Concepts

The brainstorming phase explored multiple ideas and developed solutions for various challenges identified in the capture phase. During the brainstorming sessions with the manufacturer's servitization team, components of the Art of Serious Game Design Conceptual Framework [48] were utilized. In addition to the questions used in this framework, new questions were added to help further define the manufacturer's needs and requirements. The educational aspect of the game was identified, and ideas were explored regarding the context and development process of a serious game that could encompass the key considerations/requirements.

The initial phase identified that the game needed to be of short duration, and simple to play for a diverse range of players with different gaming experiences. Based on the above, an arcade-style maintenance game was deemed ideal rather than a realistic simulation game. The latter could distract the user from the main aim of the game which is not related to the photorealism of the environment or the characters involved. Games in the arcade genre are usually easier to pick up because they have minimal, simple controls and repetitive gameplay that becomes more difficult as one progresses in the game. Art Style, Asset and Content design were purposely limited to less complex versions to make the game relatable to the manufacturer's diverse industry customer base.

This customer base is a large variety of heavy industries as the particular manufacturer provides machinery and services to a wide range of sectors which include oil and gas, mining, power generation, iron and steel, water treatment, tunnel Ventilation, and many others.

As such the users' target group was defined as the clients of this type of industry. As such the game and the provision of information had to be pointed to and designed for these clients which are typically senior managers and engineers. In addition, the other user group that should be considered was the engineers and servitization experts of the providing company/manufacturer. This second group should be supported by such a serious game to explain to the clients the servitization and conclude in a purchasing deal. The 5.1 participant's section presents detailed demographic and specialisation information for volunteers in the evaluation cohort that included members of both groups.

Although this serious game was developed exclusively for this manufacturer, the concept of the game and the modular virtual environment and user interface were designed to change easily and accommodate a plethora of other industries and providers across different sectors.

The inspiration for the final game idea came from chaotic simulation games. In such games, the users are plunged into a game that requires them to perform and learn in chaos-based scenarios. In particular, the game Overcooked (2016) developed by Ghost Town Games formed the initial concept platform for development [49]. Overcooked, depicted in Figure 2 is a complete entertainment game that only focuses on the fun aspect of gaming. There is no educational aspect embedded in the gameplay and is very far from a true simulation or a serious game.

Figure 2. Screenshot of chaotic simulation game Overcooked (2016) developed by Ghost Town Games [46].

However, the chaotic gameplay forces the players to learn the controls and game objectives at a rapid pace. The game concept and task are simple to understand, and the player can engage with the game with minimal experience. These game design considerations were in line with the proposed research agenda and requirements identified in the concept and brainstorming phase.

The proposed work conceptualized a game that revolves around an engineer whose objective is to prevent breakdowns of machinery. The objective of the game is to achieve a high score with the uptime of the manufacturer's machines. In the game, the player is placed in a chaotic environment, and you learn about the services, perks and benefits offered by the Service agreement. The services are featured as unlockable upgrades and power-ups. The prototype game enforces the players to learn through experience and highlights the practical use of the services offered by the DEAS offer. Whilst learning about these benefits and using them effectively the player can improve their score as they progress in the game.

The virtual world of the game was intentionally based on an abstracted version of a typical engineering floorplan and the machines/objects that represent the daily activities of these industries. This enabled the game to be contextualized primarily through text and attract the users' attention to the offers provided whilst presenting an immediate demonstration of their choices in the virtual environment. The machinery in the game is not explicitly described or detailed; this is deliberate to avoid limiting the design and development of this prototype to cater to one specific sector or machine. Maintaining the virtual world and objects simple in design and functionality prevented distracting inaccuracies that could draw the player's attention from the main objective of the game.

4.3. Game Development Phase

The Game development phase of the project involved an iterative approach to research, design, develop, and test a prototype game level during production. A prototype of the game was developed using Unity 3D for Android, Windows, and WebGL platforms. Throughout the development, the game was regularly play tested by the focus group to identify and promptly rectify any potential issues. The iterative design methodology enabled the prototype game level to be built in incremental stages.

This enabled the game to be designed and developed through various iterations, with repeated playtests and evaluations taking place throughout the development cycle of the game. As there were multiple versions of the game in production, this allowed development to obtain feedback, identify bugs and make corrections and adjustments throughout the production process. This resulted in increased effectiveness and appropriateness of content developed and subsequently implemented.

4.3.1. Integrating Howdens DEAS Offer with the Game Concept

Howden's servitization offer is at the center of the game and similar to its real-life counterpart, the offer works in-game in a very similar way, providing improvements to the player and simulating the benefits. This feature evolved into an upgrade system that enabled the player to select the offer to assist them with the game objective. One of the key themes of the service offer was "maintaining". This evolved into becoming the main objective of the game, where the player has to maintain several machines in the game. Drawing inspiration from management games, one of the main concepts for the game involved the player maintaining several machines, in short, chaotic rounds. Machines would break down throughout the round and would require the player's attention. The player would have to rush and prioritize which machines to maintain to score points—creating an exciting game experience.

Game design and development involved mapping the manufacturer's servitization offer into the game. To this end, the services were broken down and categorized into two categories based on how they could be communicated in-game: "Experienced through "game-play" or could be "Provided as information in the game". Figure 3 shows the alignment of Howdens DEAS offer and the Key Game Upgrades.

During the capture phase of the project, the group also identified key benefits and services of the servitization offer that should be experienced through gameplay. These were decided based on the clients' priority and what would work better if featured as an upgrade or a core mechanic in the game. As an example, the manufacturer wanted to emphasize and educate players about their remote monitoring service 'Uptime'. Therefore, this offer was embedded into the game mechanics and made available in the upgrade system, along with information contained in splash screens and links to the real-life product.

Notably, it would be difficult and ineffective to feature every benefit of the DEAS offer as this could potentially present an information overload to the players/clients. Additionally, the small difference between some of the upgrades/perks would render them almost invisible as they would be too similar and would not provide any significant improvements to the player's progression.

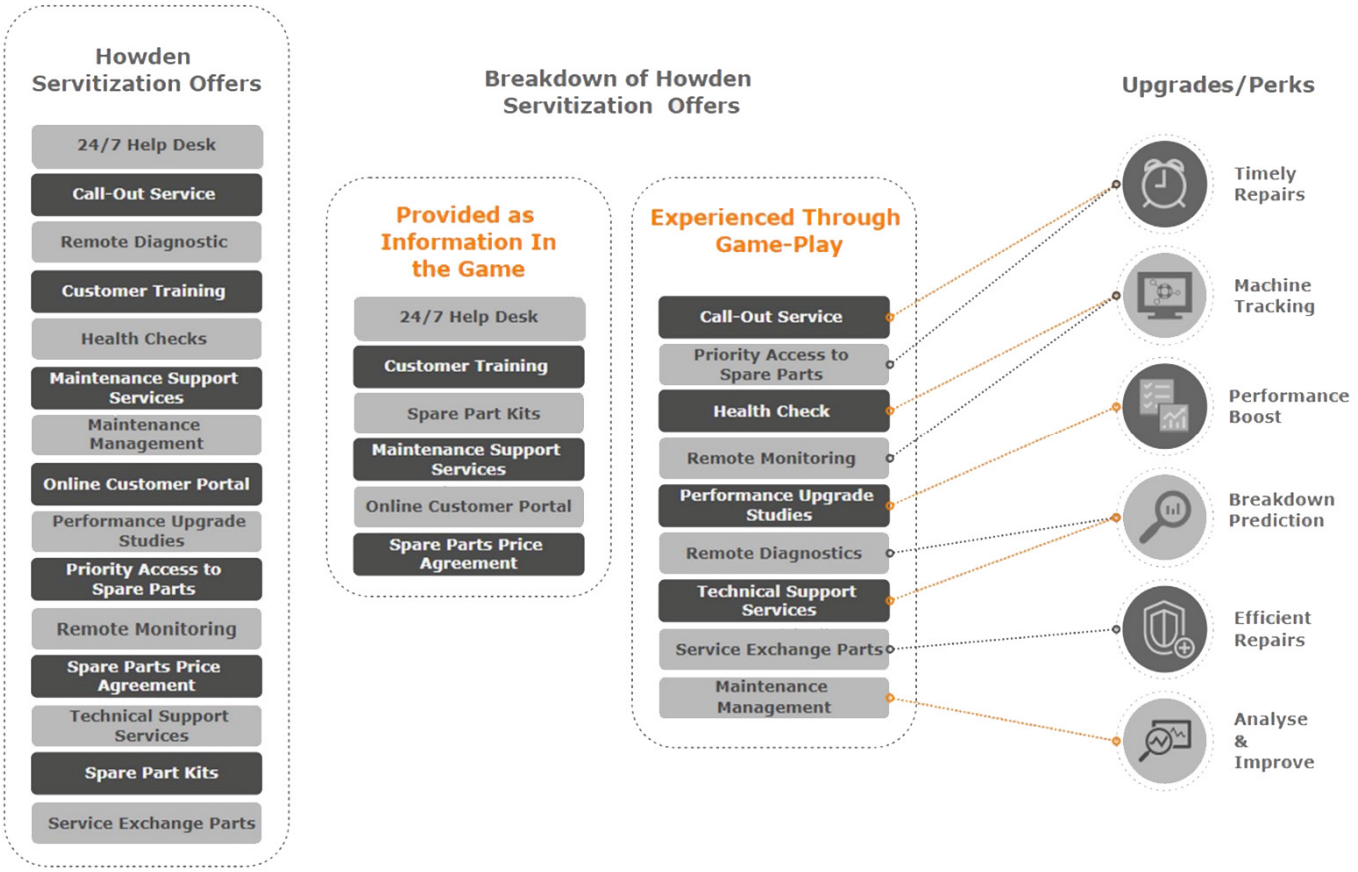


Figure 3. Alignment of Howdens DEAS offers with the Learning Outcome and Game Upgrades.

To keep the game from becoming too long and providing more elaborate detailed information than the player could remember, the number of upgrades was reduced to six. To create these key game upgrades, multiple services and benefits were combined.

A breakdown of the Howden services is shown in Figure 3, along with the formation of game perks. Several other benefits and services were decided to be provided as information during the game. These were incorporated into the narrative/story, offered as information splash screens at different parts of the level or presented in the user interface.

In addition to segmenting the servitization offer and simulating each section in gameplay, each of the main actions and goals that the player had to complete was assigned an educational value. Table 1 shows the mapping of six 'Game: Actions and Goals' with an intended 'Learning and Simulation' experience. This was conducted to tackle many of the challenges identified in the earlier phases of the project.

The simulation experience developed in this application fall under the Planning Simulations classification which presents to the user the selection and preparation of business plans with what-if models [50–54]. In this case, the business models appear in the form of servitization plans that could be experienced in real-time through the 3D gamification process. The various choices amongst the offered plans that the user can select present different benefits and a wealth of information in a simplified manner.

4.3.2. Information for the Player and the User Interface (UI)

The UI design provided timely information to guide and inform the user's progress through the game. This presented an opportunity for some upgrades to provide the player with helpful information, supporting the user to easily use the provided offers to maintain and manage the machines on the game. This upgrade enabled colour-coded arrows that point and guide the player to machines that needed immediate attention. Simulating the real-life counterpart, this upgrade reduces the guesswork in monitoring the machines. The

game ensures that there is a direct link to the manufacturer's Uptime service and power-ups supporting further the user's education.

Table 1. Mapping of Actions and Goals with a Learning and Simulation experience.

Game: Actions and Goals	Learning and Simulation
Players interact with machinery in the virtual world, to avoid breakdowns and reduce equipment downtime	Simulating a relatable experience for Howden's customer base
Players are rushed into a chaotic scenario and are instantly required to take control	Forces the player to learn and familiarise the controls and interactions of the game quickly
Player selects power-ups and upgrades at the end of each round to better their score	Player learns about the services, perks and benefits offered by the Howden servitization offer through simulated experience
Player has to complete each round before unlocking the next upgrade	Player learns through experience and highlights the practical use of the services offered without being overwhelmed with information
Player is expected to complete multiple rounds whilst making improvements based on the upgrades they have selected	Player experiences the benefits of using the DEAS offer which are directly mapped to the game's scoring system
Player is presented with information at key stages of the game with links and details on products/ services offered by Howden	Educate and link the player with Howden's servitization offer and correlate it to the in-game content

4.3.3. Control Consideration

To avoid alienating or creating difficulties for those that are less experienced with games, the game was designed with simple controls. Applying a 'Pick and Play' mantra enabled players to engage with the game avoiding a steep learning curve whilst playing the game. Despite attempting to pre-emptively account for the lack of gaming experience of some potential players during the initial design and development stage, playtesting demonstrated a visible difference in experience between users with different gaming familiarity levels.

Despite the simplification of the interactions and the game controls, playtesting highlighted issues with keyboard and mouse input. Unlike the mobile phone controls, some users that were playtesting the game on the PC/web version were not familiar with the keyboard controls. This resulted in some players not having the intended game experience by hindering their ability to progress and improve through the game. This was addressed in a later version of the game by having explicit keyboard prompts and adding an alternative set of keyboard keys to move the player's character. Figure 4 shows a screen capture taken on an android device running the Prototype Howden DEAS game, the control system is overlayed on the screen for android devices.

It was essential to make the players "see" progress rather than stating it to them in the game. To this end, the player was expected to play multiple rounds and levels in sequence and would find themselves becoming better at the game due to the upgrades they selected. This was designed to show the players, by engaging with the servitization offer, the uptime and effectiveness of their machines would be increased. This was directly mapped to the game's scoring system, where the player would be scored on the overall uptime percentage of their machines.

To assist with progression comparison, the player's uptime scores would be compared against the last round, most often showing how much they increased their uptime in the round they finished. Similarly, the player's uptime score for the round is displayed at the end of the game, often revealing a significant increase in the score when DEAS services are enabled.

Figure 4. Screen capture of the Prototype Howden DEAS game (Android device).

4.3.4. Gameplay Time and Early User Testing

Gameplay was kept simple and repetitive; a deliberate attempt was made to limit the time for each round to 1 min and 20 s. This time frame was decided after experimentation and user testing, to ensure the player did not become bored, frustrated or give up on the game without seeing benefits offered by the service agreement which are featured as upgrades. Furthermore, the player is required to play four rounds in total and unlock two upgrades after each round, prolonging each round would increase the chances of the player giving up or losing interest as some of our early user testings indicated.

The time of the rounds was selected as our user testing indicated this was sufficient time to become familiar with playing the level and see the benefits and perks of each of the upgrades after every round.

This also satisfied our diverse users/player requirements that required simple and fast gameplay. Initial user tests also highlighted keeping the same environment layout became very easy to remember and complete as well as making more aspects of the game repetitive. After each round, the environment layout changed to make the game more challenging and less repetitive as illustrated in Figure 5 below.

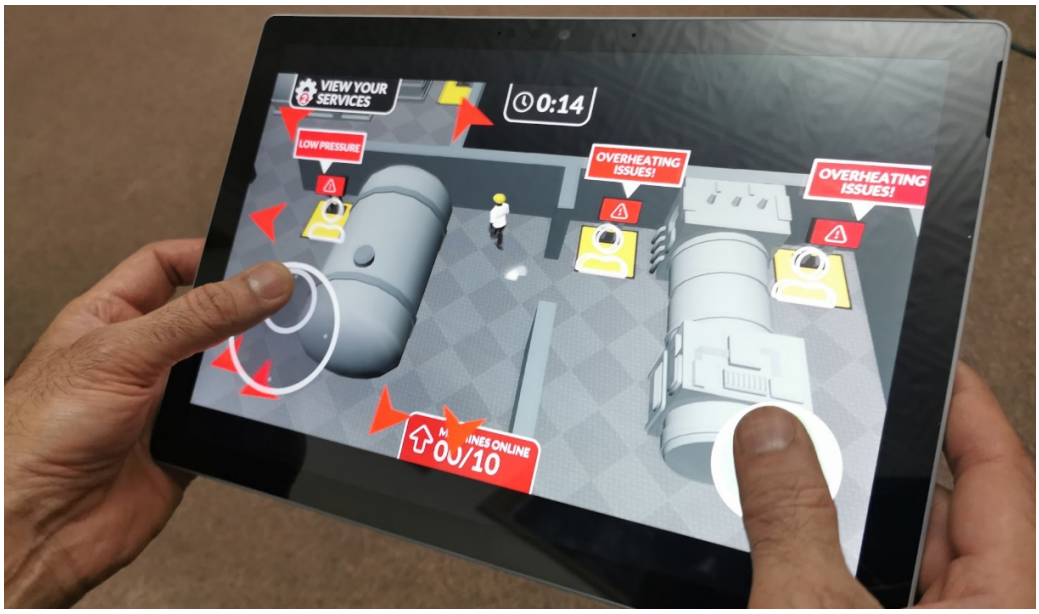


Figure 5. Screen capture of player racing against the clock to maintain the production.

5. Evaluation Method

Quantitative means were used to establish the effectiveness of the prototype game. The study included a total of 27 questions that were required to be completed after the participant had played the game. In addition to Likert scale questions, demographic questions, multiple-choice questions and open-ended questions were included in the questionnaire. The development of the questionnaire was based on previous studies that explored the use of emerging technologies and innovative solutions such as VR, 3D, Serious Games, Gamification, and Artificial Intelligence (AI) to convey complex information to particular groups of users [3,6,55]. The main categories of questions used are presented in Table 2 and described below:

- Demographic questions were used to collect the participants' background, experience with servitization and playing video games.
- Likert Scale questions were used to measure the participant's experience and learning whilst playing the game. The serious game concept, interactivity, user interface, controls and the embedded learning goals for Howden's servitization offer were all gauged with a 5-point Likert Scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree).
- Open-Ended Questions were used to collect further feedback about the user experience, identify issues and enable suggestions for improvements.
- Multiple choice questions measured the participants' understanding of the game's educational objective and their ability to recall what the servitization offer had to offer.

The types of questions aimed to acquire users' feedback on different aspects of the game mainly about the game concept (GC), user experience (UX), user interface (UI), and the embedded learning material (LM) are presented in Table 2.

Please note that this work will be presenting the objective findings of the statistical analysis carried out for the demographic, Likert scale and multiple-choice questions. Subjective findings (open-ended questions) will not be included as they are not measurable and were designed to extract additional information from the users and their suggestions.

Table 2. Breakdown and categorization of the questions asked during the study.

Category	Type		Questions
Demographic Questions		Q1	Are you familiar with the term DEAS (Digitally Enhanced Advanced Services)?
		Q2	Age
		Q3	Gender
		Q4	Which of the following categories best describes the industry you primarily work in (regardless of your actual position)?
		Q5	Which of the following best describes your role in the industry?
		Q6	How often do you play video games? (This can be on any platform: mobile phone, consoles and/or computers).
Likert scale Questions	UI	Q7	I found the prototype level easy to pick up and play.
	LM	Q8	The game concept was easy to understand and engaging.
	LM	Q9	Whilst playing the game I took my time to read and understand what the power-ups offered.
	UI	Q10	The character and controls were easy to navigate.
	UI	Q11	The interface, menu and icons supported navigation and gameplay.
	LM	Q12	The value of each power-up/perk is clearly explained.
	LM	Q19	I found a clear connection between the perks offered in the game and the benefits of Howden's long term service agreement and uptime service.
	UX	Q20	Although the information was provided, I did not read this as I just wanted to play the game.
	UX	Q23	I can clearly see the benefits of Howden's long term service agreement and Uptime service. (DEAS offer) from playing this prototype.
	GC	Q24	It was very evident that there was an educational aspect to this game.
	GC	Q25	I feel the educational material (Howden's DEAS offer) was well embedded in the game.

Table 2. *Cont.*

Category	Type		Questions
Open-Ended Questions	UX	Q13	What was your favourite moment or aspect of what you just played?
	UX	Q14	What was the most frustrating moment or aspect of what you just played?
	UX	Q15	Was there anything you wanted to do that you couldn't?
	UX	Q16	If you could change, add, or remove anything from the experience, what would it be?
	GC	Q17	How would you describe this game to your friends and family?
	LM	Q22	Any other comments related to the perks offered in the game and the benefits of Howden's long term service agreement.
	UX	Q26	Any other comments to help improve the educational aspect of the game.
Multiple-choice Questions	LM	Q18	What do you think was the key educational objective of the game?
	UI	Q21	Whilst playing the game did you click on the web link for the Howden's Uptime website?
	LM	Q27	Please select all the services that you remember and understand by playing this game.

5.1. Participants

The evaluation of the systems was performed by 30 participants which were selected randomly from a pool of engineers related to manufacturing or specialists in the servitization from both the manufacturer/provider (Howden Group) and their clients. The number of participants was largely defined by the pandemic issues and the limited availability of such specialised users. Nevertheless, multiple studies investigating the optimal number of users for usability trials, suggest that even a smaller number than 30 users offer par and valid results [56–58].

The game requirements did not specify an age group, so it was important to make the game digitally and universally accessible to a wide range of ages. To study how different age groups perceive the game, it was essential to seek participants across different age groups. The demographic analysis of the participants that took place in the study is presented in Table 3.

Table 3. Demographic analysis of the participants that took place in the study.

			Frequency	Percent	Valid Percent	Cumulative Percent
Participant Age	Valid	18–24	7	23.3	23.3	23.3
		25–34	9	30	30	53.3
		35–44	10	33.3	33.3	86.7
		45–54	3	10	10	96.7
		55–64	1	3.3	3.3	100
		Total	30	100	100	
Participant Background	Valid	Engineering	18	60	60	60
		Computer and Electronics	5	16.7	16.7	76.7
		Construction	1	3.3	3.3	80
		Health Care and Social Assistance	1	3.3	3.3	83.3
		Manufacturing	2	6.7	6.7	90
		Software	2	6.7	6.7	96.7
		Real Estate	1	3.3	3.3	100
		Total	30	100	100	
Participant Job Role	Valid	Student	7	23.3	23.3	23.3
		Trained Professional	5	16.7	16.7	40
		Junior Management	1	3.3	3.3	43.3
		Middle Management	3	10	10	53.3
		Upper Management	5	16.7	16.7	70
		Consultant	5	16.7	16.7	86.7
		Support Staff	2	6.7	6.7	93.3
		Researcher	1	3.3	3.3	96.7
		Other	1	3.3	3.3	100
		Total	30	100	100	

Table 3. *Cont.*

			Frequency	Percent	Valid Percent	Cumulative Percent
How often the participant plays Video Games	Valid	Daily	8	26.7	26.7	26.7
		Weekly	9	30	30	56.7
		Monthly	5	16.7	16.7	73.3
		Don't Play Games	8	26.7	26.7	100
		Total	30	100	100	

5.2. Hardware and Software Requirements

Unity 3D was used to develop the game, which in turn was customised for different platforms such as Android, Windows and WebGL platforms. Physical user testing utilized Samsung S8 phones for testing the Android version of the game, windows laptops and desktops were used to test windows and WebGL versions of the game. Google Forms was used to collect data, Windows Excel was used to process the data and IBM SPSS Statistics was used to carry out data analysis.

5.3. Evaluation Process

The focus group's initial evaluations were hosted at the Glasgow Caledonian University campus. The Howden staff were provided with devices with the pre-installed game as presented in Figure 6. Due to the pandemic restrictions, the following tests were performed online through a dedicated website and server that was providing the updated game versions and the relevant questionnaires for the collection of feedback. Similarly, the final evaluation was hosted in the same online environment. The participants were provided with a set of instructions to install the game on different operating systems and devices. The survey was designed to gauge if the prototype game was able to achieve its objective in communicating the DEAS offer to the player and the individual scores of the four main elements of interest, namely, game concept (GC), user experience (UX), user interface (UI), and the embedded learning material (LM) presented in Table 2. The above elements were the measurable outputs expressed through the qualitative data provided by the participants. A 5-point Likert Scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree) was used to collect their responses.

Figure 6. Participants from the Howden group playtesting the serious game.

6. Evaluation Results

In this study, a participant sample of 30 people was used to evaluate the game prototype. Among these respondents, 83.3% of them (n = 25) were male and 16.7% were female (n = 5). The sample included participants from varying age groups, amongst which ages 35–44 were the most common, making up 33.3% of the sample. A total of 82.7% of the participants had backgrounds in engineering, manufacturing, and computers and electronics.

The participants had varying experiences with playing video games: 26.7% did not play games at all, and 73.4% played games either daily, weekly or monthly. When gauging participants' familiarity with the term DEAS, the result showed that 63.3% of the participants had either heard about the concept or were very familiar with it, and the remaining 36.7% did not know about DEAS.

6.1. Liker Scale Results

Likert scale questions gained feedback to measure the participants' experience and learning whilst playing the game. The participant was asked about their experience playing the game. Statements related to the game concept, game interactivity, game user interface, game controls and the games embedded learning goals for servitization offer were provided. Figure 7 shows all the responses to the Likert scale questions.

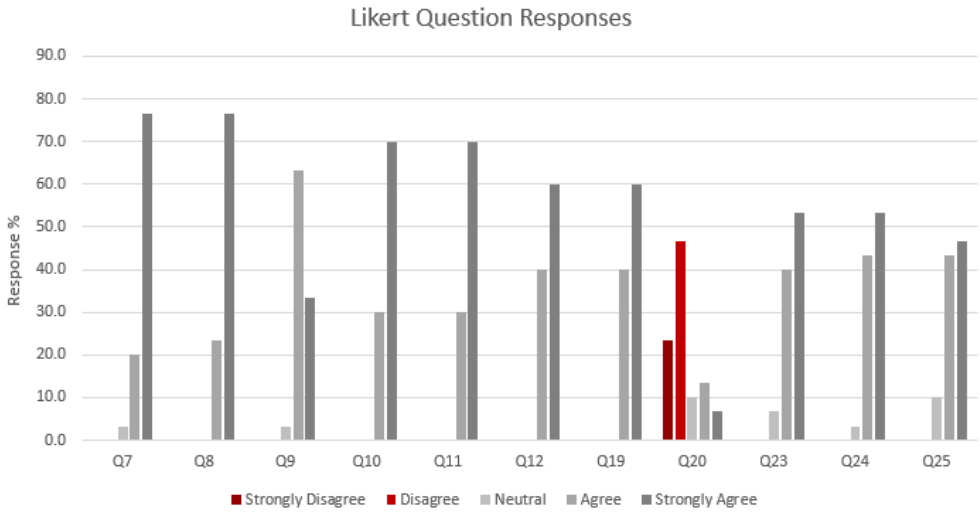


Figure 7. Likert scale results.

All Likert scale questions presented positive results, with 96.7% of participants finding the game easy to pick up and play (Question 7) and 100% feeling the game concept was easy to understand and engaging (Question 8). Furthermore, 96.7% of participants engaged with gameplay and learning content by taking their time to read and understand what the power-ups offered in-game (Question 9). Results showed 100% of the participants felt the value of each power-up/perk was clearly explained and there was a clear connection between the perks offered in the game and the benefits of Howden's long term service agreement and uptime service (Questions 12 and 19).

Results for Questions 10 and 11 showed 100% of the participants found the game controls easy to navigate and felt the interface, menu and icons supported navigation and gameplay. The result showed that 70% of participants disagreed or strongly disagreed with the statement in Question 20.

However, this was a positive outcome as this was a negatively worded statement ('Although the information was provided, I did not read this as I just wanted to play the game') with 'strongly disagree' or 'disagree' being the desired outcome. Additionally, 93.3% of participants felt they could see the benefits of Howden's long term service agreement and Uptime service (DEAS offer) from playing this prototype game (Question 23). A further 96.7% felt that it was very evident that there was an educational aspect to this game

(Question 24) and 90% felt that the educational material was well embedded in the game (Question 25).

Notably, an average of 95% of responses across all the 11 Likert scale questions were in the favor of the game and its usability.

6.1.1. Reliability Test

The value of the mean indicates agree and strongly agree in all questions apart from question 20, where the values showed strongly disagree and disagree. The values of the standard deviation (+/− mean) varied between (0.430–1.184). Cronbach's alpha was used to assess the internal consistency, of the Likert scale questions [56]. Cronbach's alpha is a measure of scale reliability, it measures internal consistency by determining the correlation of items (Likert scale questions) as a group. The results of the test are shown in Table 4.

Table 4. Shows Reliability Statistics and the Item Total Statistics.

Reliability Statistics					
Cronbach's Alpha		**Cronbach's Alpha Based on Standardized Items**			***n* of Items**
0.81		**0.837**			**11**
Item-Total Statistics					
	Scale Mean If Item Deleted	**Scale Variance If Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach's Alpha If Item Deleted**
Q7	44.67	13.747	0.542	0.625	0.790
Q8	44.63	14.171	0.542	0.604	0.793
Q9	45.10	14.231	0.395	0.556	0.802
Q10	44.70	14.976	0.254	0.419	0.812
Q11	44.70	14.355	0.435	0.552	0.799
Q12	44.80	14.441	0.375	0.435	0.804
Q19	44.80	13.338	0.694	0.545	0.778
Q20	45.73	11.444	0.407	0.651	0.835
Q23	44.93	12.754	0.659	0.599	0.776
Q24	44.90	12.990	0.677	0.768	0.776
Q25	45.03	12.792	0.600	0.789	0.781

To avoid inverse coded items loading negatively on the principal components, Question 20 was reverse coded. Cronbach's alpha is considered to determine if multiple-item measures/values of a concept are internally consistent. The derived data can be confirmed when the Cronbach alpha value exceeds 60% (0.6).

Reliability analysis of the internal reliability of the scale yielded a very good Cronbach alpha of a = 0.81. As seen Item-Total Statistics (Table 4), if an item is deleted, the Cronbach alpha could vary between 0.776–0.835.

6.1.2. Correlation Test

A nonparametric Spearman correlation test was carried out to determine the linear relationship between the Likert scale questions. The correlation test was carried out between different indices and found highly statistically significant at the 0.001 level and 0.005 levels. The result showed a moderate to strong correlation between variables of question 7 with variables of questions 8, 11, 19, and 23.

The value of coefficient *Rs* ranged from 0.518–0.637. Question 8 showed a moderate to strong correlation with questions 7, 11, 19, and 23, with the value of coefficient *Rs* ranging from 0.504–0.637. Question 9 showed a strong correlation with only Question 20, with the value of coefficient *Rs* at 0.657. Question 10 showed a strong correlation with question 20,

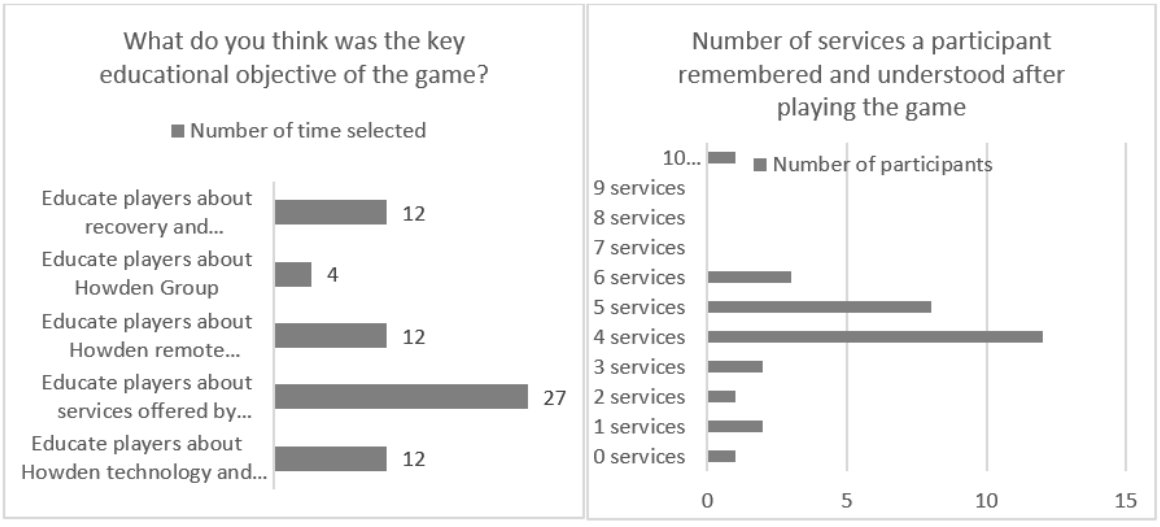
with a value of coefficient *Rs* of 0.524. Question 11 showed a moderate to strong correlation with questions 7, 8, and 10, with the value of coefficient *Rs* ranging from 0.499 −0.524. Question 19 showed a moderate to strong correlation with questions 7, 8, 23, 24 and 25, with the value of coefficient *Rs* ranging from 0.515–0.621. Question 23 showed a moderate to strong correlation with questions 7, 8, 11, 19 and 25, with the value of coefficient *Rs* ranging from 0.465–0.621. Question 24 showed a strong to very strong correlation with questions 19 and 25, with the value of coefficient *Rs* ranging from 0.547–0.844. Question 25 showed a moderate to very strong correlation with questions 19, 23 and 24, with the value of coefficient *Rs* ranging from 0.548–0.844.

A correlation test was also carried out for age (Question 2) and gaming experience (Question 6) with responses to all the Likert scale questions. The result showed age and gaming experience had no correlation with any of the variables for the Likert scale questions nor with each other.

Reliability analysis of the internal reliability of the Likert scale questions yielded a valid Cronbach alpha of a = 0.81 thus confirming this Likert scale method reliable for evaluation. The result also indicated that if question 20 was not included in the reliability test, the Cronbach alpha would increase to a = 0.835. Notably, Question 20, "Although the information was provided, I did not read this as I just wanted to play the game", was a negatively worded statement; however, 70% of participants selected the favourable outcome for this question. This was the only question that had a positive response below 90%. Potentially, if this question was positively worded it may have yielded a better overall Cronbach alpha result.

6.2. Multiple Choice Results

Question 18 (What do you think was the key educational objective of the game?) allowed participants to select more than one option for their response (Figure 8a) A total of 67 selections were made averaging a minimum of two selections per participant. Results showed that 90% of the participants selected 'Educate players about services offered by Howden and the multiple benefits of the long-term service agreement' as one of their responses. Furthermore, results presented 40% of the participants either selected '1. Educate players about Howden technology and machinery; 2. Educate players about Howden remote monitoring tools; or 3. Educate players about recovery and maintenance of specific machinery'; as one of their responses. Only 13.3% selected 'Educate players about recovery and maintenance of specific machinery' as one of their responses.



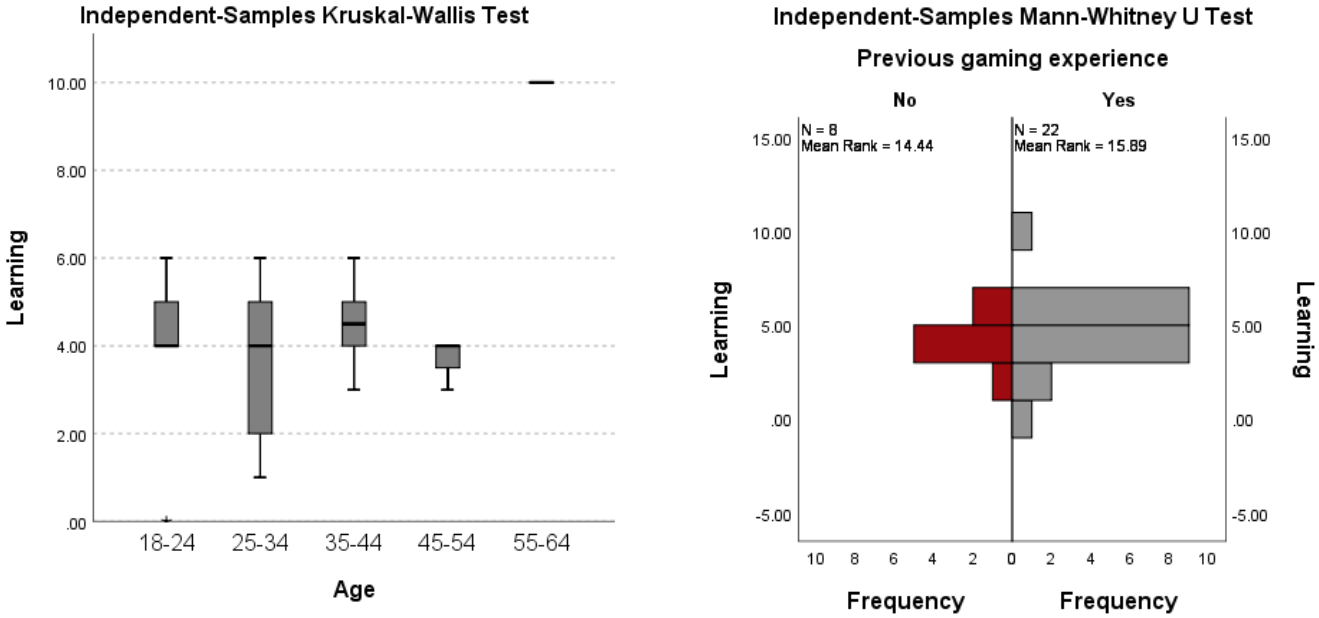
(**a**) (**b**)

Figure 8. (**a**) Participant response on what they thought were the key educational objective of the game (**b**) a count of the number of services a participant remembered and understood after playing the game.

Question 27 asked the participant to select all the services that they understood and remembered after playing the game. They were provided with 10 services that they could choose from and were able to select as many as they remembered and understood. All these services (24/7 help desk, Customer stock management, Health checks for Products, Howden Interactive Virtual Engineer (HIVE), Call-out service, Maintenance management, Performance upgrade studies, Priority access to spare parts, Remote monitoring and Spare parts price agreement) were featured in the game.

Figure 8b shows a tally of the number of services a participant remembered and understood after playing the game. The result showed 80%of the participants understood and remembered four or more services after playing the game. Participants were most commonly able to remember either four (40%) or five services (26.6%).

Independent-Samples Kruskal–Wallis Test is a nonparametric test that shows whether two or more independent variables are statistically different on an ordinal or continuous dependent variable [59,60]. An independent sample Kruskal–Wallis test was carried out to see if the distribution of overall participants learning after playing the game was the same across categories of age and gaming experience (Figure 9a). The significance level was 0.677 (previous gaming experience) and 0.259 (Age).



(**a**) (**b**)

Figure 9. (**a**) Independent samples Kruskal–Wallis Test to determine if the distribution of overall participants learning after playing the game was the same across categories of age; (**b**) Mann–Whitney U Test to determine if participants' learning differed based on participants' previous gaming experience.

In both cases, the significance level did not exceed 0.050; therefore, the null hypothesis was retained. Mann–Whitney U Test [61] was also carried out to understand whether the participants' learning differed based on participants' previous gaming experience (Figure 9b). The result showed that the significance level was 0.677, which did not exceed 0.050; therefore, the null hypothesis was retained.

Further analysis on which services were selected most showed that 83.3% of the participant selected 'Maintenance management service' as one of the services they remembered and understood. Furthermore, 73.3% selected 'Remote monitoring service', 70% selected 'Performance upgrade studies service', 66.6% selected 'Health checks for Products service' as one of the services they remembered and understood.

The 'Priority access to spare part service' was selected by 33.3%, both 'Howden Interactive Virtual Engineer (HIVE) service' and '24/7 help desk service' were selected

by 26.6% and the 'Call-out service' was selected by 20%. The least selected services were 'Customer stock management service' and 'Spare parts price agreement service', both were selected by 10% of participants.

The results for Question 21 (Whilst playing the game did you click on the web link for the Howden's Uptime website?) showed 53.3% of the participants had visited the Howdens website whilst playing the prototype game.

7. Discussion, Limitations and Future Work

7.1. Discussion

Previous studies presented in Section 2, showed that the majority of computer game-based learning and servitization has predominately been in the area of gamification rather than serious games. Furthermore, the theoretical models presented in these previous studies had not been tested or used to develop a real-life application similar to the proposed one [29,34,35]. In particular, these studies, have focused on conveying an overview of the servitization concept, rather than educating the potential clients/users about the specific advantages of advanced servitization offers. Only a single study had attempted to develop a game application, aiming to present a specific servitization offer [44]. Both the offer and the business in that study, however, were fictional and aimed purely to illustrate servitization in action and not related to real manufacturing and servitization requirements.

In contrast, the proposed work developed a theoretical model for a servitization based game, but it also further established a workflow to design, develop, implement and user test the serious game for a real company (Howden) and a real servitization offer.

Similarly to previous studies, this research also had concerns with participants' age and gaming experience concerning usability and engagement with the game [30,43,48].

The capture and brainstorming phases of the project highlighted the potential user group for this game may have varying ages and gaming experiences. Based on the above, it was hypothesized that elder participants or participants that do not play games, may not engage with the game or have a negative experience playing the game. However, the results from this study showed that neither age nor previous gaming experience correlated with LM, UX and UI. More specifically the results of the Likert scale questions (Questions Q7–Q9, Q12–Q23) that gauged the participants' user UX and LM showed that age (Q2) or previous gaming experience (Q6) did not impact the participants' responses. Contrary to our hypothesis, all participants engaged with the game and had a positive experience playing the game.

Presumed causative reasons for this favourable outcome can be attributed to the design considerations employed. Specifically, early and continuous engagement with the potential end-users in the "capture" phase of the project to identify and establish key considerations and requirements, namely: simplicity in gameplay; fun, engaging and educational gameplay; and game play, demonstrates the offer in action.

A second positive contributing factor was the specialist mapping of the 'Game actions and goals' with the intended 'Learning and Simulation' experience (Table 1). The mapping process incorporated the users' age and prior gaming experience in the formation of the final product thus likely positively affecting the final outcome.

As mentioned in the Results section, the Likert scale results showed 100% of the participants found the game concept easy to understand and engaging. Furthermore, 90% of the participants understood that the game's main objective was to educate players about services offered by the manufacturer and the multiple benefits of the service agreement. These results present a positive, it can be proposed that the game was successful in creating the optimal playing and learning experience (OPLE) for the end-users. The balance between enjoyment and educational gameplay remained essential in creating the OPLE. If the balance is not maintained, there is a risk of offering/focusing more on the enjoyment aspect, which can detach players from the learning experience. In contrast, focusing mainly on the learning experience, could reduce drastically the enjoyment factor and result in monotonous gameplay that could disenchant the player and abandon the game overall. The

proposed work balanced this in the game development phase of the project by employing an iterative game design methodology. This allowed the prototype game to be developed in incremental phases which enabled constant improvement and necessary changes. This was achieved by gathering feedback from numerous playtests throughout the development of the game to make the necessary adjustments to balance the game.

The majority of the participants were able to remember and understand approximately 5 services after playing the game from the total of ten services included in the gameplay. The top two choices were 'Maintenance management service (83.3%)' and 'Remote monitoring service (73.3%). This could be associated with important considerations made during the design of the game. One of the key themes of the servitization offer is "maintenance" which was the strategic objective of in-gameplay which was embedded in the learning experience. Discussing this further, the manufacturer was keen to emphasize the functionalities of the remote monitoring service, 'Uptime' whilst educating the users about the whole spectrum of these services. Therefore, this service was prioritized and in-game, the content was developed to educate players specifically about the remote monitoring service.

7.2. Limitations

Limitations imposed by the worldwide pandemic restricted physical interaction with the game which impacted the user testing phase of the project. The introduction of lockdown resulted in multiple disruptions in both the manufacturer's and the University's activities that lead to only remote user testing. Adapting the development process to fully remote mode and transferring all the activities online further impacted the expected delivery time of the final version of the application and the evaluation period. Limitations related to the complexity of installation and the game's availability on certain platforms also impacted participant engagement. This resulted in 30 participants taking part in this study. However, this forced the development of a multiplatform approach that could be utilized in the future to expand the users' sample for a number of evaluation purposes as described in the section below.

7.3. Future Work

The study presented an initial appraisal of the effect that serious games could have in the explanation of complex ideas, scenarios, offers and manuals amongst others, to a non-specialist audience. In this case, the DEAS offers of a major manufacturer were embedded in the game-play to achieve the aforementioned objectives. Although the results were promising, a larger users' sample could offer better granularity of the results, and additional information related to the specific users' UX and UI preferences. The latter could further enhance the game's efficiency in explaining these types of DEAS offers and other complex concepts.

In addition, the future game versions could offer a large variety of scenarios for different industry demands enabling in-game Artificial Intelligence (AI) agents to challenge the different users depending on their level of performance [62–64]. To this end, the investigation of deep learning techniques to analyze users' reactions in real-time (i.e., facial emotion recognition) in response to altering the game complexity, could provide additional information related to users' behaviour and acceptability of this technology.

In the evaluation process, the development of a customised Technology Acceptance Model (TAM) could present valuable information regarding users' acceptance of new technology based on the user's feedback. TAM's are used to measure customers'/users' attitudes towards a new technology by measuring the 'Perceived Usefulness' and 'Perceived Ease of Use' [65–67]. The aforementioned model could enable the acquisition of detailed and measurable feedback from the manufacturer's employees highlighting the use of such methods for explaining complex offers and ideas to clients, supporting in this way in-depth Human Resources Management research [68,69].

Another element for future work is the improvement of the accessibility to the application with the expansion to other platforms (i.e., IOS, Web, Android, and Windows). This

provision could enable the game to be easily accessible, simplify any future user trials and may result in much more engagement from the participants.

Finally, the transition of such game environments and their AI activities could be introduced to virtual reality (VR) manufacturing environments hosted in the metaverse, offering both detailed visual information and functionality [70,71].

8. Conclusions

This paper presented a study that employed a serious game model over gamification, to convey complex concepts and deals of servitization based on real-life DEAS offers provided by Howdens Group industries. The game was designed to offer a unique play experience to the potential clients centered on a specific DEAS offer. For the evaluation purpose, 30 volunteer users comprising the manufacturer's employees and customers participated in an online evaluation of the proposed serious game. During the evaluation, the players were challenged with random malfunctions of their equipment, forcing them to select appropriate DEAS solutions and quickly learn the value of these offers in an intense virtual environment. The maintenance of their equipment's functionality and the constant production flow was visibly affected by their choices. Their playtime choices and movements within the game environment as well as their subjective feedback were recorded and analysed through quantitative means to establish the effectiveness of the prototype game.

The evaluation results highlighted the users' preference towards the proposed approach for dissemination of information through a game environment. Their subjective feedback offered encouraging suggestions and commendations for the game's further development and evolution to a more advanced and complete system. As stated above, the future tentative plan of work will entail the incorporation of AI for improved scenarios' complexity, adaptability in real-time, an extension of the user group to employees and overall expansion of the user sample for enriched data acquisition and analysis results.

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