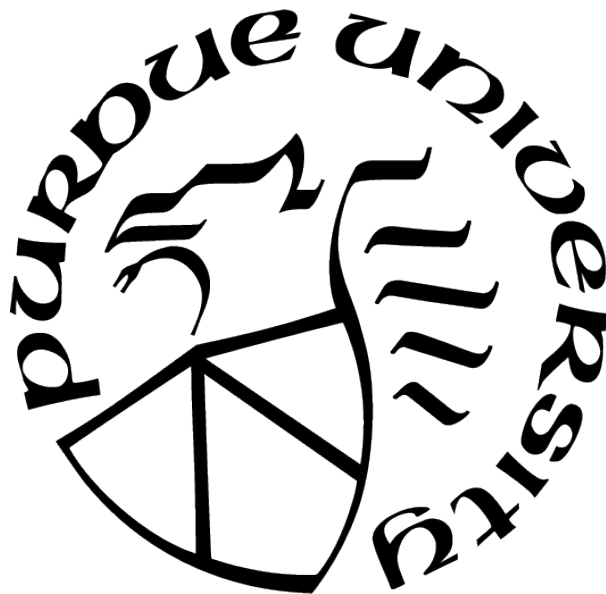# NURSING PROS: A SERIOUS GAME TO MASTER NURSING PROCEDURE SKILLS

by

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To my parents

ACKNOWLEDGMENTS

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ABBREVIATIONS

CP   Control Panel

GUI   Graphic User Interface

IRB   Institutional Review Board

PPE   Personal Protective Equipment

UI   User Interface

VG   Video Game

ABSTRACT

Procedure skill competency is a crucial element in nursing education. However, there are several barriers to skill competency and proficiency, which include limited simulation faculty, lab time, and resources. Serious gaming has proven to be an effective approach to enhance knowledge attainment, promote problem-based active learning, and encourage critical thinking in many industries, including nursing. Therefore, we proposed a virtual serious game featured with a realistic environment, considerable interaction and animation, user-friendly graphic interface, and an innovative evaluation system for nursing education. This game was deigned to complement traditional pedagogical methods in attaining nursing procedure skills competency. This game provides a supplemental learning methodology for undergraduate nursing students, enabling them to practice the skills on their own time in a safe and innovative environment. Incorporating a serious game into undergraduate nursing education can circumvent the problems of scheduling, individualized instruction, physical requirements of facilities, equipment, and supplies, and geography constraints.

1. INTRODUCTION

1.1 Background and Motivation

Healthcare professionals are required to follow standard procedures when providing patient care. Failure to follow standardized processes and protocols can led to serious adverse events and patient harm. Therefore, to ensure the safety of patients, professionals must learn the standard procedure and develop muscle memory prior to performing the skill on live patients. Traditionally, nursing students were taught procedure skills in class and were required to demonstrate theoretical competency in the simulation laboratory. Due to limitation of lab hours, deficiency of equipment, decline in nurse educators, and financial implications, the opportunity for students to practice the standard procedures has been restricted [1][2]. Additionally, faculty face challenges of large class sizes, space constraints, and limited manikins affecting the value of the instruction provided and student retention. Therefore, students are not able to receive adequate feedback and assistance to be competent in skills. Recent research in the healthcare field [3][4] have demonstrated that traditional methods of learning are inadequate in developing competency and proficiency. The development of procedure skill competency is twofold, the student's ability to memorize sequential steps and developing muscle memory. However, the limited availability of the simulation lab is a barrier to the development of muscle memory. A safe and efficient supplementary tool for practicing procedure and problem solving skills for nursing students is needed.

Researchers have found the use of an interactive skill development based video game as a promising teaching methodology in improving standard procedure skills [5]. Interactive games with sufficient complexity and playability have shown to efficiently improve skills among nursing students as compared to the traditional teaching methods [5]. Moreover, the interactive environment provided in the game helps enhance the retention of knowledge, increase student engagement in learning, promote problem based active learning, and encourage critical thinking [6]. In particular, serious gaming can provide a method for students to memorize skills steps prior to practicing in the simulation lab. The memorization of the steps during gaming can optimize time in the simulation lab. Additionally, a recent survey by researchers in the field, show that many of the nursing students were supportive and had

a positive attitude towards the use of new media technologies as a complement to traditional nursing education [7]. There are a multitude of supplemental tools currently available that are presented as 3D book-based tutorials, however, they lack intractable objects and corresponding feedback that provides a vivid impression for memory retention and enough stimulation for critical thinking [6]. Nurses must incorporate critical thinking skills into the performance of a procedural skill for patient safety, therefore memorization alone does not promote skill mastery. The incorporation of critical thinking increases the educational value. The inclusion of critical thinking also allows for the ability to customize the experience based on the student's ability and skill set. The interactive environment should reflect real world environment to assist students in smooth transitioning from training to real life practicing. Maintaining a domain as close to a real experience as possible provides engaging, immersive, and authentic context of learning as compared to traditional virtual environment.

With this motivation, we designed a 3D virtual hospital environment by simulating the real counterpart with multiple interactive models, adding real-world pictures, incorporating tutorial videos, designing a user-friendly graphical interface, and including an evaluation system. This 3D design allows nursing students to practice standard procedure skills interactively with the virtual objects. The design helps students improve their procedure skills through simulating the procedure of `Insertion of Nasogastric Tube`, allowing the user to practice the procedure step by step in a third person perspective, and practicing corresponding behaviors such as checking of patient's wrist band, raising bed, placing supplies, and updating score and report. The game is designed for single user and is Windows based.

1.2 Related Work

According to the research [8], currently healthcare is experiencing a nursing shortage exacerbated by a nursing faculty shortage and increasing workloads for faculty. One solution to these challenges would be the use of simulation tools and distance education. Serious gaming has been confirmed to be a more effective and less expensive training technology for health related education and many researchers have been focusing on this area of research through design and implementation of such games [9]. Researchers have designed video based scenarios with real chronic obstructive pulmonary disease (COPD) patients and a

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registered nurse as an actor to build a game in order to aid nursing students learn clinical reasoning and decision-making skills [10]. The reviews on such games included comments of being useful, usable, and satisfying from the end users. In addition, games like *Doc and the MACHINE*, provided real-time assessment and feedback in cultural competence training. It also provided the learners with answers to specific questions or problems [11]. Games proposed in [12], simulated different scenarios that usually happen in emergency rooms to familiarize students with emergency rooms atmosphere. Similarly, according to the researchers in [13], *PHARMACOMM*, an interactive tool for pharmacy education, updates the medications as response to interaction with patients.

Although there are already many serious games designed for nursing education in the market, most games only cover one or two aspects of the core competencies (specific procedural, health assessment or communication skills) [14]. Therefore, there is a need for more educational games focusing on the mastery of fundamental skills, tasks, activities and operations to match the desired learning outcomes. [14][15]. In this paper, we describe a new serious game which combines 3D models and real world live videos and images to make the environment look more realistic. In addition, the game consists of a user friendly graphical interface to drive the story and help students retain knowledge. It features interactions and animations to stimulate engagement, active learning, and critical thinking. Moreover, the proposed game incorporates the user's performance and assesses the student's progress. This enables students evaluate their performance in real-time and increase critical thinking skills.

1.3 Thesis Outline

The thesis is structured as follows:

- Chapter 2 discussed the methodology used to implement the game including 3D modeling tool and game engine, and introduced the software design of the game framework.

- Chapter 3 presented the overall virtual hospital environment designed for the proposed serious game framework.

- Chapter 4 introduced the features implemented for the game from different aspects and the general game mechanism designed for evaluating practice performance.

- Chapter 5 elaborated the preliminary test conducted for the game with analysis to the result.

- Chapter 6 concluded the proposed game framework, analysed the limitation, and pictured potential future work direction.

2. METHODOLOGY

Serious gaming enhances patient safety, standardizes training, lowers cost, increases accessibility, and can be adjusted to meet specific learning objectives [16]. However, if students do not engage and partake in the serious game objective to learn new skills, it will not be effective [17]. Therefore, like general video games, it has to be made engaging in order to encourage its usage and to increase memory retention through practical learning. To achieve aforementioned goals, the game design should involve different factors such as backstory, realism, adaptability, interaction, and feedback [18]. The proposed game begins with a backstory to provide a setting and guide the user through the game. In order to provide a realistic setting for the game we designed a 3D hospital environment that replicated a real hospital environment, detailed virtual environment design would be presented in Chapter 3. Further, in order to make the game playable, we incorporated interactions and animations to 3D models such as computer, supply closet, multifunctional hospital bed and many more. Moreover, a novel game mechanism was created to address wrong step selection by the user. Finally, we implemented a real-time score and report system to evaluate user's performance and to give feedback. More detailed implementation would be presented in Chapter 4.

To achieve such development of 3D virtual hospital environment and game features, 3D modeling tool and 3D game engine is required, 3ds Max and Unity 3D was selected to accomplish these tasks, the detailed reasons of choosing these two tools are discussed in this chapter.

2.1 3ds Max Modeling Tool

3ds Max, formerly known as a 3D studio and 3D studio Max, is a 3D professional modeling, animation, and rendering application build for making 3D animations, models, interactive games, visual effects for the entertainment industry [19]. It has strong rendering abilities, users can view the rendering results without actually rendering the scene, which saves the time of the user to do extra work. For networking with other tools, it not only works and blends greatly with other Autodesk products, but also have better format support for Unity 3D game engine [20]. Although it's not easy for beginner to work with 3ds Max,

the clear and user-friendly interface, workspaces, tools, and commands make the learning process quiet effortless for simple modeling task.

The proposed game framework is designed to use third person perspective view to lead user throughout the game, and third person perspective needs a model of a character that would require the modeling tool to be able to handle character modeling. 3ds Max includes simulations for hair, skin, fur, and cloth, these built-in tools reduce the time spending on modeling and enhance the detailing of character modeling. Moreover, the plugins functionality in 3ds Max boosts it's feature and allows user to use render program like V-ray with great ease and without any lagging [19], which is helpful in editing models used in this game.

In addition, students and educators can get free one-year educational access to Autodesk products and services after verification [21], which makes it a better tool for student use. With all the benefits it can bring for the implementation, and the basic knowledge of using 3ds Max, 3ds Max was chosen to be the modeling tool of this project.

2.2 Unity 3D Game Engine

Unity is an intuitive cross platform mobile game development engine that offers a vast array of features for both 2D and 3D game development, and is the registered trademark of Unity Technologies [22]. According to article [23], among the top 5 game engines: Unreal Engine [24], Unity [22], Corona SDK [25], Lumberyard [26], and Cocos2D-x [27], Unity is one of the best engines for cross-platform 3D mobile game development. It has strong capabilities for building high quality cross platform video game [28]. Following are the features Unity can provide for game developing:

- High Quality & Efficiency: Unity had been marked as best app for game development in case of visual platform due to it's effectiveness while rendering 2D and 3D scenes, and the high rendering quality offered compared to other products [28].

- Cross Platform: Unity supports 25+ platform and technology, as shown in Figure. 2.1, it can easily transform game to run on multi-platform with online and offline modes on Windows, Mac, Linux, mobile, and other platforms [29].

Figure 2.1. Unity supported platforms and technologies

- Support variety format model importing: Unity supports models in FBX, SBX and OBJ formats, and assets from major 3D applications like 3ds Max, Maya, Softimage, CINEMA 4D, Blender etc. [23].

- Assets Store: Unity has built in assets store that contains vast amount of assets, user can easily find useful assets for creating virtual environment and implementing game features.

- Easy to use: Unity 3D is easy to use and has shorter rendering duration which makes it most suite for game developers [30].

- Free Personal Edition: Despite not being open source, Unity provides free Personal Edition which includes most common features that already met the requirement of our project, which makes Unity the best choice for building multi-platform 3D virtual serious game.

The proposed game requires the game engine to have great support for 3D virtual environment, graphic user interface, multiple format material, interaction, and animation. As mentioned above, Unity 3D can not only support these features but also provide extra benefits like getting existed models from assets store instead of creating from scratch, and saving time from it's efficient rendering performance. With all the advantages Unity 3D compared to other products, Unity 3D was chosen to be the game engine of the proposed game.

Apart from the game engine, choosing the preferable programming language is also important for game developing. Unity 3D currently supports 2 programming language: `C#` and `Javascript` (Used to support `Boo` until it was dropped in 2014). `C#` is one of the most popular programming languages which is used to create games in the Unity game engine and Unity has chosen `C#` instead of Javascript to move forward because of its learning curve and its history with Microsoft. In addition, `C#` is easier to learn than languages like `C++`, the accessibility is a huge draw for game designers and programmers in general, with Xamarin mobile development and ASP.NET web applications in the mix, `C#` language is the best choice for Unity 3D game developing [31]. With the huge advantage `C#` can bring to Unity 3D game development and the fact that the learning time of `C#` is significantly less than `Javascript` in our case, it has been chosen to be the programming language for this game development.

2.3 Software Design of Game Framework

This serious game was designed for undergraduate nursing students for practicing procedure skills. In order to make the serious game extendable for developing similar programs, this game was designed based on a general framework. The framework provided the key elements of 3D virtual hospital environment, control over the avatar, interaction and animation with virtual objects, flexible virtual scene transition, and the procedure evaluation system. To make this game reusable and easy to extend and maintain, the framework's function was categorized into several modules. In this section, we will discuss the details of the general software design of the framework.

2.3.1 Use case of the overall framework

This serious game provides three basic use cases as shown in Figure. 2.2, user can choose to start practice, watch tutorial video or exit the game. When the practice starts, user has the control over the player avatar to navigate the 3D hospital environment, interacts with objects that featured of interaction and animation. When the procedure is executed, the underlying evaluation system will analyse user's performance by validating the order

of the procedure executed and by activating learning panel to evaluate user's knowledge attainment.
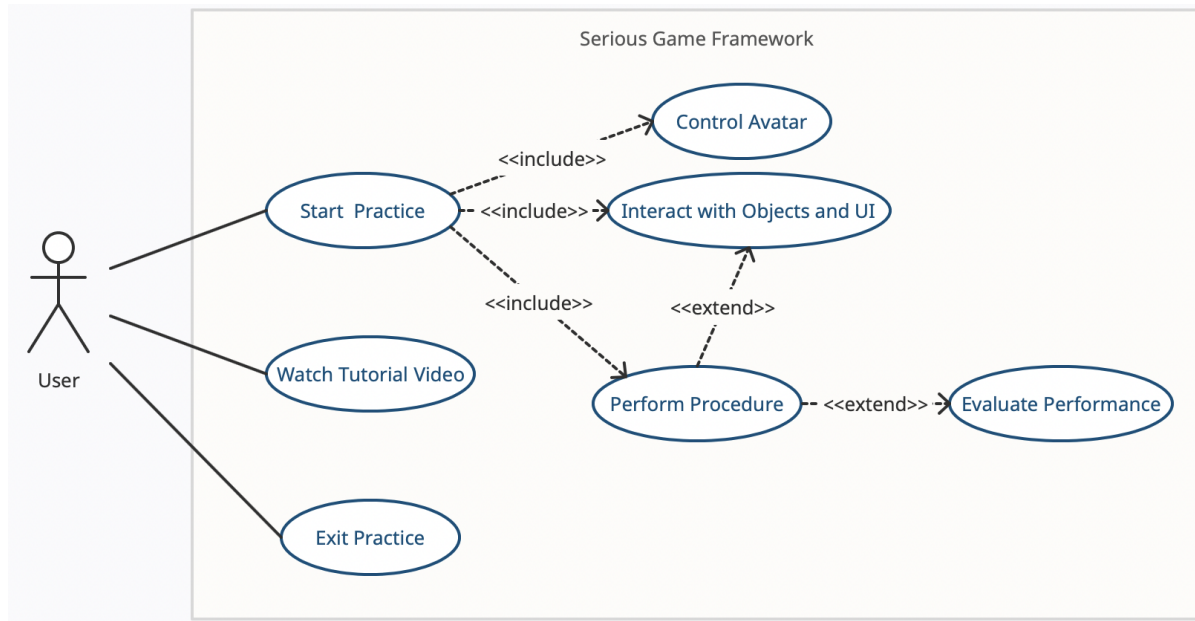
Figure 2.2. Use case diagram of the serious game framework

The use case of `Control Avatar` is to monitor keyboard and mouse input and drive the player avatar to navigate and provide adjustable view point on the basis of third person perspective. The use case of `Interact with Objects and UI` handles the events of interaction and animation triggered by user's interaction with objects and procedures execution. During the interaction, feedback provided to end user includes real-time practice performance, backstory convey and helpful instruction, multiple learning panels. The use case of `Perform Procedure` executes every procedure the user activates, connects to the `Evaluation Performance` use case, determines if the executed procedure is valid to proceed, give feedback based on the validation, triggers interaction, animation or learning panels, updates the report, and/or initiates the practice progress.

2.3.2 Class diagram for general game design

Figure. 2.3 shows the general class diagram for the whole game design. It was designed to have one data type `NERcord` to hold information for different procedures, a `CameraDragVertical`
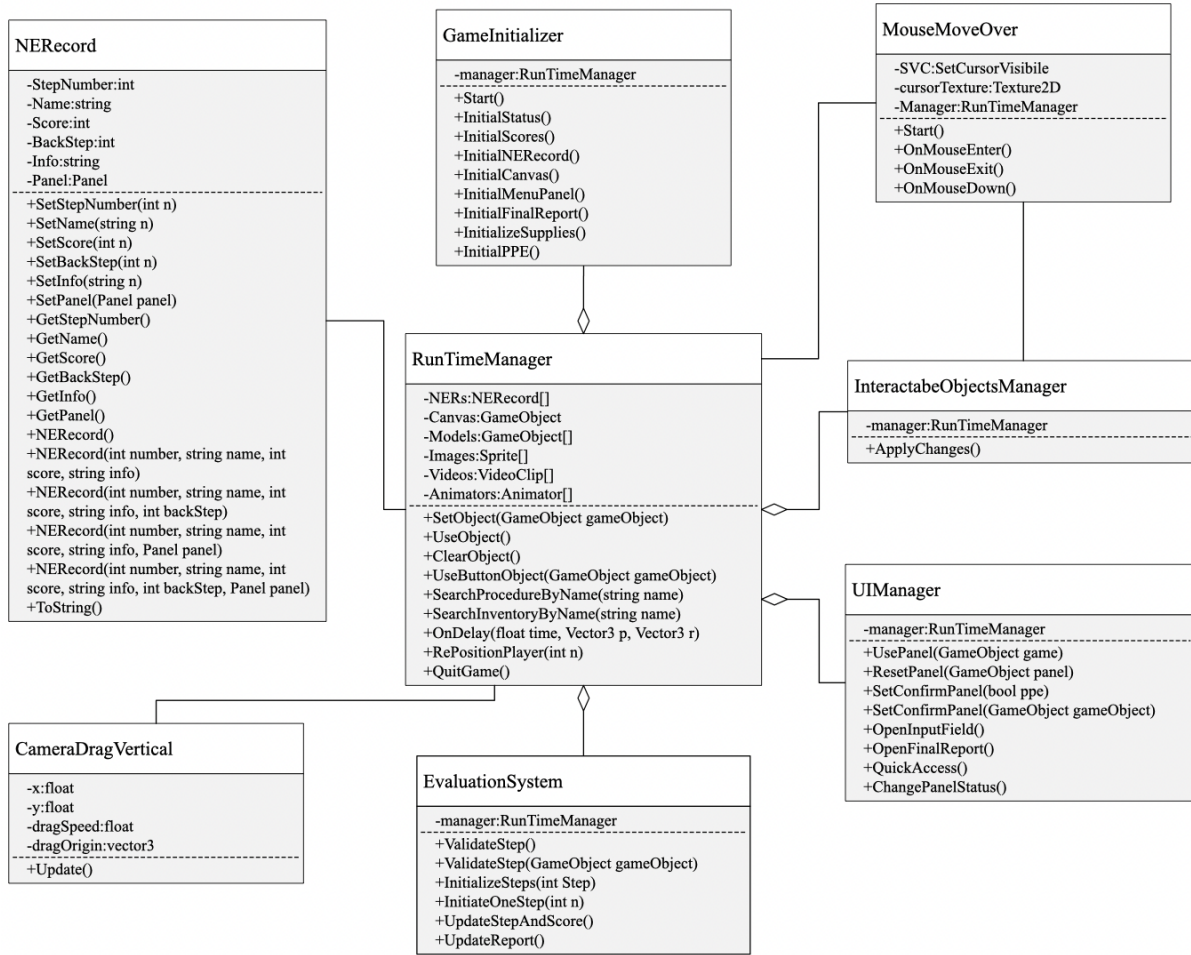
Figure 2.3. Class diagram for whole game design

to provide view changing support, one `MouseMoveOver` class to help user identify and interact with objects, and a centered class `RunTimeManager` to monitor and manage all game assets with four different modules to handle detailed tasks including `GameInitializer`, `InteractableObjectsManager`, `UIManager`, and `EvaluationSystem`. The `NERcord` is the data type to hold the procedure, and it contains `StepNumber` to ensure the procedure is executed in correct order, `BackStep` to indicate the damage it would bring if it was wrongly executed and also to provide information of what needed to be initialize to fix the mistake. Score represents the score user could gain for correctly perform this procedure, Name and Info provide information to locate procedure and give feedback, and the Panel represents which learning panel this procedure should bring up. The `NERcord` class also provides all set and get methods as interface for convenient data access and editing, multiple overrides

constructors to meet the requirement of different procedures to provide more flexibility for developers to set up different attributes to be able to customize procedures based on requirement. The `CameraDragVertical` class provides support for using mouse to change view point to get better perspective. The `MouseMoveOver` class initializes mouse cursor properties using Unity's methods `OnMouseEnter` and `OnMouseExit` to change cursor shape to help user distinguish interactable objects, and use method `OnMouseDown` to activate interaction and animation.

The `RunTimeManager` class maintains all the game assets used in the game and passes them to the four associated modules. `RunTimeManager` class holds the complete procedure lists, the UI canvas `GameObject`, all models, image and video materials, and animators that manage the animations, which reduce the load of having to assign same game assets multiple times to different classes and makes sure the integrity of assets while maintaining the code in a better shape. It has some general methods for seting up current procedure object, searching method for invoking these four modules. The `GameInitializer` class has one clear task which is to start the game and initialize all animations, interaction, and UI when the user starts the practice.

2.3.3   Model interaction module – InteractableObjectsManager

The `InteractableObjectsManager` class handles all interaction and animations featured in this game, as shown in Figure. 2.4, it has two sub-classes to handle animations and interaction separately to better optimize the implementation, and it is also associated with `MouseMoveOver` class to detect and activate interactable objects. Animations are managed by `AnimationManager` class, which accesses all the animation animators using the instance of `InteractableObjectsManager`. Figure. 2.5 shows the animator of multifunctional bed's `HighFolwer` and `LowFolwer` animation, which is able to be adjusted to three levels from 0 degree to 90 degrees forward and backward. `AnimationManager` receives calls from `InteractableObjectsManager` and activates animation using the corresponding methods. `PPEManager` is another important component of `InteractableObjectsManager`, it manages the PPE on and off function, along with the hand sanitizing function. `MouseMoveOver` class manipulates all the other mouse related interactions. `InteractableObjectsManager` is to

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call `ApplyChanges` method and make changes to the corresponding objects, and acts as an unified layer between `RunTimeManager` and other detailed functions.
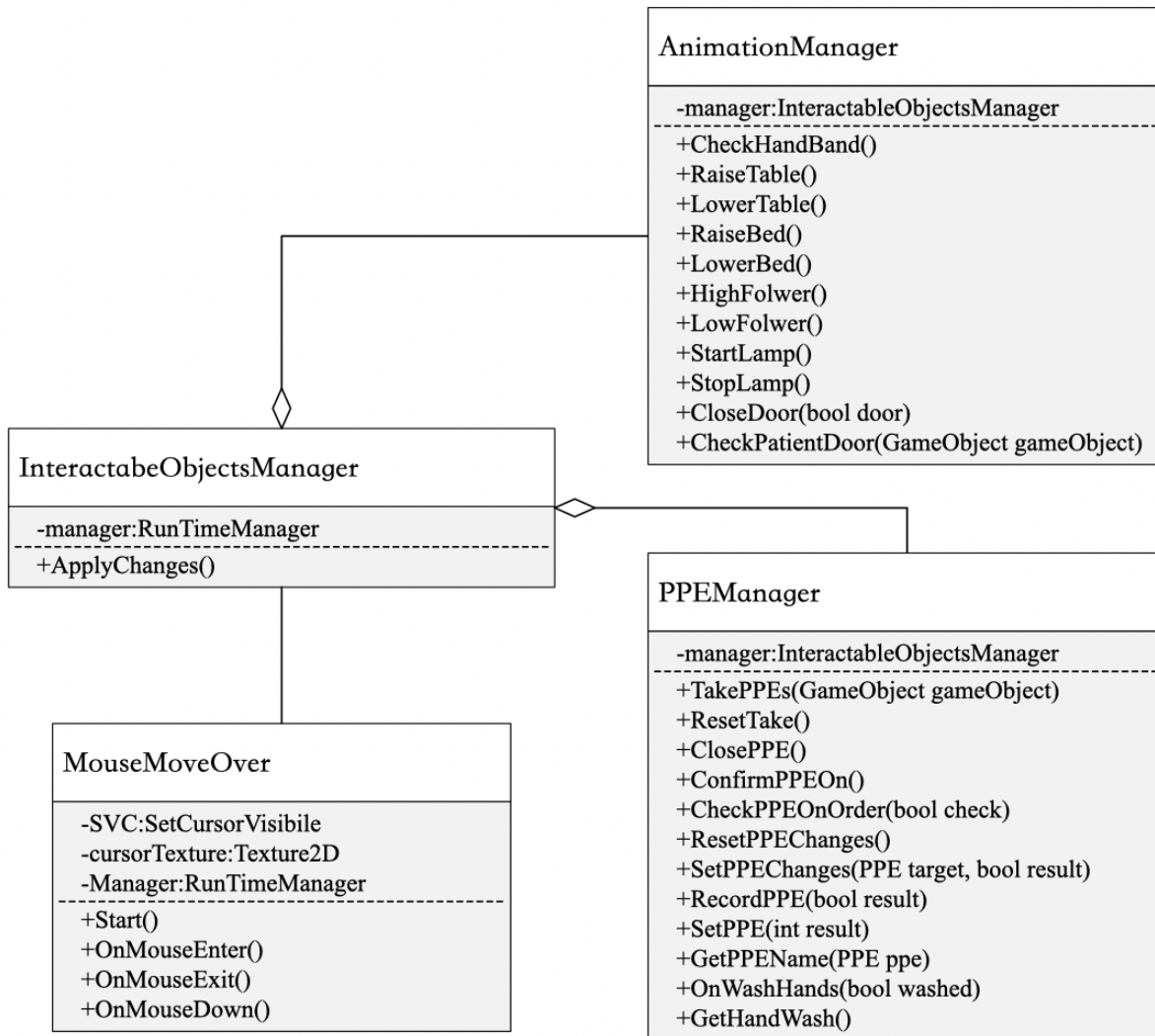
Figure 2.4. Class diagram for Interactable Objects
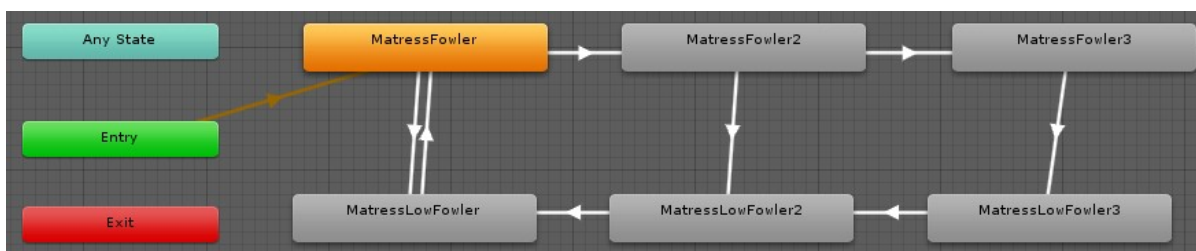
Figure 2.5. Animator of multifunctional hospital bed
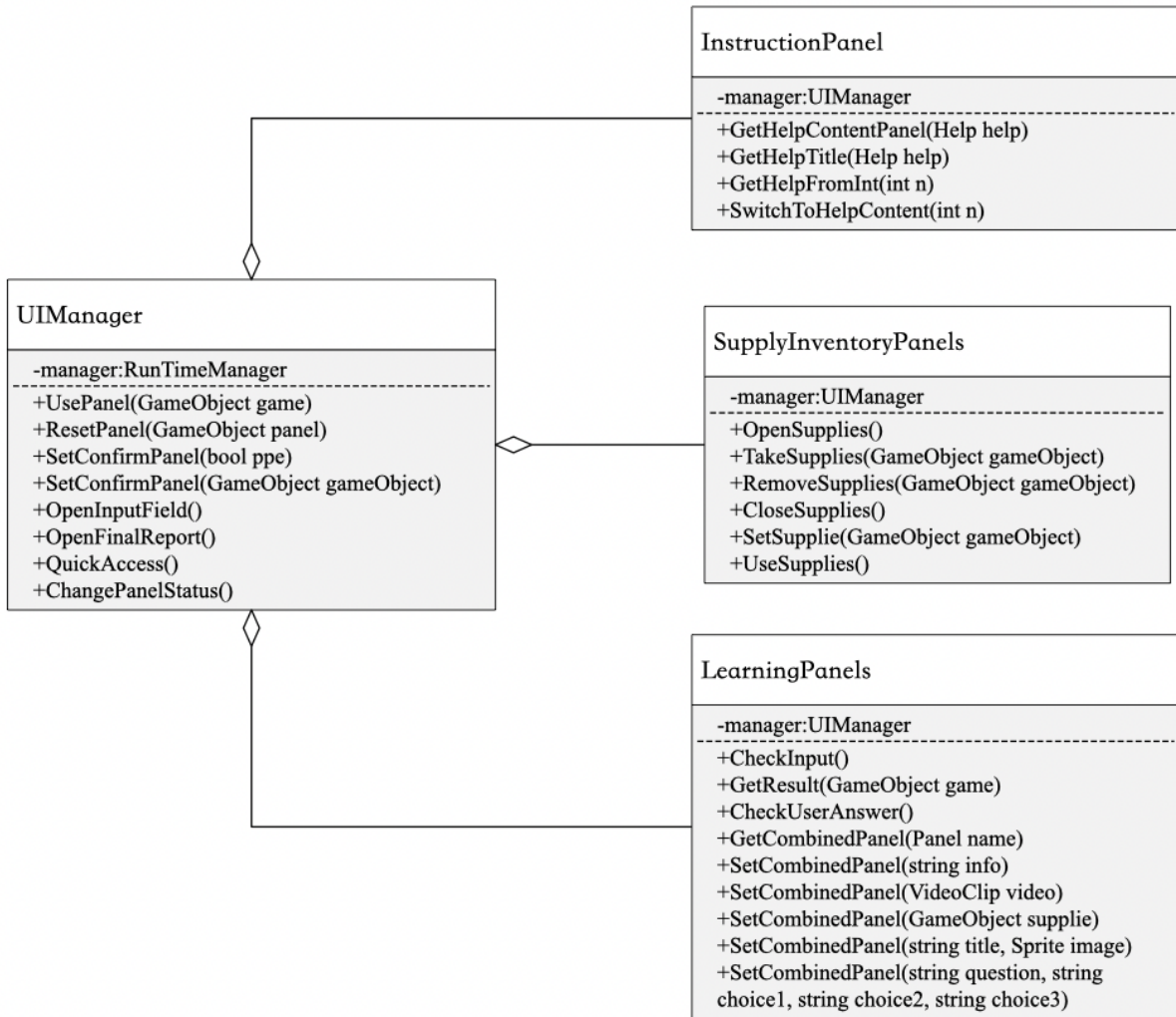
Figure 2.6. Class diagram for User Interface

2.3.4 User interface module – UIManager

UIManager class conveys information, provides feedback, and promotes underlying logic, which has three specialized components as shown in Figure. 2.6. **UIManager** class takes the general responsibility of configuring panels, and opening panels, while **InstructionPanel**, **SupplyInventoryPanels**, and **LearningPanels** class manages all detailed categorized UI events. **InstructionPanel** class is responsible for maintaining the functionality of instruction panel which is designed for beginner to better learn about how to start practicing procedure skills by taking advantage of all the game features designed in this game. **SupplyInventoryPanels** is responsible for supply related functions, for example initializing

supply closet and inventory before opening the panels, taking and removing supplies, and using supplies. `LearningPanels` class sets up different learning panel for each procedures, and there are five kinds of panels integrated into `CombinedPanel` which we have designed five methods to configure by simply changing input parameters without considering the underlying programming logic. In Addition, to further assist user while interacting with UI button elements, we designed several different animators shown in Figure. 2.7 to use color, size, or image changes to help user better interact with different UI elements.
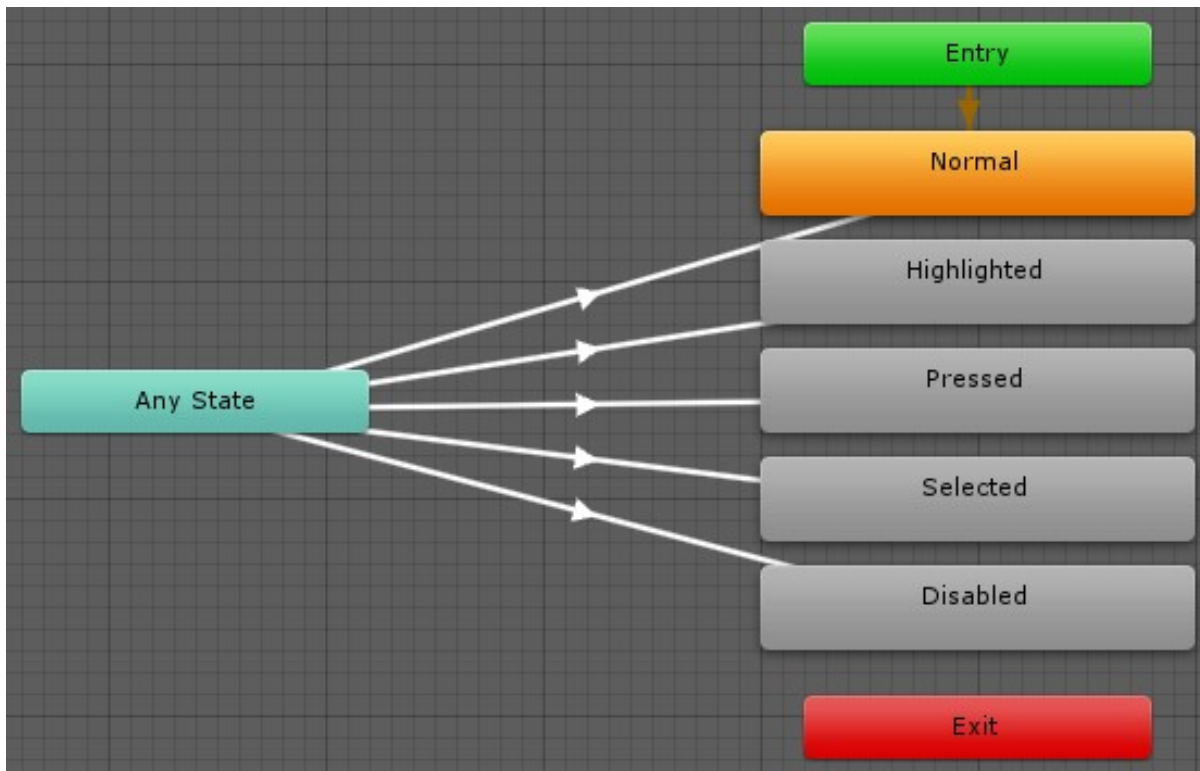
Figure 2.7. Animator of UI buttons

2.3.5 Sequence diagram of a valid procedure execution

`EvaluationSystem` class is responsible for enforcing the user to perform procedures in a correct order, which is the core element of this game. Figure. 2.8 presents the underlying sequence of successful execution of a procedure. User activates a procedure by clicking procedure in control panel or interacts with procedure related objects, `RunTimeManager` will receive the call and request `EvaluationSystem` to validate the procedure. When `RunTimeManager`
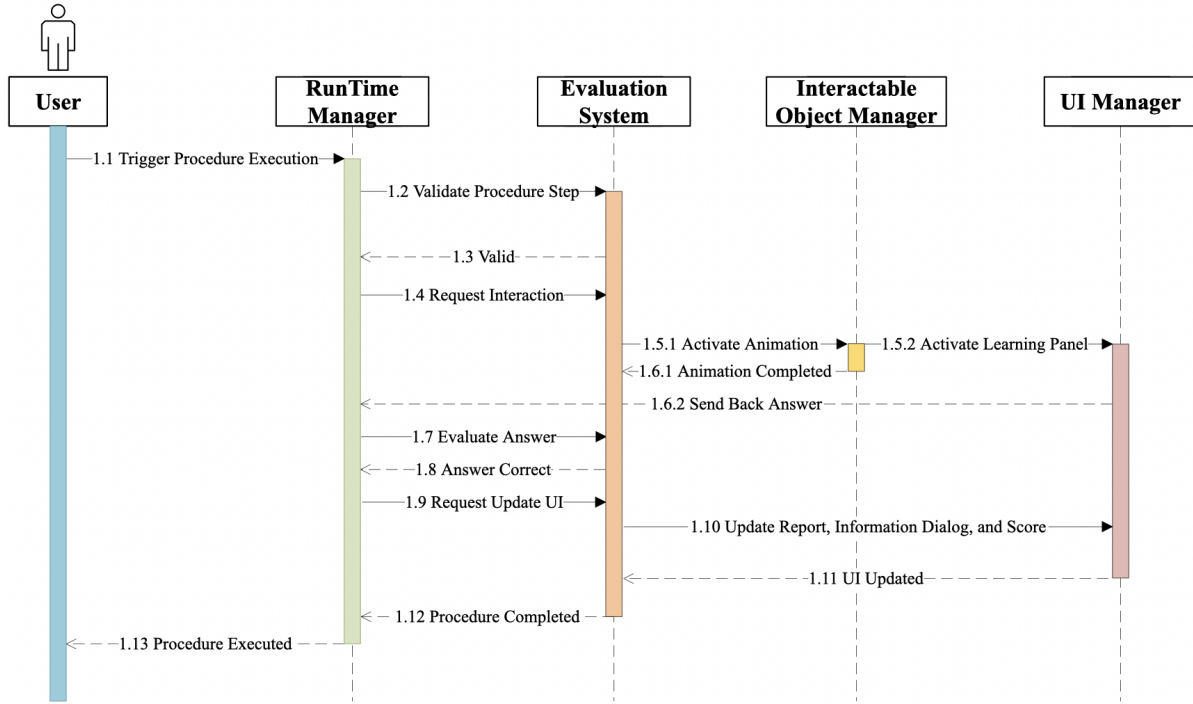
Figure 2.8. Sequence diagram for a valid procedure execution

receives valid feedback, it will request `EvaluationSystem` to proceed the procedure based on the procedure step received from `RunTimeManager`. `EvaluationSystem` will send request to activate animation or interaction, and also send the request to `UIManager` for triggering learning panel. `InteractableObjectsManager` receives the request and checks procedure information for animation or interaction, and sends back completed information to EvaluationSystem when animation is completed or no further interaction is requested for the procedure. `UIManager` will check corresponding learning panel information and promote learning panel accordingly. If answer is needed for such learning panel, it will send back the answer to `RunTimeManager`. `RunTimeManager` will decide if a validation of answer is needed based on the answer sent back from `UIManager`. If the feedback contains answer for learning panel, it will send another request to `EvaluationSystem` for validation. If the answer received is correct, then `RunTimeManager` will request `EvaluationSystem` to update procedure information, and `EvaluationSystem` will call the right method to update back-end data, and request `UIManager` to update UI information accordingly such as report, information dialog, and score. When the UI updates are finished, `UIManager` sends back confirmation to

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`EvaluationSystem`, and then `EvaluationSystem` will send confirmation of procedure completed to `RunTimeManager`, and User will see real time changes on UI and have corresponding interaction and animation for such a procedure.

The software design of this game is aimed to be sustainable, extendable, and reusable. To achieve such goals, we referred multiple concepts from previous research of software design and game design patterns [32][33]. The design includes module of control over avatar and view point, module of interaction with game object, module of interaction with user interface, and module of procedure evaluation. Each module can be separated to run individually. The general manager class is to maintain and provide access overall, which has methods for potential reusability and extendability.

3. DEVELOPMENT OF VIRTUAL HOSPITAL ENVIRONMENT

The 3D hospital environment is the first stage to ensure user experiences better practice by smoothly transiting their procedure skills from serious game to real life operation. Therefore, to ensure realism, the 3D hospital environment was designed based on pictures of a real hospital.
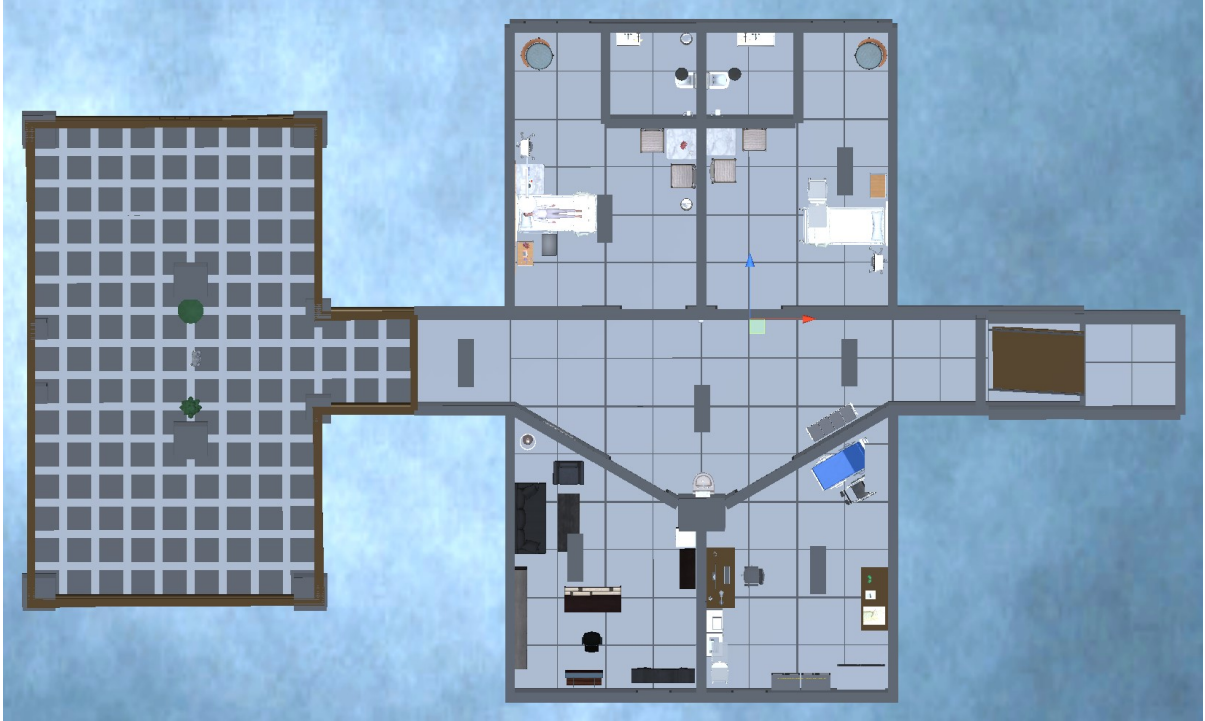
Figure 3.1. Top view of virtual hospital environment

The top view map of the 3D virtual hospital is shown in Figure. 3.1, includes a waiting room, two patient rooms, a storage room, an office room, and a long corridor area. The waiting room located in the left part of the hospital as shown in Figure. 3.1, is the first place user would see in the beginning of a practice. Patient rooms located in the upper part of the top view, they are the rooms where most of the procedures proceed. Storage room located at the bottom right part of the top view, it stores supplies and allows user to access medical orders. The corridor area is in the middle, it is the area to put on and take off the PPE and perform other operations. The office room located to the left of the storage room is reserved

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for future use. In this chapter, each room or area would be detailed explained for it's set up and it's purpose.

3.1 Waiting Room

The waiting room depicted in Figure. 3.2 is the starting point of the game which located at the left of the top view. This room has the basic set up of few plants, lights, and a door in front of the user. The purpose of this room is to provide a space for the user to receive backstory of the practice and allow user to get familiar of how to use each feature built for the game. In this area, user can safely practice how to control the player avatar, learn how each component work through the instruction panel and more. When the user is ready to start the practice, the journey is started by the avatar walking through the door in the front.

Figure 3.2. Waiting Room Area

3.2 Corridor Area

Corridor area as shown in Figure. 3.3 is the place after getting through the door from waiting room. It is the center line of the hospital, it connects to all the rooms with door

and stores objects such as PPE box, hand sanitizer, sink, and waste bin. The purpose of this area is to simulate real world hospital environment, which allows user to perform hand sanitizing, checking precaution board, checking medical record, taking PPEs before getting into patient room and more. The existence of this area provides real world experience which helps the user quickly blend into the practice and easily switch skills to real life.
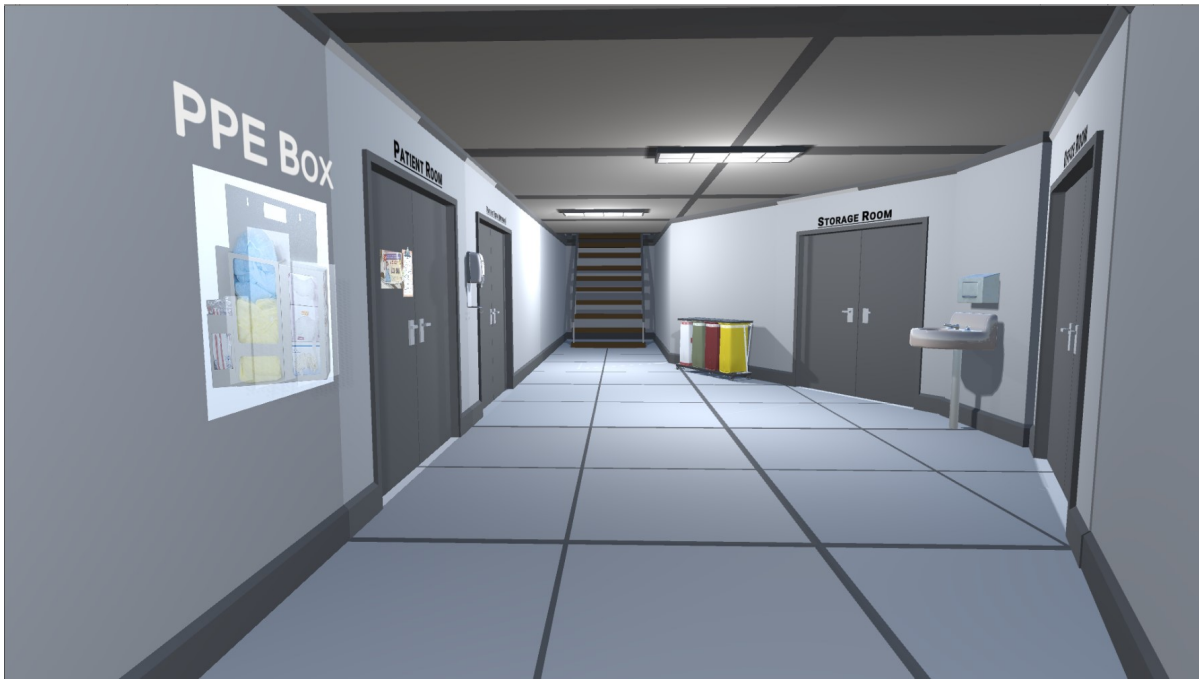
Figure 3.3. Corridor Area

3.3 Patient Room

Patient room Figure. 3.4 is the main room that was developed for the procedure `Insertion of Nasogastric`. This room has a patient lying on the multi-functional hospital bed in the middle, with all the medical equipment around as showed in Figure. 3.5, table and chairs for visitors, and a well designed rest room behind the wall in the back. The patient room is designed based on an real world hospital patient room to help user quickly getting into the practice environment. The purpose of this patient room is to allow user to get familiar with real world practice environment and perform procedures and getting corresponding feedback to effectively practice fundamental nursing skills.

Figure 3.4. Patient Room

Figure 3.5. Patient and Medical Equipment

3.4 Storage Room

Storage room as shown in Figure. 3.6 was set up with medical closet, computer station, and all other kinds of medical equipment. The purpose of this room is to allow user to practice checking medical records using computer, and collecting required supplies from supply closet as they were required in real world practice.
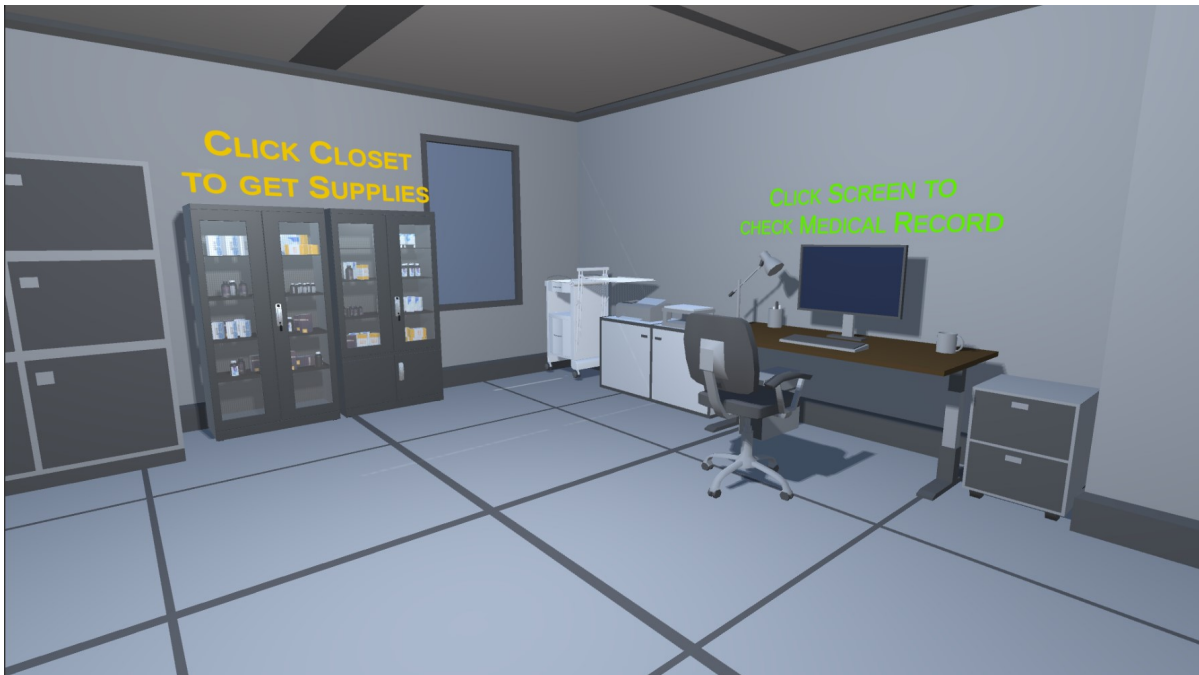
Figure 3.6. Storage Room

3.5 Reserved Room

The current procedure `Insertion of Nasogastric Tube` mainly used one patient room, storage room, and the corridor area, but for more potential procedures two rooms were reserved with basic set up. The second patient room as shown in Figure. 3.7 and office room presented in Figure. 3.8 are reserved for future use. The patient room has similar set up as the patient room motioned above with multi-functional bed, table and chairs for visitors, medical equipment and rest room. The office room have the basic set up of office desk, book shelf, reception area and some decorations. The purpose of these two reserved rooms is for procedures other than `Insertion of Nasogastric Tube`, it might require different

procedures and operation set up, with the basic rooms set up, new procedures can be easily set up for using instead of building from scratch in the future.

Figure 3.7. Patient Room Reserved

Figure 3.8. Office Room

All the 3D models used in this game were downloaded from 3D model websites [34] [35] [36] or imported from Unity assets store [37] and have been modified and edited in 3ds Max [38] or rearranged in Unity [22] to build the desired environment. In addition, all these models are reusable for other procedures necessary within nursing field, and can be easily modified to meet future needs.

4. IMPLEMENTATION OF GAME FEATURES AND GAME MECHANISM

The game starts with a menu featured with two options, either to directly start practicing procedure skills or a tutorial video option to watch the standard procedure for the first time users as shown in Figure. 4.1. In the tutorial video, the user has options to either go back to the menu or start practicing instead of having the whole tutorial completed. Once the practice begins, as shown in Figure. 4.2 the game displays a story of a patient who needs the procedure of `Insertion of Nasogastric Tube` by the user. Then, the user clicks on "Challenge Accepted" button to start the journey, the game is story based to attract the user's attention and stimulate active learning as it is one of our primary goals. One challenge former researches [39] faced in such story based game is whether to let user choose the wrong answer or not during the procedure training process. Some serious games allow the user to choose wrong answers [40], while others do not [41]. To solve this challenge, we proposed a new strategy which allows the user to select wrong answer, however, instead of ending the game, the game would redirect the user to a former step where the wrong procedure would cause problem. Using this method of redirection allows the user to continue staying in the game and assists the user to identify the error in the step. This ultimately provides the user with direction on where they can safely restart the skill. The workflow of the mechanism is shown in Figure. 4.21, where each step the user chooses to proceed will trigger the decision tree and gives the responding result. The detailed mechanism on this would be discussed in section 4.3. Finally, when the user reaches the last procedure, the report would automatically be generated and presented for user to evaluate their performance.

In this chapter, all the features implemented to the proposed game were discussed. From interaction and animation which makes the game more playable, to user friendly graphic user interface that enhances the complexity, and finally to the novel evaluation system that provide real time feedback and much more. Details about the three key components was presented in each section.
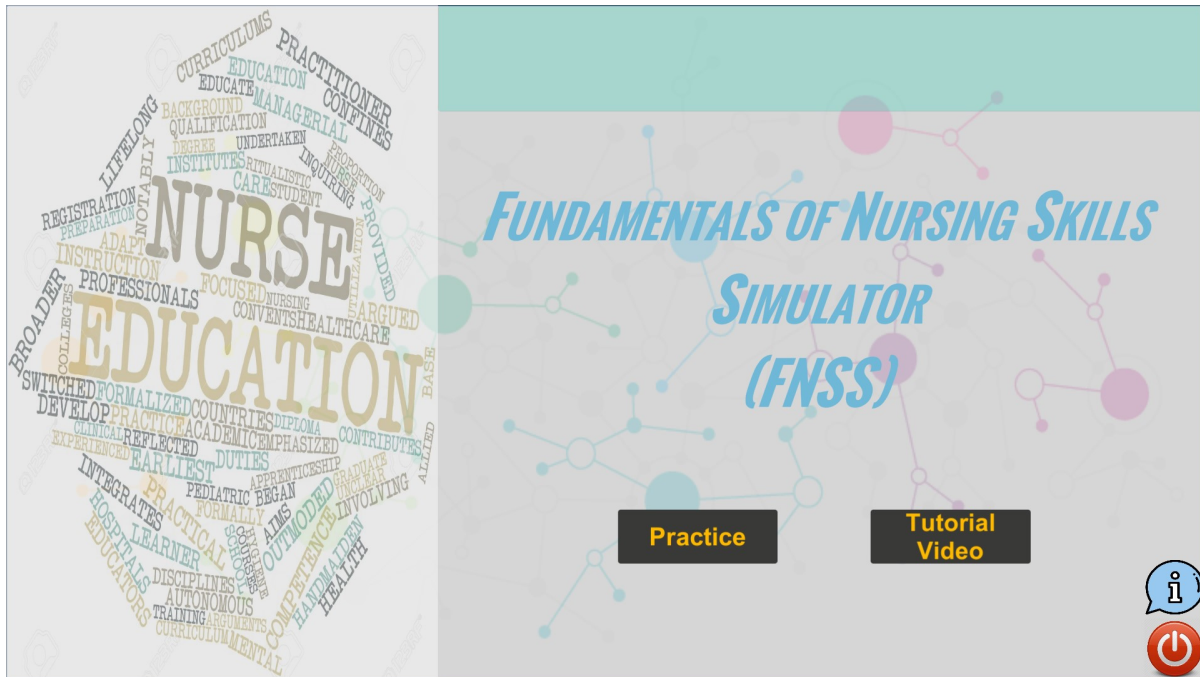
Figure 4.1. Game Menu
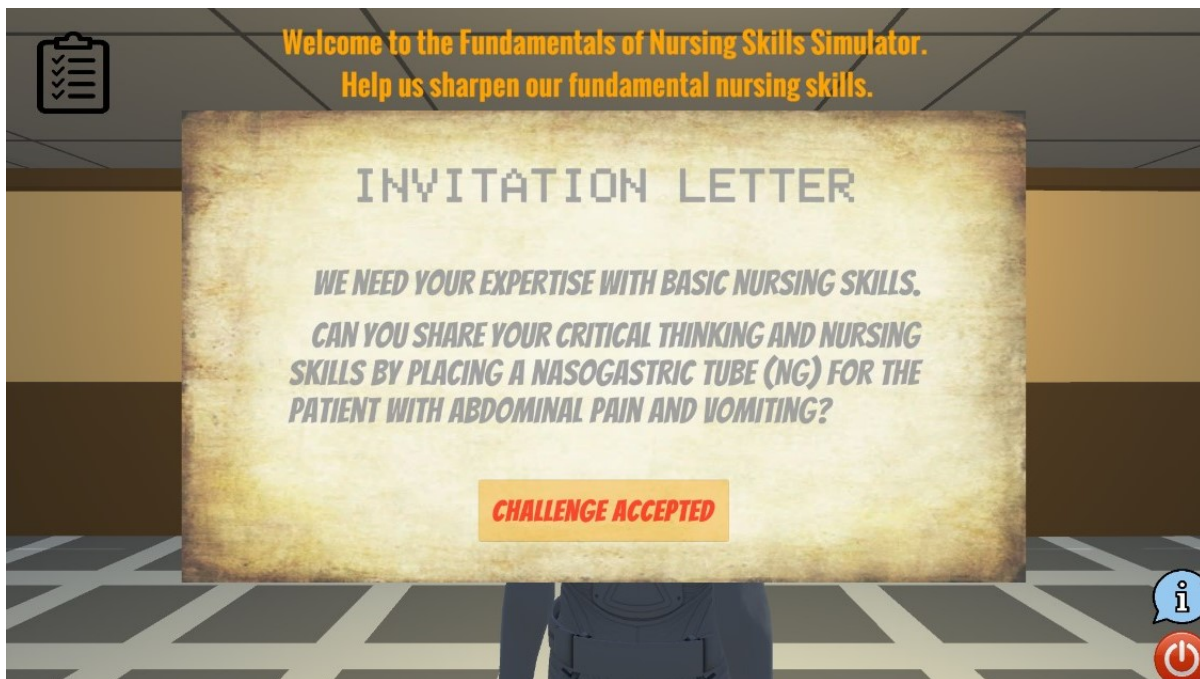
Figure 4.2. First scene after start practice

4.1 Interaction and Animation

Featured interaction and animation helps reduce cognitive load of learning, and reduction of cognitive load can result in more effective learning [42]. To achieve such effective learning, we designed many interactions between the user and the game along with multiple intriguing animations to make the game playable and fun for the user.

4.1.1 Interactive Objects

To separate interactive objects from others in the proposed game, the cursor of mouse has been set to change icon when it hovers over interactive objects. Beside the interactive 3D model objects, all the graphical user interface have interaction with user and this will be discussed in the graphical user interface section. The interactive objects in the game has been listed below with corresponding actions.

- All the doors: Click door to open/close, at most one side door was animated to support walk through, the door on the other side was fixed to hold clipboard and other objects.

- Computer Screen: Click on the screen to simulate logging in the computer and check a medical record. After the animation completed, the medical record would show up on the screen, user can then click on the record to open medical record panel which contains detailed information of medical order and record.

- Supply Closet: Click to open the supply panel and inventory panel to fetch supplies.

- Clipboard: Click to bring up the panel for detailed information of patient inside the room.

- Precaution Board: Click to bring up precaution board panel, which have the precaution information for PPE taking direction.

- Hand Sanitizer & Sink: Click to perform hand hygiene, double confirmation required.

- Personal Protective Equipment (PPE) Box: Click on each PPE area to put on items such as gloves, gown, and mask, double confirmation required.

- Medical Table: Click to change location of table between corner and bedside.

- Handrail of the multi-functional hospital bed: Click to raise/lower the handrail of bed, featured on all handrails.

- Waste Bin: Click to open/close the lid for toasting waste.

- Trash Can: Click to perform remove extra equipment procedure.

4.1.2 Animations

This game features multiple animations for objects to create an intriguing environment for the user to provide a fun experience while practicing skills. It incorporates critical thinking and aims to decrease the memorizing of a concept or step. Many objects in our design have been designed as interactive and animated ones to achieve this goal such as:

Figure 4.3. Initial set up for patient room
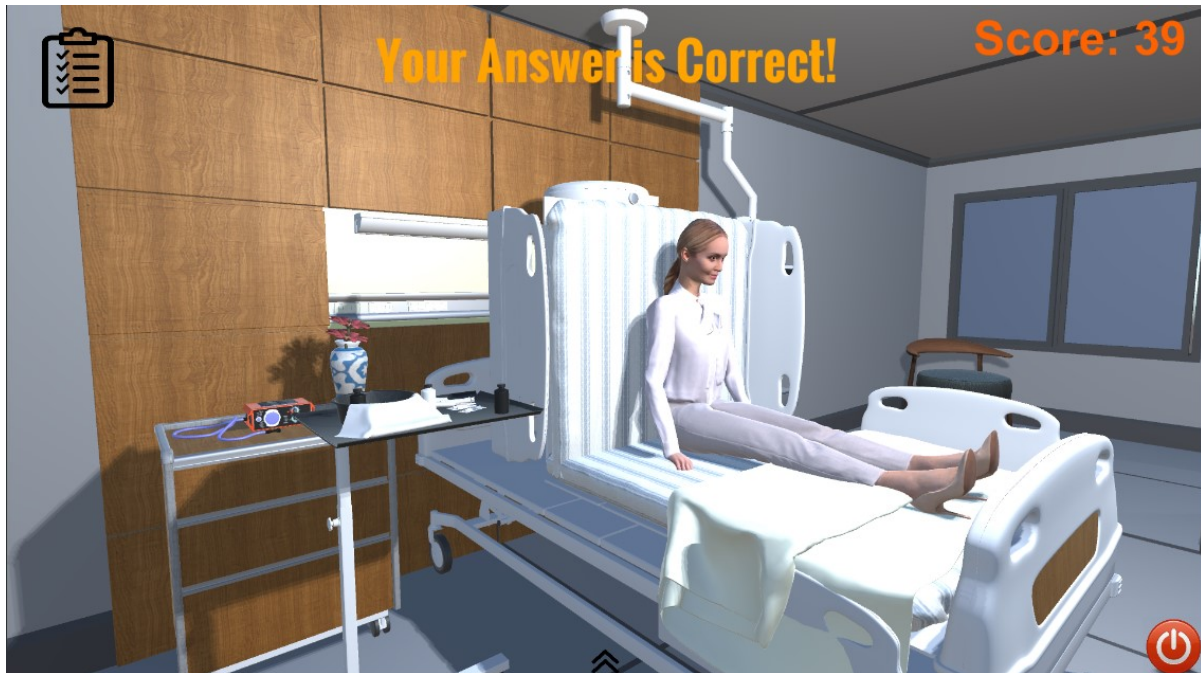
Figure 4.4. Animated Multi-functional Hospital Bed

Figure 4.5. Animated over head lamp

- All the doors: Animated with open and close event responding to user's interaction.

- Waste Bin: Animated to open/close the lid for clicking event.

- Computer Screen: Animated to power on and off with gradient animation to simulate computer starting.

- Hand Sanitizer and PPE Box: Animated to change color while mouse hovers over it indicating interact-able.

- Medical over head lamp: Animated to stretch, rotate, light up, and reverse to simulate real world functionality as shown in Figure. 4.5.

- Medical Table: Animated to change height, move between corner and bedside, and place supplies as shown in Figure. 4.4

- Multi-functional hospital bed: Animated to raise/lower bed, to change the head of the bed to high fowler as 30/60/90 degree, to remove pillow when the head of the bed reaches 90 degree, and animation for lowering/raising each handrail. Figure. 4.4 as compare to Figure. 4.3 demonstrated the animated effect of raised bed with the head of the bed of 90 degree high fowler and lowered handrail.

- Patient: Animated to have small motion such as blinking and slightly moving head while idle to improve realistic, to raise hand and rotate head for wrist band checking during patient identification procedure, and to adjust body posture according to the angle of the head of the bed as shown in Figure. 4.4.

- Graphical User Interface: Animated to change color, size, position etc. for interaction.

4.2 Graphical User Interface (GUI)

GUI is an important part in game design, it conveys information, provides human-computer interaction, and enhances the efficiency of the underlying program logic. For our game, the target was to practice procedure skills by conveying nursing knowledge through explanation, interaction, and evaluation to the user. To efficiently convey the information and to make the game easy to use, several user friendly graphical interface were designed.

4.2.1 Run time interface

As shown in Figure. 4.4, when the practicing of procedure is activated, the run time interface has the following features: a "Menu" button on the top-left corner, an "Information dialog" on the top, a "Score" display on the top-right corner, a "Exit" button on the bottom-right corner, and a "Insturction" button above the "Exit".

- The "Menu" button opens the main menu panel and has 5 options for checking the PPE worn, opening control panel, checking report, opening checklist, and using "QuickAccess".

- "Information dialog" displays the information of procedure tracking such as step validation, step completed, material pending, and the error made when the procedure performed is wrong. It provides user real time feedback to assist better practice and gaming experience.

- "Score" keeps track of the earned score during the current procedure practice and provides feedback to the user in real-time.

- "Exit" button provides the option of quitting game at any point of time in the game, double confirmation required.

- "Insturction" button contains instruction help for all the feature might used during the practice, detailed information would be discussed in following section.

4.2.2 Three level control panel

Figure. 4.6 presents the three level control panel, which controls most of the interactive features in the game. The first level is "Main Menu" which has 5 options for general functions; the second level is "Control Panel" which lists all the procedure categories; and the third level is "Procedure Panel" where all the individual procedures are located.

"Main Menu" as shown in Figure. 4.6a can be accessed by clicking the "Menu" button as mentioned in section "run time interface". It have 5 general functions:
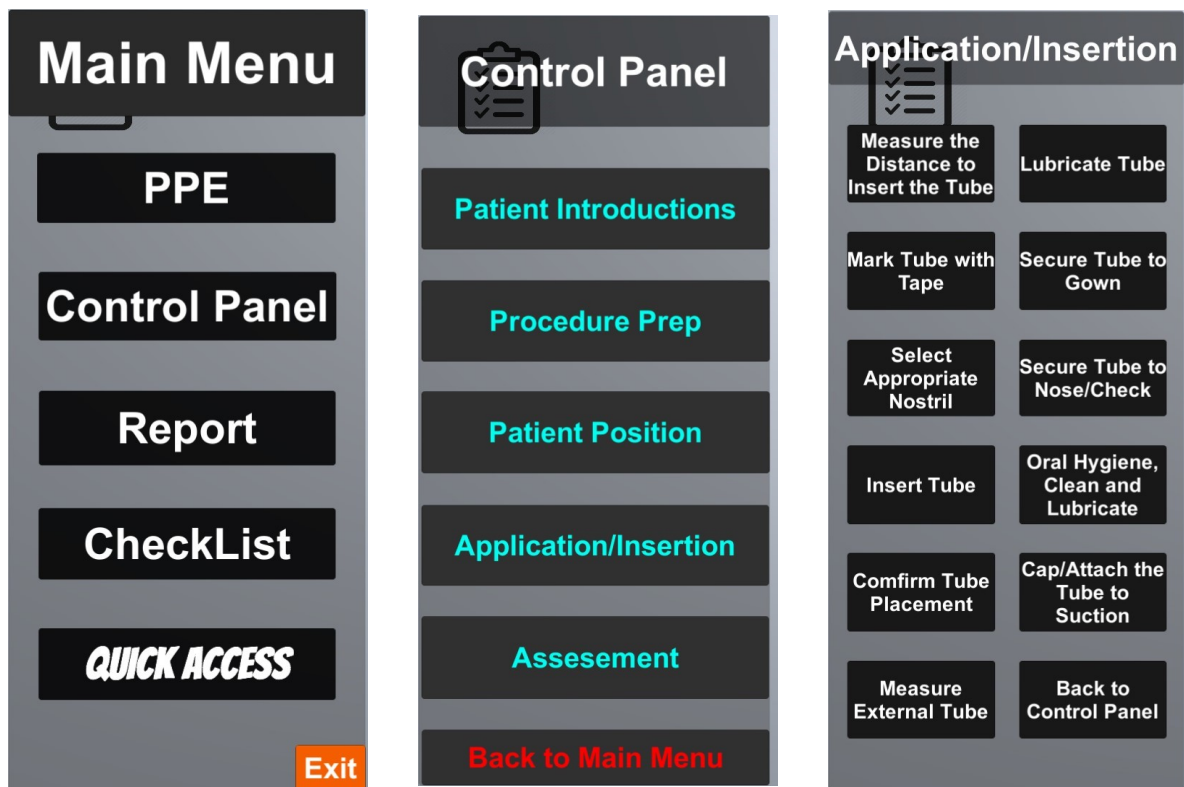
(a) Main Menu (b) Control Panel (c) Procedure Panel

Figure 4.6. Three Level Control Panel
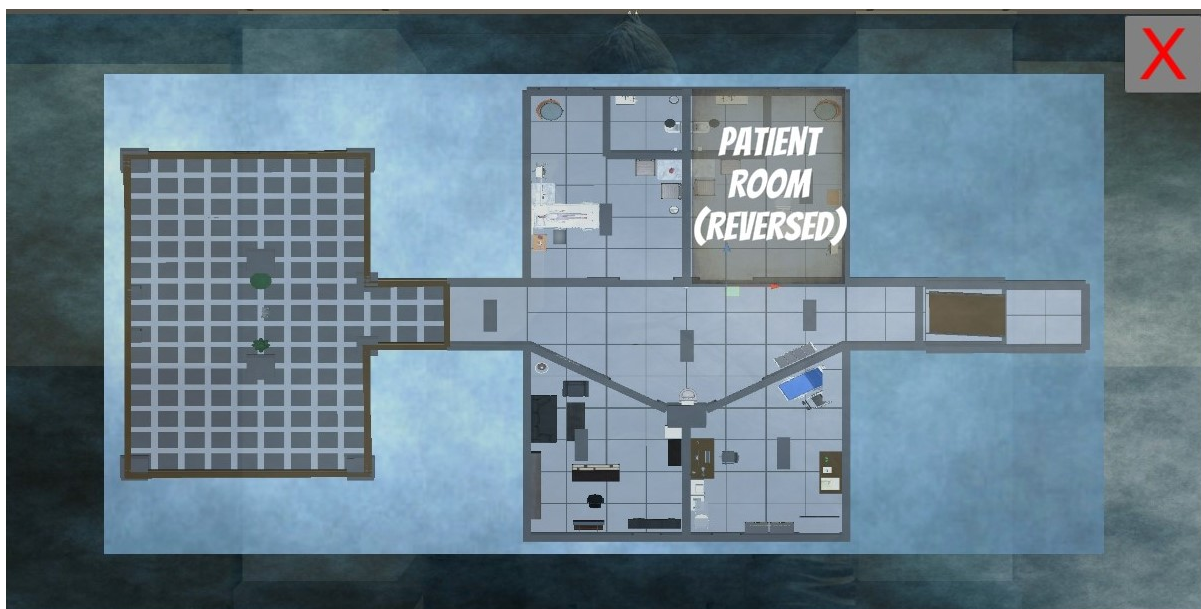
Figure 4.7. Quick-Access Panel
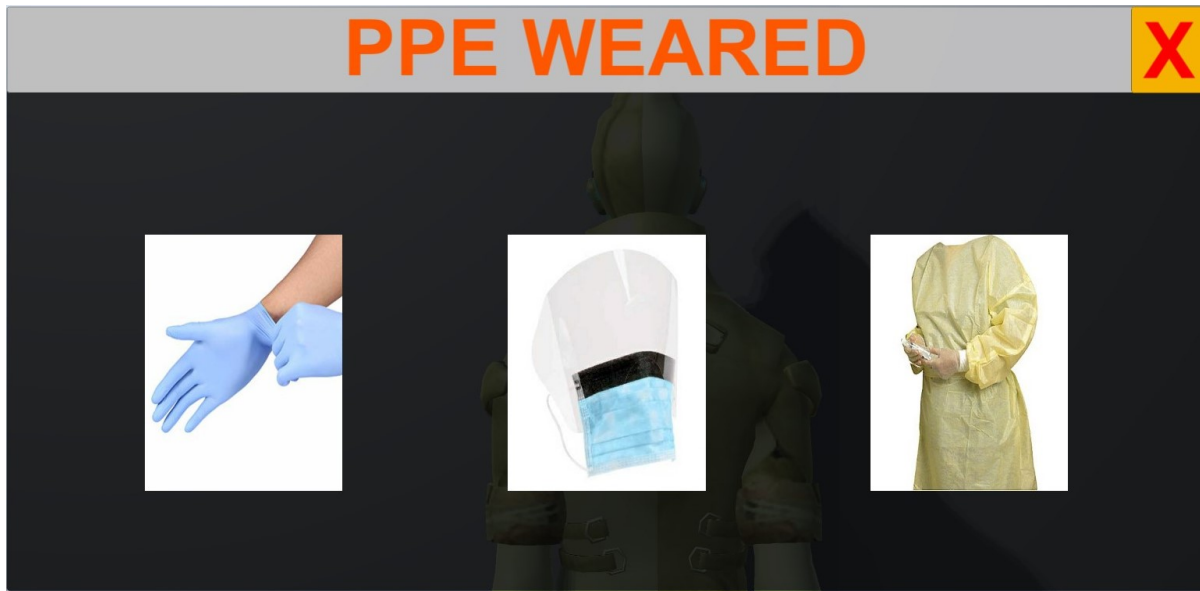
Figure 4.8. PPE Weared Panel

- "PPE": for opening PPE weared panel as shown in Figure. 4.8, which contains all the PPE user currently weard, in this panel user can perform procedure of taking off equipped PPE where double confirmation is required to prevent accident operation;

- "Control Panel": for opening the second level panel, which contains most of the procedures;

- "Report": for opening report panel to allow user to track progress and score in real time;

- "CheckList": as shown in Figure. 4.9 to provide the standard procedure checklist to user as a reference to complete the practice. For first time user, a complete game procedures was also provided as reference, which can be accessed by clicking the bottom-center button "Procedure";

- "QuickAccess": as shown in Figure. 4.7 serves as a quick transit method to transfer game character from one location to another making the the process convenient to the first time users and saving their time from doing unnecessary moves as well.

(a) Checklist First Page   (b) Checklist Second Page

Figure 4.9. Evaluation System

To help user locate specific procedure, "Control Panel" was designed to categorize all the procedures into 5 different categories as shown in Figure. 4.6b. In this way, user can easily find the procedure they want to proceed instead of searching a procedure in a table that contains all the procedures which can usually be more than 25.

Level three is "Procedure Panel" and it has 5 different panels where each panel represents one category of procedures. Figure. 4.6c depicts one of the procedure panels which contains up to 11 individual procedures with an option of "Back to Control Panel" as well. User can proceed a procedure by clicking the procedure button and the game would provide corresponding actions and feedback to user accordingly.

To make the interface user friendly, in level three, the procedure panels have a option on the bottom right to go back to the second level – Control panel. The second level panel also has an option to return to the first level on the bottom as shown in Figure. 4.6b, and the

first level can be closed by clicking the exit button on the bottom right of the main menu. These three options allows the user to easily switch between three levels control panel and the hospital environment. All three panels was set to be transparent to allow user to practice procedures continuously without having to close and open these panels repeatedly.

4.2.3 Supply and inventory

Gathering of needed supplies before performing care to patient is critical. To simulate this procedure, we designed a supply-inventory system that simulates user collecting supplies from supply closet and putting into inventory as depicted in Figure. 4.10.

Figure 4.10. Supply and Inventory Panel

- A supply closet panel was designed to display all the supplies in the store with a picture and name indicated on each supply. User can select supply by clicking the picture in supply panel and it would be stored in the inventory. Each supply can only be selected once, selected supplies would be not interact-able and covered with shadow in supply closet panel as shown in Figure. 4.10.

Figure 4.11. Using supply in Inventory

- Inventory panel stores all the items picked from supply with picture and name. A remove button has also been provided for removing unexpected supply from the inventory back to supply closet. The inventory panel can also be hidden by clicking the downward arrows above the inventory panel, and the inventory panel would be placed out of screen to provide better view point during the practice. A small upward arrow would stay on the bottom to allow user to open the inventory panel when needed. Inventory panel can be accessed at any time after the supply closet is opened and user can use supplies in inventory to perform procedure by clicking the supply icon in inventory panel, double confirmation as shown in Figure. 4.11 is required for confirmation.

4.2.4 Multiple learning panels

To enhance the complexity and playablity and to evaluate application of concepts, multiple learning panels as shown in Figure. 4.12 were implemented. Unlike traditional explanations based User Interface (UI), we designed several panels using different learning methods

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and materials namely multi-choice, true or false, input-field, image information, and video-player to help user enhance knowledge. Each kind of learning panel tests and evaluates user's skill and knowledge competency in different aspect, which combined enhanced the overall procedure skill and knowledge attainment through critical thinking. Detailed information regarding each learning panel implemented in this game has been elaborated below.

(a) Multi-Choice

(b) True or False

(c) Image Information

(d) Video-Player

(e) Input-field Panel
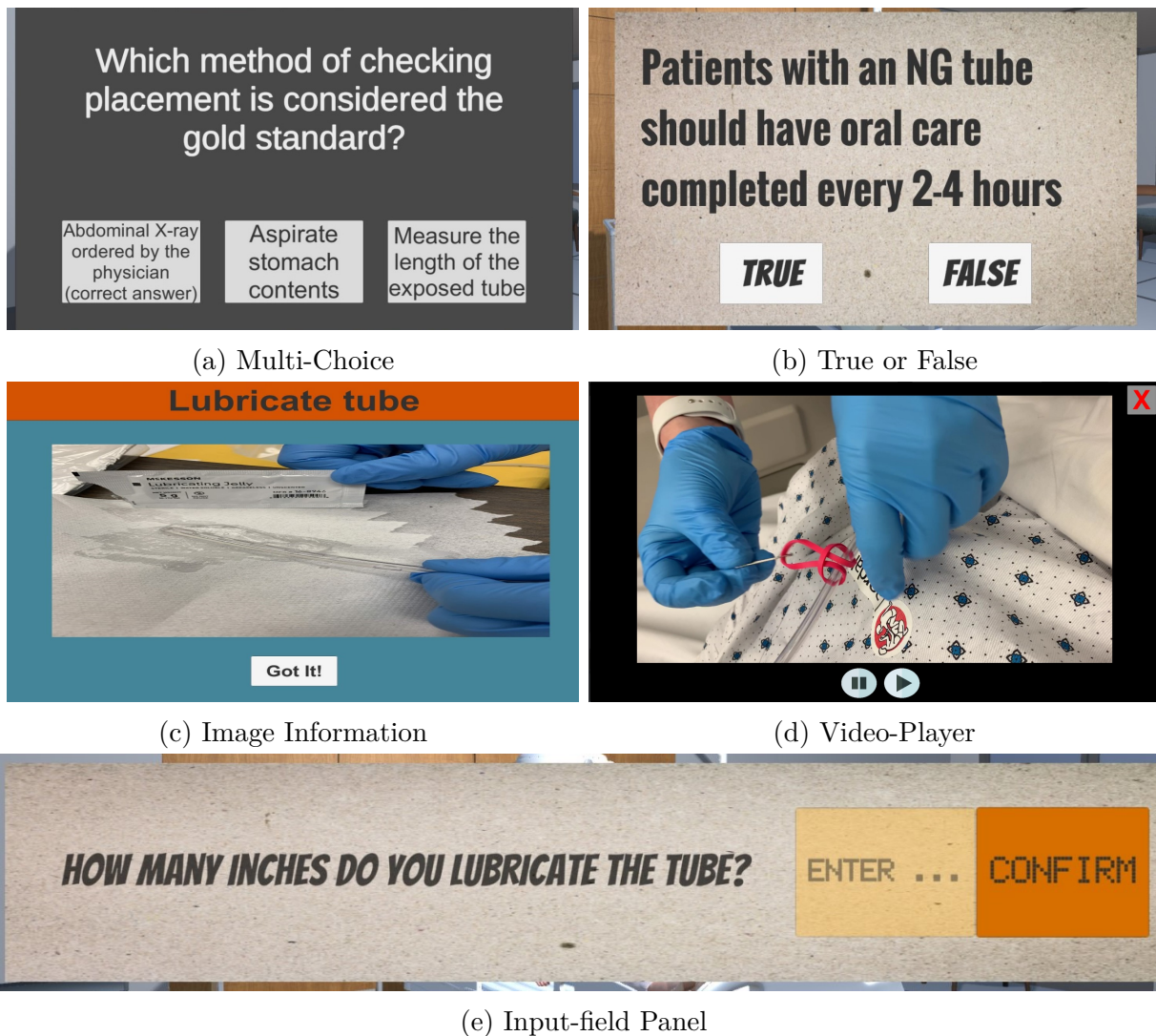
Figure 4.12. User Interface Components

- Figure. 4.12a presents the multi-choice panel, which allows the user to choose one or more correct answers from the choice listed. The text information can be easily replaced by picture material to provide visual input. In this way, user can test their knowledge

by choosing answer from the choices instead of passively accepting to promote active learning.

- Figure. 4.12b shows the true or false panel, in this panel user is questioned in such a way that he/she have to just choose either true or false for any particular question. This approach has an advantage over multi-choice panel because user does not have to read choices and it saves time.

- Figure. 4.12c illustrates image information panel, it allows image material to be presented to make detail information clearer for specific procedures which combine with text information further enhance the knowledge attainment.

- Figure. 4.12d depicts video-player panel, it provides video tutorial instead of giving text or image information to help understand complex procedures, and allows user to play the video over and over till they grasp the skill.

- Figure. 4.12e presents the input-field panel that allows user to give their own answer regarding the question instead of choose from possible answers, which requires more robust skill knowledge to proceed.

To ensure the user can start the game and effectively practice procedure skills, helpful settings were implemented. This involved setting of panel to be transparent to allow user to gain a better perspective while having these panel opened. User also have the flexibility to change view of perspective by simply clicking and dragging the right key on mouse. Further, to avoid user from unexpected interactions with the model, the game was set to prevent changing the view when clicking through UI. In addition to this, double confirmation was implemented to many interactive objects and UI components, user has to confirm action to trigger the event instead of instantly trigger to avoid accident interaction during the game.

4.2.5 Instruction panel

To help first time user quickly getting start with this serious game, Instruction Panel was implemented. User can open this panel anytime during the game by clicking the icon

on the bottom right corner, right above the exit icon as shown in Figure. 4.13. In this panel, user would be able to find detailed instruction about how to utilize all the Graphic User Interface(GUI) to interact with the game, how to use mouse and keyboard to control and relocate the avatar in the game, how to detect and interact with interact-able objects to trigger procedure event, and more information about this game. The instruction panel mainly consist of pictures and text information, text information explains the general function of specific objects, and pictures was edited to help user quickly and better understand the content. There are also animations built in instruction panel to demonstrate some procedures to help user have better understanding of the game mechanism.
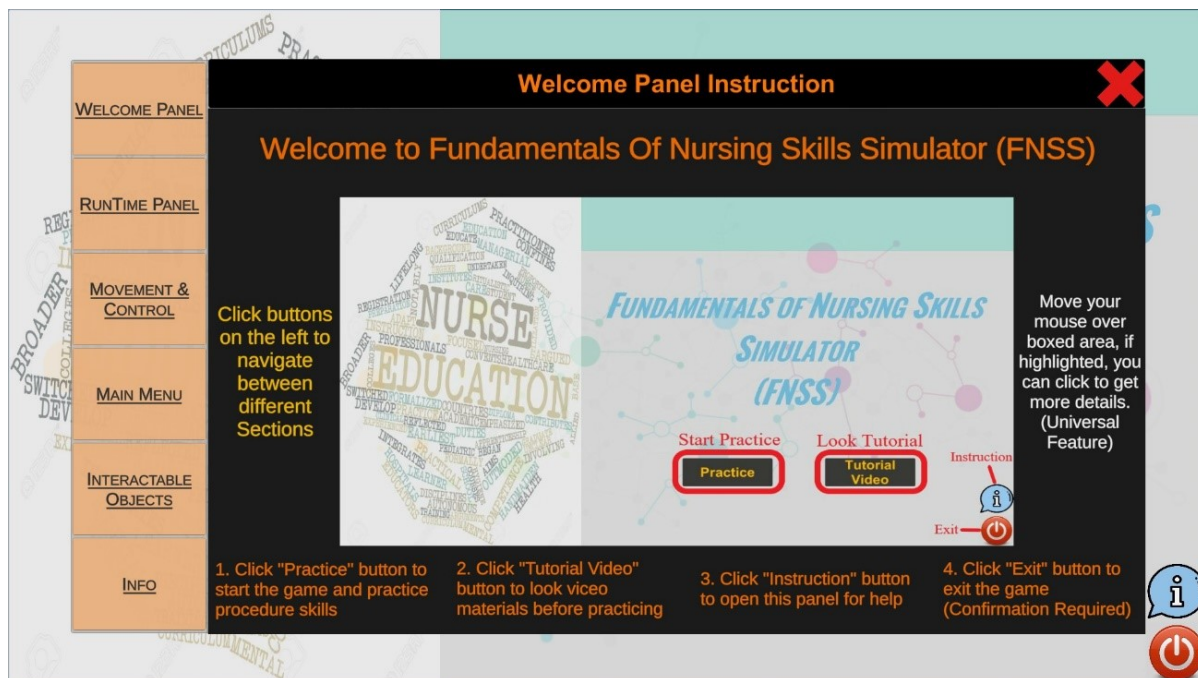
Figure 4.13. Welcome Panel Instruction

Figure. 4.13 shows the first page of the instruction panel when you click the icon. This panel gives the information about the functionality of each button on the welcome panel of the game. All the buttons was highlighted by red box, and labeled using simplified meaning. The bottom part detailed explained what would happen when each button is clicked. In addition, the yellow text on the left side tells the user that they can switch between each tabs to check other aspects of instruction of the game by clicking the buttons on the left bar, and the white text on the right side tells the user the animation built in this instruction

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panel. The instruction panel is also animated, when mouse moves over certain area the area featured with animation would be highlighted by an red layer. By clicking the area, new image would show up to demonstrate the simplified result of clicking that component during the game.
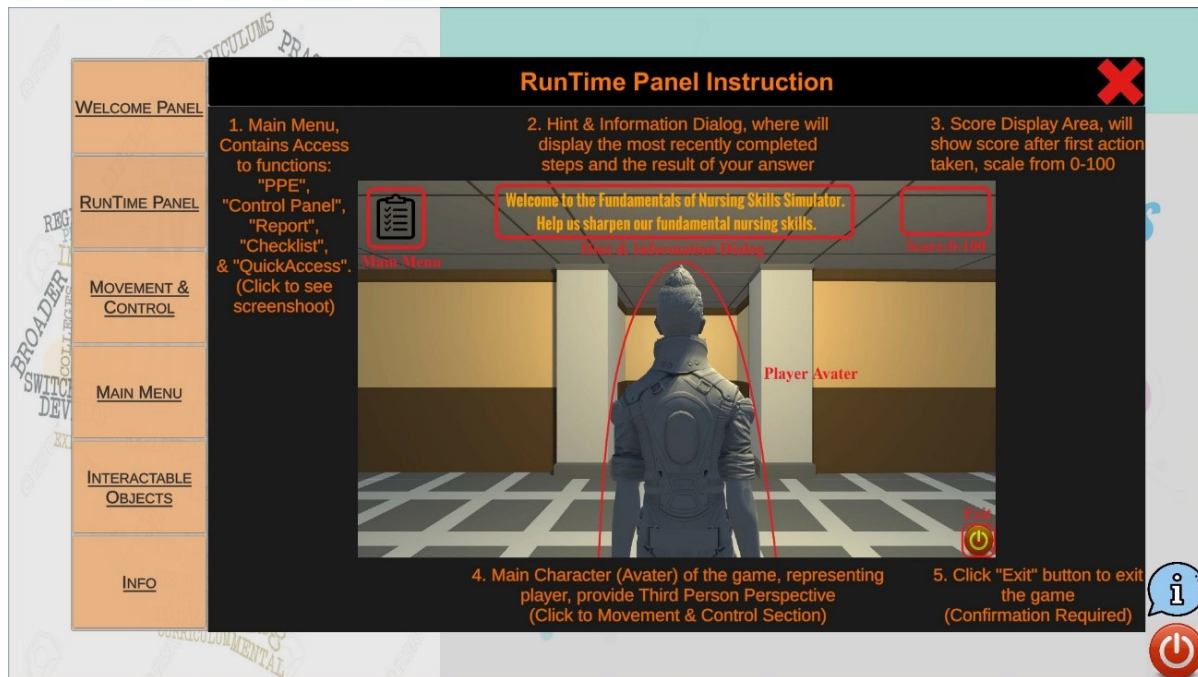
Figure 4.14. Run-Time Panel Instruction

Run-Time panel as shown in Figure. 4.14 introduced the run time user interface, including the main menu, information dialog, score area, exit button and the player avatar. Animation was built in main menu, exit button and player avatar. When main menu was clicked the main menu panel would show up, clicking the main menu would direct the user to Main Menu Instruction tab. Exit button would bring up the double confirmation panel to allow user to get familiar to the setting. By clicking the highlighted part of the player avatar, the user would be directed to Movement and Control Instruction for detailed information about how to control the player avatar.

Movement and Control Instruction is important information to first time user since the user need to manipulate the player avatar to each area to complete tasks. Figure. 4.15 shows the content of movement and control instruction, images were located on the left side, and the corresponding explanation is followed to the right. This section included three parts,

keyboard control, mouse control, and quick access. This section introduced these three ways of movement and control to the user to help them quickly get started. Moreover, the two different shape of cursor introduced is to indicate different kind of interaction.
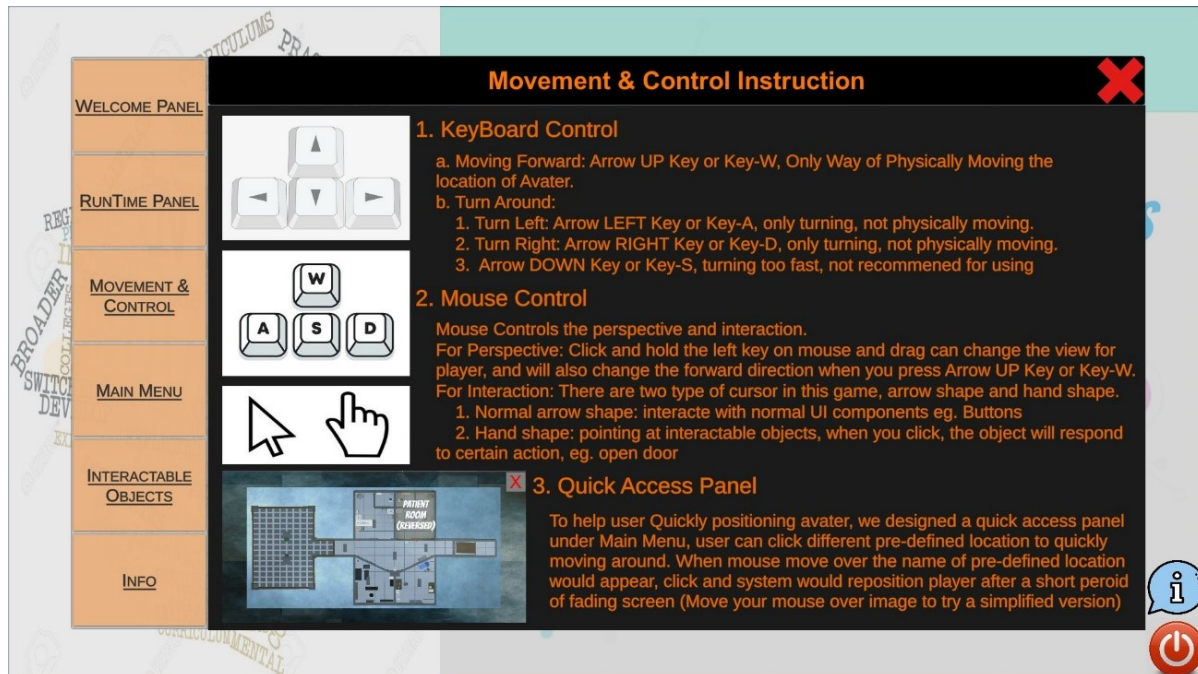
Figure 4.15. Movement and Control Instruction

As presented in Figure. 4.16, Main Menu panel was designed to just as it would be like in real game event. User can navigate the main menu panel by clicking the buttons on main menu panel on the left side, each option would bring the user to a new tab of combined pictures and detailed explanation on the top.

- PPE option would bring the user to take on and off PPE operation.

- Control Panel option would show the three level panels together with explanation as shown in Figure. 4.16.

- Report option would show the initial empty report and a filled report as comparison to demonstrate how the report is generated, and text information would explain the possible result shown in each report step.
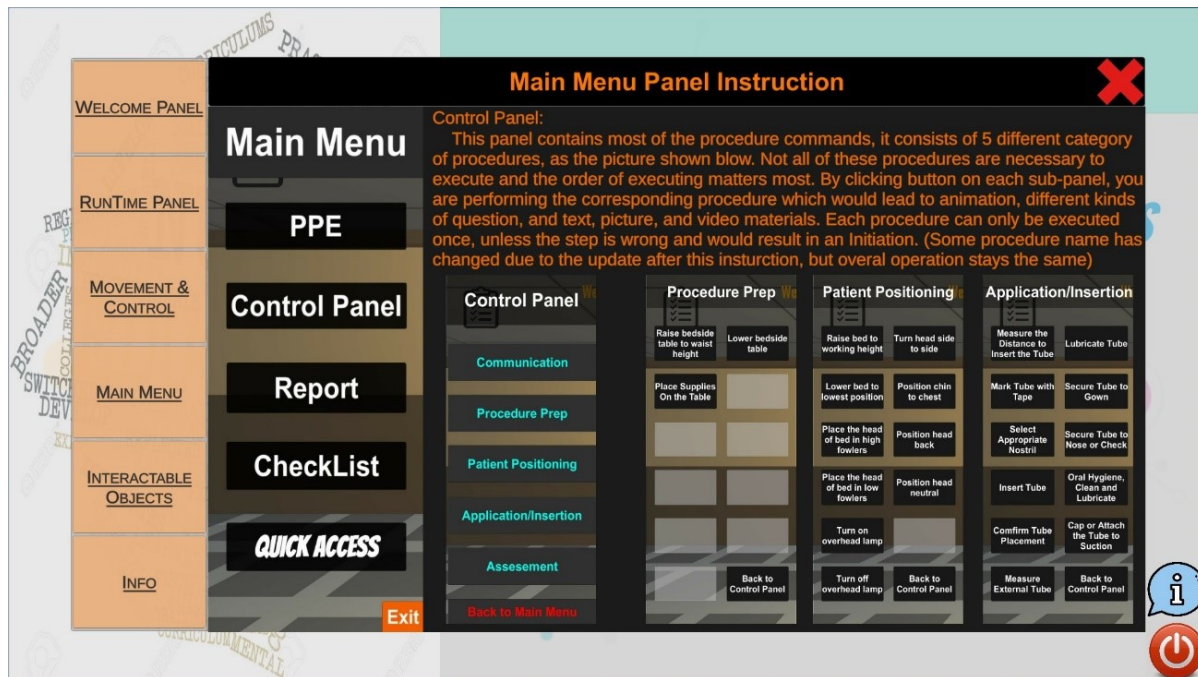
Figure 4.16. Main Menu Panel Instruction

- Checklist option shows the checklist for the game procedure and lets the user know there is an option of digital procedure checklist they can refer to when hard copy is not available

- Quick Access option shows the Quick Access panel with simplified animation, the animation allows the user to try out how to use the panel and to experience the procedure of relocate player avatar.

- Exit option allows user to return to the tab as shown in Figure. 4.16, indicating the effect of exiting the main menu panel.

Interact-able Objects Instruction was separated to two categories, introduction and actual detailed explanation about each interact-able object. Introduction contains the general information about this section, introduced how to distinct interact-able object with others, how and where to activate the animations featured with these objects, and how is this section organized. Detailed information about each objects were categorized by their physical location: patient room, corridor, and storage room.
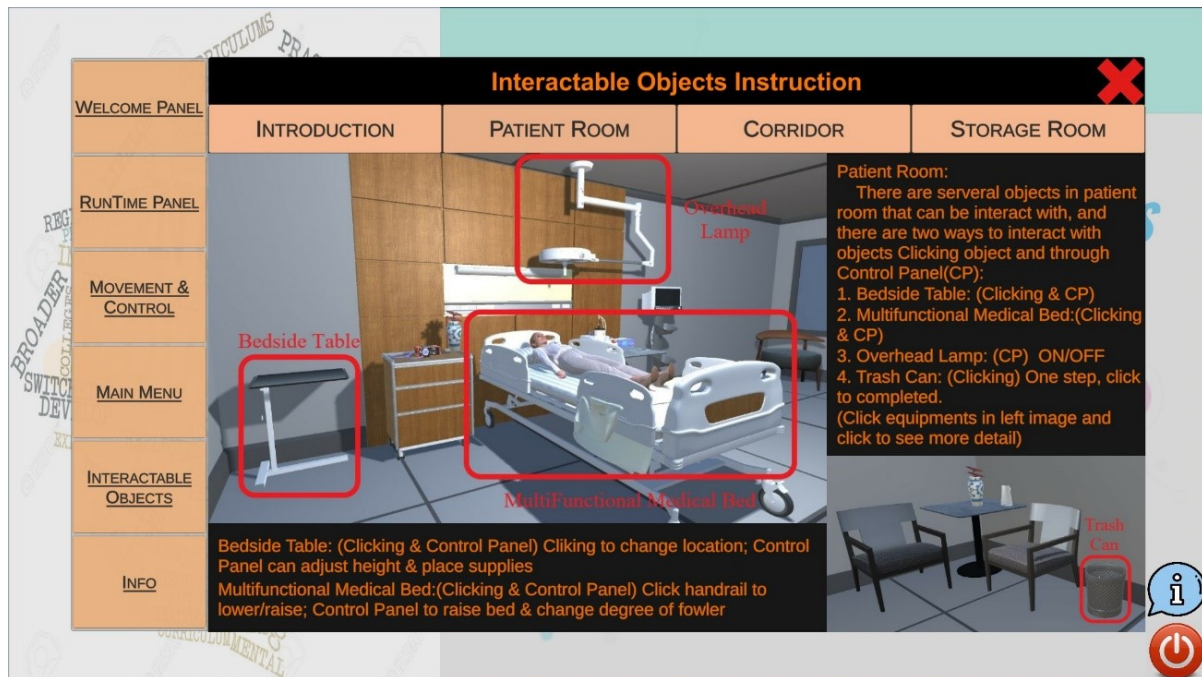
Figure 4.17. Interact-able Objects Instruction: Patient Room
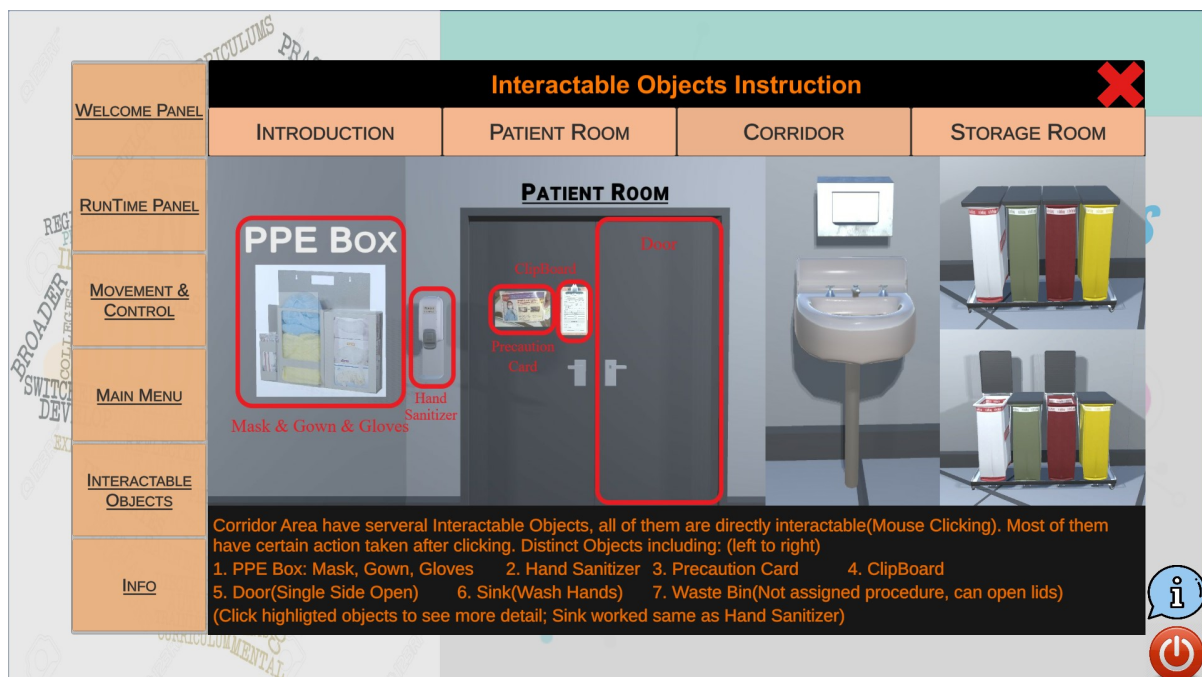
Figure 4.18. Interact-able Objects Instruction: Corridor

- Patient Room as shown in Figure. 4.17 contains four interact-able objects, bedside table, multi-functional medical bed, overhead lamp, and trash can. Except the trash

can, all other three objects were featured with animation, user can click the specific area to see the picture of completed effects.

- Corridor area contains seven different interact-able objects as listed at the bottom of Figure. 4.18, the first four objects are featured animation in this instruction tab. Follow the instruction, user can have a basic understanding of how these interaction work.

- Storage Room has two major objects: computer and supply closet as shown in Figure. 4.19. These two objects was placed on the left area of the instruction tab, and right side was the detailed information. User can switch content on the right side by clicking each object same as the setting during the game. Supply closet tab featured with multiple layers of animations is for explaining how the supply inventory works.
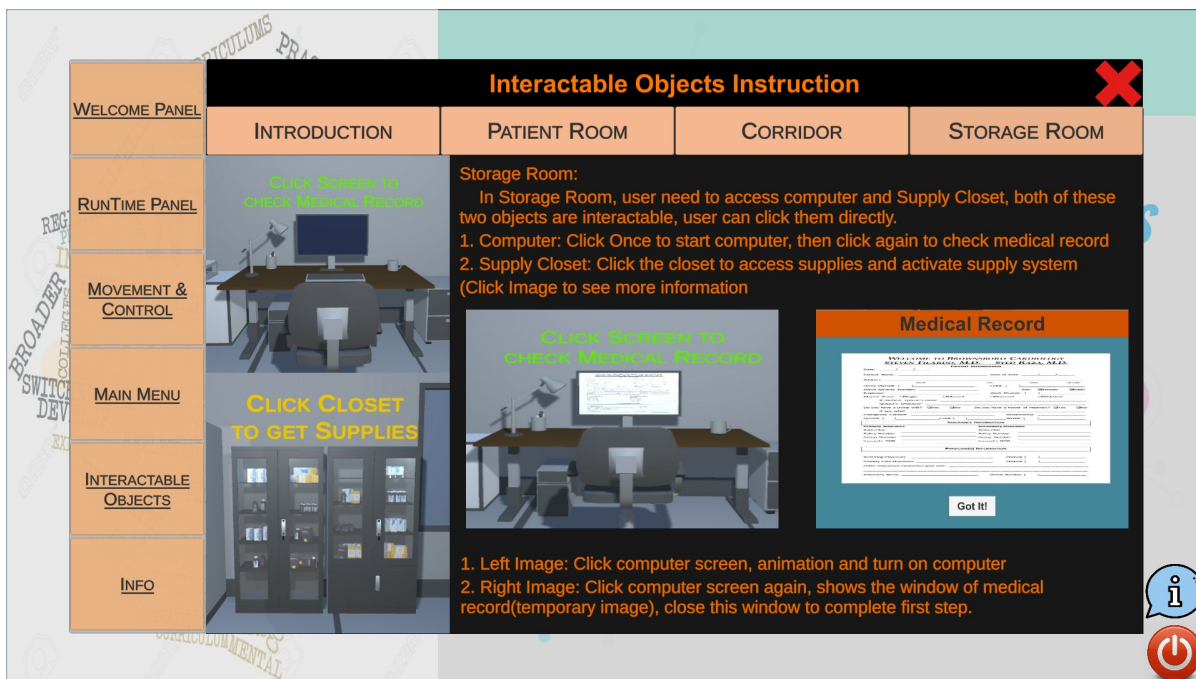
Figure 4.19. Interact-able Objects Instruction: Storage Room

The instruction panel was designed for user to have better understanding of how to take advantage of all the features implemented to the game and for user to be able to quickly start the game. This instruction introduces the game from almost all aspects, the graphic

user interface, the game control, and the interactions. Provides answers for all the possible questions for the game, and adds as much as possible animation to help user have better experience of using this simulator for practice nursing skills.

4.3 Evaluation System

In this section, we propose an evaluation system to record procedures performed by user and to provide the user corresponding feedback. The basic mechanism of the evaluation system has been listed in Algorithm. 1, and the final report generated by the evaluation system has been depicted in Figure. 4.20. As shown in Figure. 4.20, the report consists of two parts, procedure step record that records performed procedure information, and score that provides credit point for each correct procedure.

Algorithm 1 Procedure Evaluation System

1: **for** Every procedure step **do**
2:     **if** This step is valid to proceed **then**
3:         Perform step procedure
4:         **if** Question not required or answer is correct **then**
5:             Update Record, Score, report, and Information Dialog
6:         **else**
7:             i ←The predefined return step number for this step
8:             **while** i $<= CurrentStepNumber$ **do**
9:                 Initiate game setting, Record, Score and Report for step i
10:                 i = i + 1
11:             **end while**
12:         **end if**
13:     **else**
14:         Initiate game from predefined return step to current step
15:     **end if**
16: **end for**

The term procedure step means step number, which has been used as validation criteria in "validate step" of the flowchart as shown in Figure. 4.21, and the actual procedure performed in game is interaction and question. The procedure step and score both starts at 0 and each procedure the user performs should pass the step validation, then the right answer about the procedure question (if applicable) given by the user will be counted as credit. After that,

the evaluation system records the information of the completed procedure and updates the score, report, and information dialog as illustrated in Figure. 4.4 in the real-time.

(a) Report: top

(b) Report: bottom
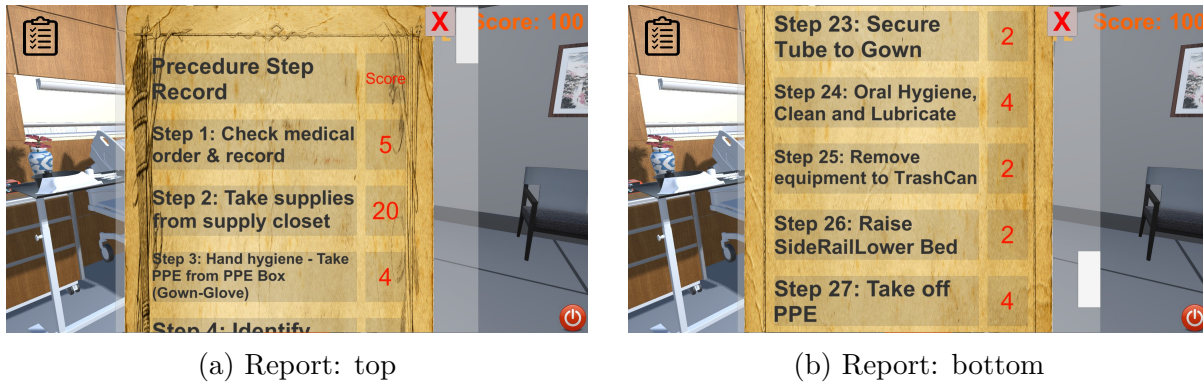
Figure 4.20. Evaluation System

The step validation process works as shown in algorithm. 1. To start with, normally a step procedure is valid if it is the next step of the last procedure completed. However, there are some exceptions such as the procedure "explain discomfort to the patient" which would be a good practice but not a necessary procedure to proceed successfully. Therefore, procedures that would not affect the fundamental functionality would be categorized as "can be skipped" in our application as shown in Figure. 4.21, and would only cause losing some points without affecting to continue the procedure. However, other procedures that are much critical and might affect former procedures such as "Insert Tube" would cause an initiating step back to a predefined step to eliminates all the possible problems. Besides, if the procedure proceeds with a question, then the user needs to provide correct answer to gain credit, incorrect answer would be treated same as an invalid step.

Therefore, if the procedure is not valid or an incorrect answer for procedure is given, the system decides which former step the game needs to initiate from based on the predefined standard procedure provided by the healthcare professionals in the field. In this case, the game starts from the predefined procedure step because of the wrong step/answer given, then it clears all the record and score till the current step. The information dialog on the top would inform the user the reason for the failure of step validation or the answer provided was not correct and further provide information on which step the user should start from.
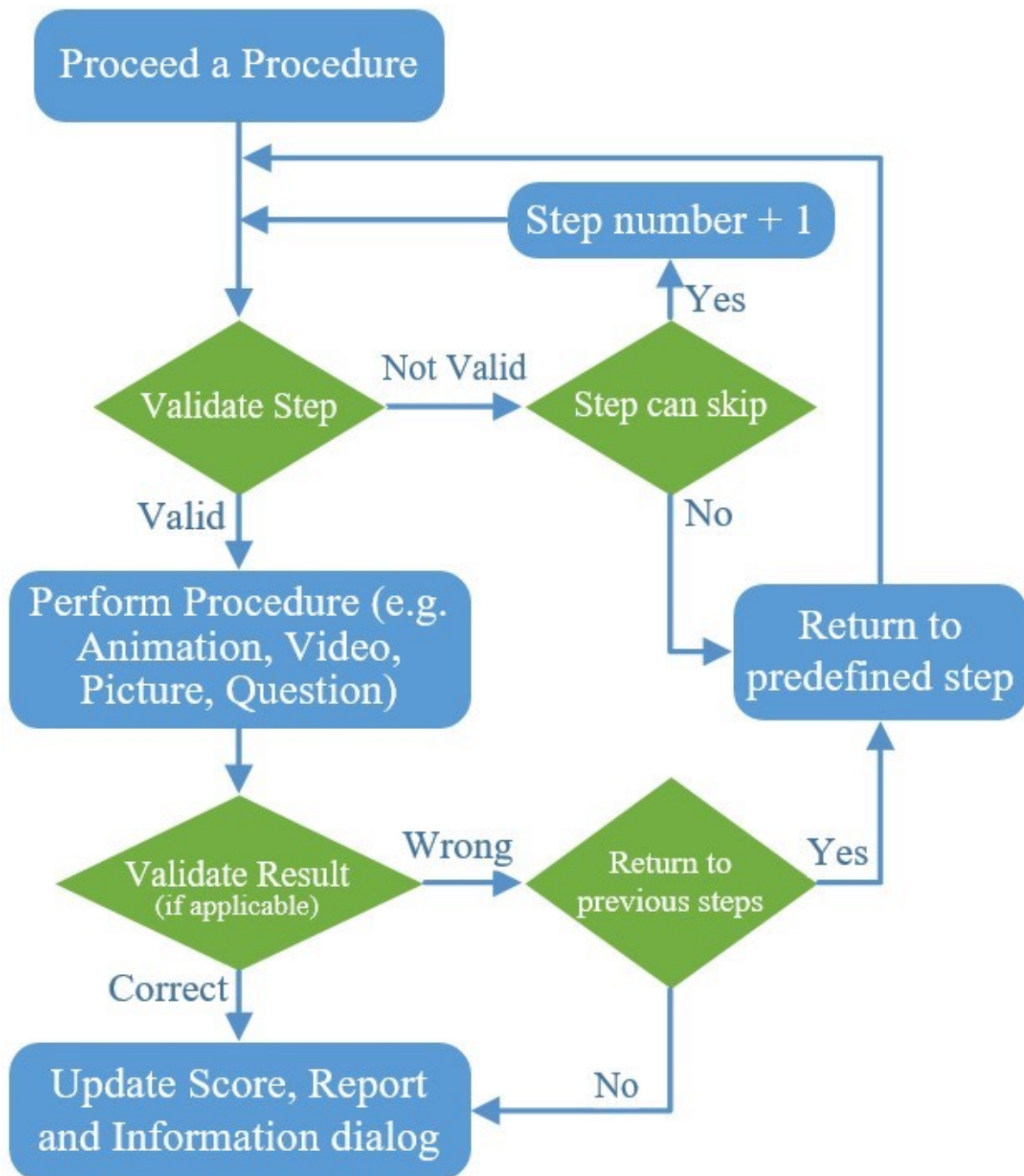
Figure 4.21. Game Mechanism Flowchart

The report system records all the procedures performed by the user and calculates the score for each procedure and total score gained. If procedure was skipped, the record would show as "Missed Step" and score would be zero for that step. Each time an initiation happened, the report would be initiated correspondingly to track real time performance of

the practice. When the user completed the practice, the report would generate a simple conclusion regarding the score gained by the user for review.

By following the standard procedure and the guide, when the end of the game is reached, the user is guaranteed to practice the standard procedure completely at least one time. Moreover, the system also keeps track of the procedures performed by the user and updates record and score after a complete procedure step is finished. User can access the report anytime during the game through main menu panel, and when the final procedure is completed, the report is automatically generated and presented to the user as a feedback. The determination of fairness will be determined when evaluated in future work.

5. PRELIMINARY TEST AND ANALYSIS

A preliminary test was conducted in an undergraduate nursing class `NUR 19202 Foundations Of Nursing` in `Purdue University Northwest`. Two unexpected reasons lead to a small sample results returned due to the pandemic of COVID-19. One is that the process of IRB approval was delayed. Due to this reason, when the software was presented to the nursing class, the students have already completed the learning topic covered in the software, and therefore many students are lack of interests in testing out the software. The second reason is that the nursing class is converted to online learning format this semester. It is challenging to demonstrate such a game over a virtual zoom meeting to the whole class. This caused that the preliminary test was conducted unsupervised, the result was collected through voluntary and anonymous survey, and only eleven reports were received from the test.

5.1 Test Subject Information

As listed on Table. 5.1, the age distribution of these results were: seven from age 21 to 25, two of age from 26 to 30, and two from age 35 to 40; all eleven results were from female. Seven of them were enrolled on traditional track, four on accelerated track. Two Junior year, five Sophomore year and four 1st semester accelerated as listed on Table. 5.2. Among these eleven students, four of them were current video game player, and two of these four play games 2 to 4 hour a week; one use to play on regular basis, five rarely play video games and three never played video game before as listed on Table. 5.3.

Table 5.1. Test Subject Information - Age & Gender

	Age Group			Gender	
Category	21-25	26-30	35-40	Male	Female
Number	7	2	2	0	11

5.2 Preliminary Test Result and Analysis

According to the result listed on Table. 5.4, two students found the game easy to navigate and the avatar is easy to control, which is consistent with the game play statistic that only

two students were currently game player and play games in weekly basis. Three students believe the game provided helpful feedback, four student found the video and audio materials provided in this game was helpful, and seven students think the graphic and environment feels realistic.

Table 5.2. Test Subject Information - Enrollment

| Category | Enrolled Track | | School Year | | |
	Traditional	Accelerated	Sophomore	Junior	1st Semester Accelerated
Number	7	4	5	2	4

Table 5.3. Test Subject Information - Game Play

| | Current VG Player | | Weekly VG Play Time | | | |
Category	True	False	Never	Rarely	Use to Play	2-4 hours
Number	4	7	3	5	1	2

Table 5.4. Game Control & Experience

	Easy Navigate	Helpful Feedback	Video & Audio Helpful	Graphic Realistic	Easy Control Avatar
True	2	3	4	7	2
False	9	8	7	4	9

The data on Table. 5.4 shows clearly differences between video game player and student who have no experiences on playing video game. These two regular video game players give positive respond on all control and experience items. As for material used and realistic experience, seven out of eleven test subjects provided positive feedback. As for the avatar control, which is not a focus for this game, only the students who had gaming experiences can easily control avatar. The major reason for having negative feedback according to these data was the experience of playing video game and the fact of that none of the test subjects were trained to use the game before.

Four feedback address that the checklist was helpful and can be easily referenced as the one received in class. Three enjoyed the graphic and felt it was realistic, and liked the setup of entering into a patient room virtually. Two found that the clipboard, precaution board, and PPE box around the patient room door area were helpful as real practice. One liked that the control over the avatar, one stated playing the video game was preferred to reading or watching videos. The students enjoyed that the game was specifically designed for nursing students. Additionally, subjects felt that the game provided more hands on experience and real time feedback (using the report function).

The students identified several areas for improvement which included: lack of avatar control, poor viewer perspective, poor bed positioning functions, and frequently needing to open the menu. Users identified areas for improvement which included the following: feedback for incorrect step during procedure and provide a method to complete physical assessments. Most of the dislike part and the part they want to improve was caused by the lack of experience of gaming and the fact that they have not received any training or information about how to use the game for practice. To address these problems, instruction panel was created to help students quickly learn to use each feature of the game. More user friendly settings would be implemented in the future to help users who did not have adequate gaming experiences.

Among the eight feedback collected for question "What other nursing skills do you think that a game like this could help improve?", all responds received were positive. The students believed that the perfected game would assist them in being successful in test-outs. They believe this kind of game could improve the process of steps and confidence, basic procedural practices and bed side care, nursing skills checklist in general, and "a lot of skills in the foundations class such as catheter insertion and removals, doing a bed bath, re-positioning patients, wound dressing changes, etc.". In addition it could provide more options for communications. Five out of eleven students suggests that they would use this game to practice for skill test out.

In general, these eleven preliminary test results shows positive attitude toward the proposed game despite most of the test subject have very limited gaming experiences, and none of them have received any training of how to use the game to practice prior to the test. This

test was very limited on time frame, evaluation plan, test preparation, and most important test subject amount, but the result still indicates useful information due to the varied age distribution, the distinguish gender preference, and the lack of gaming experiences, which provided valuable improvement suggestion for the future development of the proposed game.

6. CONCLUSION AND FUTURE WORK

We implemented an innovative serious game as a complementary tool for undergraduate nursing students to practice procedure skills. In the game, we created a realistic 3D hospital environment, featured plenty of intriguing interaction and animation, designed different kinds of user friendly graphical interface, and developed a novel evaluation system. The interaction and animation in our game provides fun and playability to user for sustained learning. The various GUI and the evaluation system brings considerable complexity. The realistic hospital environment makes the game an effective supplement for nursing education. Finally, the proposed game allows user to practice procedure skills in a safe and effective environment, helps solve the problem of increasing enrollment, deficiency of nurse educators, and insufficient simulation opportunities in the nursing field.

The preliminary test shows that the proposed game was supported by nursing students, and could potentially improve the process of steps and confidence, basic procedural practices and bed side care, nursing skills checklist in general, and "a lot of skills in the foundations class such as catheter insertion and removals, doing a bed bath, re-positioning patients, wound dressing changes, etc.".

In regards to the future work, with the responds we collected from the preliminary test, the proposed game can be improved by adding more user friendly features to make the game easier to play and by making the real-time feedback more evidently to help nursing students improve their procedure skills by using it. Other than updating the game features, there are two directions that can help improve the current result. One direction is to design a more comprehensive evaluation plan to assess the effectiveness of the game, and the other direction is to implement more procedure for practicing purpose. Further, this game can also be transferred to other portable platforms such as mobile devices and VR/AR.

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A. USER MANUAL AND PROCEDURE CHECKLIST

Movement & Control: Keyboard Control

Keyboard control have two ways, using WASD keys or using arrow keys. As shown in Figure. A.1, key W works same as Arrow Up key, key A works same as Arrow Left key, key S works same as Arrow Down key, and key D works same as Arrow Right key. The function of each key has listed below:

- Moving Forward: Arrow UP Key or Key-W, Only Way of Physically Moving the location of Avatar.

- Turn Around:

  - Turn Left: Arrow LEFT Key or Key-A, only turning, not physically moving.

  - Turn Right: Arrow RIGHT Key or Key-D, only turning, not physically moving.

  - Arrow DOWN Key or Key-S, turning too fast, not recommended for using.
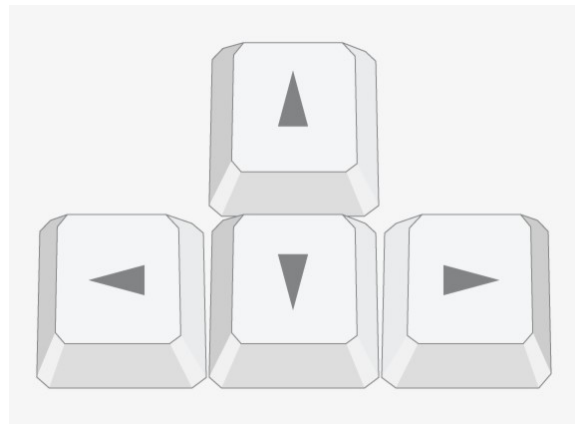
(a) WASD Key   (b) Arrow Key

Figure A.1. Control Keys

Movement & Control: Mouse Control

Mouse Controls the perspective and interaction.

- For Perspective: Click and hold the left key on mouse and drag can change the view for player, and will also change the forward direction when you press Arrow UP Key or Key W.

- For Interaction: There are two type of cursor in this game, arrow shape and hand shape. Normal arrow shape indicates interacting with normal objects or UI components eg. Buttons. Hand shape means pointing at interact-able objects, when you click, the object will respond to certain action, eg. open door

Movement & Control: Quick Access

To help user Quickly positioning avatar, we designed a quick access panel under Main Menu, user can click different predefined location to quickly moving around. When mouse move over the name of predefined location would appear, click and system would re-position player after a short period of fading screen.

Interact-able Objects:

The serious game featured with several Interact-able Objects to enhance the playability and realistic of the game. There are in general 2 ways to interact with this game: Interact with Objects(Models), and Interact with User Interface(Buttons).
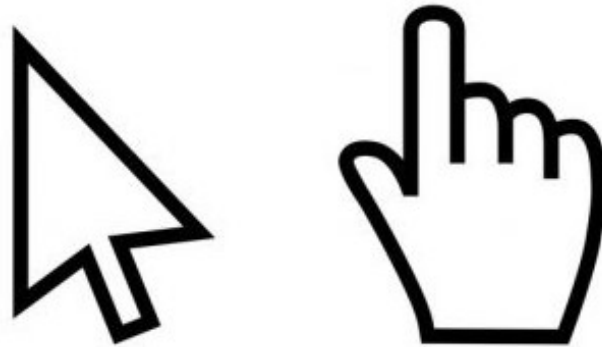
Figure A.2. Two Cursor Shape: Arrow & Hand

As mentioned in Movement & Control Section, there are two shape of Cursor: Arrow and Hand Shape as shown in Figure. A.2, this is the easiest way to decide if an Object is directly interact-able. Arrow shape cursor means mouse is interacting with User Interface(Buttons), and can be used to change view. Hand shape cursor suggests that user is pointing at interact-able objects, user can interact with object by directly clicking the object.

Some of the Object need to use Control Panel(Under Main Menu) to interact with, for example execute "Position Bed to High Fowler" would bring up a Multi-Choice Question and would raise the Fowler accordingly.

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Procedure Checklist:

The proposed game simulated the procedure of `Insertion of Nasogastric Tube`, like a lot of other procedures, a checklist was provided for practice. In order to make the game serves the purpose of practice, to make the game playable, and to make the game considerable complex to help knowledge retaining, the checklist was redesigned specifically for the game. The revised checklist followed the original checklist for nursing practice and added information specific for the game.

The revised procedure checklist has been integrated into the game's Main Menu-Checklist-Procedure part, user can access the checklist anytime during the practice as reference. The revised procedure checklist was listed below on Table. A.1, the table contains three columns:

- Step: indicating the step number, user need to proceed these procedures in order. In addition, this step number can be used to locate current step when step initiation happened(Wrong procedure executed and validation system would redirect the user to predefined former step to fix the potential issue).

- Content: the brief version of the content of specific procedure, this name is closer to the original checklist for user to be able to quickly transit skills to real life practice.

- Action Name(Location): this column is the specific procedure in a step/sub-step and the name of object or procedure name to execute the procedure. Inside the parentheses is the location to find the procedure, it could be a physical location like Storage Room, or it could be inside CP(Control Panel) or Inventory. The format used to indicating procedure inside CP(Control Panel) was using "-" to represent next level panel, for example "CP-Communication" means go to control panel and select communication panel. Some special ways also been addressed inside parentheses, for example computer need to click twice to activate first step.

The Procedure Checklist was designed to help user quickly start the practice , easily locate current step, and smoothly transit to real life practice.

Table A.1. Procedure Checklist

Step	Content	Action Name(Location)
1	Verify medical order	Computer (Storage Room, Click Twice)
2	Gather equipment	MedicalCloset (Storage Room, Click)
3	Hand Hygigene & PPE	PPEBox (Correct Order)
4	Identify Patient	Patient Identification (CP-Communication)
5	Explain Procedure	Explain Procedure (CP-Communication)
		Address Procedure Discomfort (CP-Communication)
6	Assemble equipment	MedicalTable (Patient Room)
		Raise table to waist height (CP-Procedure Prep)
		Place Supplies On the Table (CP-Procedure Prep)
7	Close patient's door	PatientRoomDoor (Click to close)
8	Overbed operation	Raise bed to working height (CP-Procedure-Prep)
		Place bed in high fowlers (CP-Patient Positioning)
		11-Disposable pad (Inventory)
		12- Emesis basin (Inventory)
		9-Medical Tissues (Inventory)
9	Measure distance	Measure the Distance to Insert (CP-Application)
		Mark Tube with Tape (CP-Application)
10	Lubricate tube	3-Water-soluble lubricant (Inventory)
		Lubricate Tube (CP-Application)
11	Select appropriate nostril	Select Appropriate Nostril (CP-Application)
12	Head back	Position head back (CP-Patient Positioning)
13	Insert Tube	Insert Tube (CP-Application)
14	Chin to Chest	Position chin to chest (CP-Patient Positioning)
15	Sip water & advance tube	10-Glass of water (Inventory)
		15-Straw (Inventory)
16	Secure tube to nose/check	Secure Tube to Nose/Check (CP-Application)
17	Confirm Placement	Call Physician (CP-Communication)
		Confirm Tube Placement (CP-Application)
		Measure External Tube (CP-Application)
18	Apply skin barrier	17-Skin barrier (Inventory)
19	Secure tube around tube	8-Nonallergenic tape (Inventory)
20	Clamp tube	Cap/Attach the Tube to Suction (CP-Application)
21	Measure exposed tube	16-Tape measure (Inventory)
22	Turn head to opposite side	Turn head side to side (CP-Patient Positioning)
23	Secure tube to gown	Secure Tube to Gown (CP-Application)
24	Oral hygiene & lubricate	Oral Hygiene, Clean and Lubricate (CP-Application)
25	Remove equipment	TrashCan (Patient Room, Click)
26	Adjust siderail and bed	Raise HandRail (Patient Room, Click HandRail)
		Lower bed (CP-Patient Positioning)
27	PPE & Hand hygiene	PPEPanel (MainMenu-PPE)

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