Serious Games Fire Safety Awareness

Univeristy west of scotland | Computer Games Technology

A software solution for fire training procedure

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# Abstract

TBC

# How to read this paper

The paper will start with an introduction in the first chapter where the most recently available statistics reveal a problem with the current fire safety knowledge amongst people and is immediately followed by a suggested solution to use a software application in an attempt to increase the awareness through a serious game. The second chapter starts by presenting the topics covered in the literature review, covers previous work done related to the topic and displays the conclusions of the findings. The third chapter will present the design of the application and will output the available scenarios in the application. In the fourth chapter implementation details will be revealed related to the approach used for the development and tools and assets used to achieve the production of the application. The paper concludes with the evaluation of the game and an individual critical appraisal from the authors.

# CHAPTER 1 - Introduction

## The problem

Even in this modern era, the fire still seems to be one of the most dangerous hazards, causing damages that are difficult to recover. According to FIRE AND RESCUE STATISTICS SCOTLAND 2014-15[[1]](#endnote-1) there were 25,002 fires in Scotland of which 10.629 were primary fires: 8,219 (77%) *accidental fires* and 2,410 (23%) deliberate.

Although the number of fires is on a descend trend in Scotland, the dominance of accidental fires is very worrying.

The SFRS’s Strategic Plan for 2016-2019 reinforces that their purpose is “*to work […] on prevention, protection and response, to improve the safety and well-being of people throughout Scotland”* [[2]](#endnote-2). The emphasis should be on the key word *prevention*. This paper tries to help improve the prevention task using the serious game FSA.

This would provide more accessible knowledge regarding the fire safety regulations and using the computer it will make the training more appealing, safe, interactive and easier to understand.

## The solution

The Fire Safety Awareness application (hereinafter called FSA) is a serious game, a software prototype designed to help trainees to become proactive and reactive to fire events. The application is being developed using the Unity game engine and consists of a fire safety awareness presentation, fire safety tests and a mock certification. More details about the application’s design can be found in chapter 3.

## Learning Outcomes

From the start of the application, FSA is designed to have an educational purpose. Because it uses information from The Order[[3]](#endnote-3), the game is very accurate and very good at displaying to the regular user essential information related to the current fire safety standards.

After completing the tutorials in the game the user will gain more knowledge about fire hazards, will improve its fire safety awareness and will be able to:

* Identify fire hazards and learn about the fire triangle
  + Identify sources of ignition
  + Identify sources of fuel
  + Identify sources of oxygen
* Identify the fire safety elements
  + Signs and notices
  + Fire doors
  + Escape routes
  + Lighting
* Evacuate a building in case of a fire or a drill
* Identify and correctly use the right type of fire extinguishers
* Virtually put out a fire

# CHAPTER 2 – Literature review

## 2.1 Overview

This part of the paper will analyse the work done previously in the same area where FSA resides. Amongst topics discussed, the review will cover the following (not necessarily in this order):

* the current state of training
* the benefits of using a serious game over traditional methods
* the issues with serious games
* the difference in costs involved when using a serious game compared to a fire training
* the current limitations

## 2.2 Background

Researchers Chittaro and Ranon (2009)[[4]](#endnote-4) found that current reactions to fire emergencies are inadequate. The main issue is not only the lack understanding on how to deal with a fire properly but is also down to so called “panic” reactions which disable occupants from applying their limited knowledge to the situation. In their paper they refer to this as the “cognitive paralysis” phenomenon where people do not take any action at all leading to fatalities in completely survivable situations. The research highlights that traditional methods are not working. It also states that in 2007, 3000 civilians lost their lives in the US alone.

### 2.2.1 More training is required

Research by Silva et al. (2013)[[5]](#endnote-5) found that major hospital fires which have well planned emergency procedures still resulted in fatalities due to unpreparedness for emergency conditions.

Yang and Chen (2015)[[6]](#endnote-6) took a mathematical approach on the spread of fire safety awareness in a University Campus. They revealed a generalised parametrical formula and putting different parameters for students’ awareness about fire safety they concluded that having most students with *Strong* fire safety knowledge, part students with *Medium* fire safety awareness and less students with *Weak* awareness will reduce fire risks and accidents from the source. This only demonstrates that a higher fire safety knowledge and awareness will reduce the risk significantly and backs up the need of training.

### 2.2.2 Current training

NorHazren and Kherun (2014) highlight the need of training on hazard identification. They define hazard as “*a source or a situation with a potential for harm in term of human injury or ill health; damage to property and to the environment; or a combination of these”[[7]](#endnote-7)*. They describe the current structure of a training, which consist of a lecture, hands-on and video demonstration and promote the need of training on hazard identification. While they put emphasis on a more practical approach when delivering the training, their solution – a technology application, a game – contradicts their suggestion.

They discuss the fact that training is not only costly, but also lacks hands-on input. Using games, training becomes more safe, interactive and entertaining, but dealing with fire in a hands-on situation, better prepares the trainee to take the right decisions and reduces the fear of fire.

DeChamplain et al. (2012)[[8]](#endnote-8) has highlighted a severe lack of preparedness for fire emergencies with only 23% of those going through house fires in the US stating they had an evacuation plan they executed for their home, showing that preparedness is not just a problem for large urban buildings, but also smaller buildings such as homes as well.

After analysing these articles, it is possible to identify a gap in the current understanding amongst citizens in how to deal with common fire threats and evacuations when presented with a fatal fire. Current training is inadequate due to its inability to simulate proper “panic” conditions to test the subject’s reactions and decision making in this critical juncture. A proper alternative to current training available, which adequately trains people to deal with hazardous situations, would need to ensure that any simulation does its best to mimic real world conditions.

### 2.2.3 Serious games – issues and advantages

Chittaro and Ranon (2009)[[9]](#endnote-9) state that current 3D game engines are unable to provide the immersive graphic fidelity they would expect. This is not a valid statement anymore… the lack of graphical fidelity is a state of the past, which is expected as this paper was written in 2009. Current game engines are capable of photo realistic scenes and these are no longer seen as a limitation. However, the development of realistic assets to be imported into the engine is a limitation, as extra work needs to be inputted in creating an environment that is immersive. Serious Games simulation can only go so far as their paper points out. The ability to simulate fitness, toxic smoke, strength and injuries are all conditions that cannot be realistically simulated for obvious reasons. While game mechanics can be introduced to fake these effects, it will still relegate a Serious Game on fire training to be a supplement to established traditional training.

In a more recent paper Chittaro and Sioni (2015)[[10]](#endnote-10) discuss how serious games could be used to prepare people for emergency situations. They found that people understood the severity of situations much more clearly in a serious game setting, and their knowledge was vastly superior to people who had not tried the serious game. This aligns closely with the core idea of FSA, as the main purpose of FSA is to teach people knowledge so they are much better equip to deal with emergency-fire situations.

Research conducted by Capuano & King (2015)[[11]](#endnote-11) show Serious Games offer a way of navigating skill and knowledge retention issues that most training methods suffer from today. They found that most training is forgotten about or simply ignored by its participants as they judge it to be mediocre and unimportant to their daily duties. They reveal that Serious Games can be effective tools to support training for emergency preparedness due to their immersive approach. They also identified that gamification resulted in increased learning transfer and retention solving the issues identified in traditional training methods. What is more interesting however is the possibilities above just user simulation but enhanced evaluation.

In their case study Kapralos et al (2013)[[12]](#endnote-12) found that while Serious Games are very popular in today’s world, representing a $1.5-billion-dollar industry in 2010, the market has been cluttered with too many examples of ineffective Serious Games. Indeed, the market is cluttered with ineffective examples, but there is at least little learning experience in any game that defines itself serious. The conclusion found in the research paper states that it is more of a product of ineffective instructional design rather than Serious Games as a medium being unable to support learning activities.

Smith and Trenholme (2009)[[13]](#endnote-13) talk about how it is difficult to stage fire-drills in modern buildings, and some of the downsides, like lack of smoke or blocked exits. They found that one developer could create a virtual environment in around three weeks, which could be used indefinitely. This has obvious benefits over a fire drill, which cannot be re-created the same was as often. They also found they could see where people went wrong, since all the information of what a person was doing and when was stored. It would be almost impossible in a real-life drill setting to track people movements in the same manner and discover if they endangered themselves when leaving the building, like running down a smoke-filled corridor. FSA uses this idea, by giving the player a "score" of how well they did at the end, based on their reactions and decisions taken when dealing with the issues presented.

Bernardes, Robelo, Vilar, Noriega and Borges (2015)[[14]](#endnote-14) talk about how serious games and a virtual environment can be used as a tool to save people money in fire-safety training. They found that, as the serious game could be stopped at any time to issue individual feedback to players, it was much more valuable than a drill, in which more general "group" feedback is applied.

In his research Moreno-Ger (2014)[[15]](#endnote-15) shows a key advantage of Serious Games, the ability to provide in detailed assessment that provides a better understanding of a trainee’s progression. He also suggests how this can be expanded on with custom assessment profiles and in detail report generation to provide view of a subject’s skills that goes far beyond a traditional training assessment. Serious Games offer a way around the knowledge retention problem that general education suffers from today and offers ways of analysing subjects that are unseen in traditional training methods. Using Serious Games, we have the ability to attract an audience by going beyond traditional training and providing realistic 3D simulations that is only possible when technology from games are leveraged. Serious games are an opportunity to forego identified issues and present a training alternative that will properly prepare users for fire emergencies through realistic simulation and in detail performance analysis.

Ericson (2007)[[16]](#endnote-16), shows that there was some success in using serious games to teach fire safety to children. Ericson talks about how serious games introduced a “fun” aspect, which many of the children in her study found engaging. In the second iteration of her experiment, she allowed the children to explore the area themselves and found that, without a guide, many of the children enjoyed the experience more and learned how to react in emergency situations better. This demonstrates that, by using a serious game, people can explore otherwise dangerous environments themselves, and become more familiar with how to proceed in an emergency.

Meesters and van de Walle (2013)[[17]](#endnote-17) discuss the use of a serious game over a recreation of a disaster or a drill. They put forward the idea that a full-scale recreation can be overwhelming to newcomers. The paper finds that all the decisions are very similar to the real-life, even if they had no prior knowledge. This shows that serious games could be used for more fully to train people for emergencies.

Kobes et al. (2010)[[18]](#endnote-18) also discusses how people react different in real-life drills and virtual reality. They also found that the participants had very similar times for the drill and the serious game. However, the virtual reality serious game had other benefits over the drill, including being able to simulate smoke which would block exit signs or even make corridors unusable.

### 2.2.4 Previous fire safety applications

In their “Blaze” game, DeChamplain et al. (2012)[[19]](#endnote-19) address the problem of evaluating the fire. Most fire safety games are related to the evacuation procedure, but “Blaze” also teaches the user how to put off a fire if is safe to do so. In the application, the user should only evacuate if the fire becomes too large. The action takes place in a home rather than an office, which makes the user more comfortable and more connected to the environment as all the items seem familiar to the player.

FSA will try to replicate the scenario where the trainee needs to evaluate the fire before deciding to extinguish it or to evacuate.

Radianti, Lazreg, et al. (2015)[[20]](#endnote-20) discuss a serious game where they show how flame, smoke, and heat affects a five-story apartment over time. Even despite some limitation in the application, it yielded positive results and players were able to improve their real-time decision making in an emergency situation and react to different dangers. This is similar to the Fire Safety Awareness application (FSA), where players will be able to see how a fire affects a building over time. However, FSA goes one stage beyond this, and allows the user to actually experience dealing with the fire rather than just observing.

Almeida, Jacob et al. (2014)[[21]](#endnote-21) developed a serious game to track subject’s reaction for evacuation scenarios. Their project technology stack and idea will be similar to what FSA will produce. They used Unity 3D game engine and created a few scenarios. While their paper was mostly focused on evacuation, the benefits of serious games are easy to observe again, as repeating over and over the right procedure can only better prepare the subject for a real live scenario in the event of a real fire alarm.

In a different paper Ribeiro et al. (2012)[[22]](#endnote-22) noticed that the average time for evacuating a building in a virtual 3D environment is actually higher than the real life time interval. This only reveals that the evaluation contained a large tolerance for error. It is not mentioned either if the scaling of the 3D models used or if the physics are correctly applied in the application. Even if their serious game was developed using Unity and physics is granted from the start, scaling the models correctly, adjusting the right movement speed of the player are key aspects that need to be perfectly tweaked in order to deliver a player behaviour which can be measured in real time and return satisfying results.

The researcher also points up that the regular game players obtained better times. This could falsely result in a statement that the users with more gaming experience are better at preventing, or extinguishing a fire.

Xi and Smith (2014)[[23]](#endnote-23) bring to the topic the addition of a Non Playable Character (NPC) when simulating fire drills using serious games. They draw the attention to the fact that NPCs have limited, scripted reactions when are modelled as a finite state machine, while a human would take decisions by also considering social factors. They mention the alternative approach to model a NPC using a Multi-Agent System (MAS) which can simulate basic behaviours, such as “target finding, target recognition and rescue pathfinding”, but raise the problem that not too many of these systems have fire science integrated.

Even though adding NPCs to our application would increase interactivity and realism, this is outside of the scope of this project and NPCs will not be implemented in our fire training scenarios.

Park, Kim et al. (2015)[[24]](#endnote-24) come with an interesting solution related to fire safety. In their experiment a HARMS (Human-Agent-Robot-Machine-Sensor) system is used to identify a survivor in a fire scenario. Their solution sounds safe, but even ignoring the flaws noticed by the authors, this does not seem to be something that companies would embrace, due to the high costs of the necessary equipment.

While this scenario sounds plausible and would be nice to have in FSA, the training would be more related to controlling the systems involved in the HARMS solution rather than being focused on human knowledge related to fire safety.

McGrath and Hill (2004)[[25]](#endnote-25) discuss a simulation of a mass-causality incident developed using the Unreal game engine. They found that, compared to traditional methods, their work had a lower cost and much more re-usability compared to traditional methods, like arranging a fire drill. While FSA is being developed with Unity, not Unreal, the benefits a game engine provides for productivity still apply, which is strengthens the choice of using of a good game engine like Unity when developing an application like FSA.

Fang, Di and Jun (2014)[[26]](#endnote-26) created a whole system for organisations which allows real-time monitoring to be performed. While their platform could gather statistics about places with most frequent fire alarms and could also suggest where renovation and maintenance should be carried out, these places also highlight where the personnel would need more fire safety education, as it is not only authorities’ responsibility to prevent fires.

Rüppel and Schatz (2010)[[27]](#endnote-27) discuss how the Building Information Model (BIM) can be used to rapidly create some recreations of some buildings which cannot be closed for training, like a hospital. The paper finds that simulation elements, like smoke, closely mirror their real-life equivalents and provide a realistic experience for firefighters. This is similar to FSA, which will have a "evacuation" mode in where players have to escape a burning building in which some exits may be blocked. The paper also discusses how using a serious game is much more cost-effective for the company compared to a drill, as they do not need to shut down during it.

In a more recent paper (2011)[[28]](#endnote-28) they use the BIM and virtual reality to present the effects on the condition of a building during a fire evacuation. They found that, using BIM, they could easily import different scenarios. This allows people to get more comfortable dealing with an emergency in a variety of office settings. This is similar to FSA, as people are given multiple scenarios to deal with in a fire-emergency situation, so that they will be more comfortable in a larger number of situations.

## 2.3 Conclusions and discussion

Following the literature review a few conclusions stand out:

* fire safety awareness training is needed to reduce fire risk and to prepare people to deal with fire scenarios
* serious games provide a cheaper alternative to the real training
* a software application enlarges the interest towards learning as it is more comfortable, entertaining, safe and provides subliminal learning due to its iterative property (repeating the scenarios until a pass is obtained helps understanding the right procedures to follow)
* using a game engine helps prototyping the software solution with more ease now than it was previously possible
* serious games allow timing, tracking and recording of people behaviour during various scenarios and can provide a better analysis, can create hypothetic scenarios without impacting the real world and can accurately model a real fire event
* using serious games will not replace the effectiveness of a real fire training as panic and emotion cannot be entirely accurately reproduced using a game, and these factors can lead to a different (maybe wrong decision) in a real life scenario. Having the best score at extinguishing a virtual fire, does not make one a firefighter, but the proactive aspect of the serious game can significantly reduce the risks.
* The FSA application will take elements from the current findings and try to learn and produce a better fire safety product, which hopefully will increase people’s respect for fire and people’s fire knowledge

# Chapter 3 – Application Design

FSA will be a serious game and a fire training material. The game itself comprises of three main parts: the theory, the practice and the acknowledgement. The theory consists of short educational videos offering enough information to pass a scenario. The practice are the scenarios themselves where the user needs to identify items in a scene or put off a fire, depending on the current scenario. The acknowledgment is the part where the all the progress and score is being calculated to output a pass or fail result.

## 3.1 The main components

The theory will contain many videos that will be mixed with the practice. The lecture video will cover an experiment about the fire triangle and will reveal how to put off a fire by removing one of the three components of the fire triangle. Other videos are depending on the scenarios the user will play and will be short presentations or reminders related to fire safety, fire hazards, evacuation and fire extinguishers.

The practice component is divided into 4 scenarios:

* The good: the user will identify as many fire safety elements within 30 seconds.
* The bad: the user will identify as many hazards within 30 seconds
* The runner: the user will need to evacuate. The completion time will be recorded
* The fighter: the user will put off a fire using the right type of extinguisher.

First the user will play a scenario without any given information. The score is recorded and then helping information related to the scenarios will be given and the user will play the scenario again.

The acknowledgement part takes the scores from all scenarios, records the progress and sends it to the evaluation engine, returning the outcome to the user: a pass or a fail. For a pass a mock certificate will be generated using the name taken when the game started.

## 3.2 The scene

The scenarios will be taking place in an office set building comprising of 9 superior floors and one ground floor. The building will be accurately created to include office elements (desks with monitors, keyboards, mice and desk phones), fire safety elements (exits, signs, lights, etc.) and hazards (any source of heat or fuel).

Figure 1. The office building model and an internal render from the building

## 3.3 First person

### 3.3.1 The character

The character is an office employee with fire marshal training. He works on the 5th floor and is responsible only for the 5th floor of the building. The character’s access to any other floors’ office space is restricted. The character can use the lifts and open all doors where he has access to.

### 3.3.2 Movement

Movement will be done using the classic W, A, S, D and SPACEBAR for jumping. The character will use the mouse for looking around and the keys for movement. The left click will also be used to confirm the identification of an item or the use of an item and the right click will cancel the identification of an item or abandon using the current item.

### 3.3.3 Scenarios identification task

The good and the bad are both scenarios where the user must lookup items in the office specific to the scenario. The identification will use a crosshair in the centre of the screen and a description box on the bottom right which will reveal what the description of the item the user is currently pointing to as shown in the following image.

Figure 2. The identification tools: the crosshair and the description box

For example, if the state of the game were like in Figure 2, left clicking will add the item “WALL” to the identified list. To remove one item from the list, the user must point to it again and right click. To remove the item “FIRE ALARM” the user must point first to the fire alarm item and then right click.

## 3.4 The scenarios

Each scenario should be played twice. The first attempt will allow the user to solve the scenario without any given information. The score in this scenario will not count towards the pass/fail result but it will be recorded to highlight the progress when compared to the second attempt. After the first attempt, the user will watch a small video where information about what to look for in the specific scenario will be given.

### 3.4.1 The Good

In this scenario, the user must identify as many safety items as possible from the scene within 30 seconds. In this category, the following items are included (but not limited only to these): fire doors, emergency exit sign/light, evacuation procedure sign, fire procedure sign, fire alarm trigger sign, fire alarm, fire alarm trigger, emergency exit door release, fire extinguisher sign, fire extinguishers type A, B, C, D, water hose sign, water hose, fire blanket sign, fire blanket, first aid box, sprinklers, smoke alarm, fire alarm light, etc. The more items the user identifies, the better the score. To pass this scenario, the user must identify 10 correct items. This limit should be changeable externally as well as the time limit.

### 3.4.2 The Bad

This scenario is very similar to “The Good” scenario, only this time the user needs to identify hazards like: any source of ignition (microwave, vending machines, computers, desk-phones), any source of heat (microwave, radiators, pc), any source of fuel (open windows, opened fire-doors, fuel cans), anything that can slow an evacuation (blocked emergency exit) etc. The user should identify at least 5 items within 30 seconds to pass.

### 3.4.3 The Runner

In this scenario, the user will be suggested to freely inspect the office, to get used to the layout of the building. Once 50 meters of distance have been travelled (in any direction) the fire alarm should be trigger. At this point a timer is started and it shall be stopped only when the user reaches one of the 2 emergency exits at ground floor. When the alarm is triggered, the closest emergency exit should be identified and if the user does not evacuate through the closest exit, 10 seconds should be added to the total time. If the user would take the lift, it should automatically fail this scenario once it reaches the emergency exit. A minimum acceptable time should be created and all the users who obtain higher times than the minimum should fail.

### 3.4.4 The fighter

#### 3.4.4.1 Types of fire

There will be three main locations where the fire will be generated:

* At the lifts, where an electricity fire will be generated. This should only be put off with an extinguisher of type blue (dry powder) or black (CO2)
* In the kitchen, at the bins, a combustible material fire will be generated close to bins. This can be put off with any extinguisher type except the black one.
* Close to the radiators, near windows, where fuel cans are located. This can only be extinguished by the blue type (dry powder).

Depending on the fire size there will be two types of fire: extinguishable fires – the small ones, and dangerous fires, the big ones. In the case of dangerous fires, the user should never attempt to put them off and should evacuate. The difference between a small and a big fire should be noticeable to avoid any ambiguities when taking decisions.

#### 3.4.4.2 The flow of the scenario

In this scenario, a random type of fire will be created and the user will be spawned in the proximity of it (so the user will notice it). A timer will start from the beginning of the round. The user should first raise the fire alarm, then should evaluate the fire and choose either to evacuate or fight the fire. No matter if the fire is big or small, if the user always chooses to evacuate, it is an acceptable outcome. If the user chooses to fight the fire, this is the right decision only if the fire is small. If the user decides to fight a big fire, the scenario should instantly fail.

When the user chooses to put of a small fire, it must identify the right type of extinguisher.

The user must point to an extinguisher and press left click to equip it. To unequip it, the user should press right click. Once the user has an extinguisher it should aim at the bottom of the fire and hold the left button clicked. If the user is not aiming towards the bottom of the fire, the fire should scale up gradually. If a certain amount of time has passed (if the fire evolved) the scenario would end in a failure. If the user aims to the fire within time and the fire shrinks until it is put off, then the scenario has been a success no matter how much time it elapsed.

## 3.5 The acknowledgement

This part concludes the training and evaluates the results. If the user managed to obtain acceptable scores in all the training scenarios, the user will be forwarded to a screen where a mock diploma is displayed containing the user’s name and date and the confirmation that the user passed the fire assessment training.

If any of the second attempt scenarios has been failed, the user will be suggested to watch the theory again and to try harder.

This repetitive approach will eventually make the user learn the right procedures by the time a pass certification is issued.

## 3.6 The Menu

The Menu should be a simple list with the following options available for the user:

* Start Training – will start the game
* Theory – will show a list with all videos available
* About – will show information about the application
* Quit – will exit the application

If the user has just passed the Training, in the menu an extra option “View Certificate” should be available.

## 3.7 The application flow

The application flow is best described in the Figure 3. The application starts, records the user name and then shows the main menu. The main menu normally has 4 options, but if the certificate has been enabled for the current user, then it will have:

* [optional] View Certificate
* Start Training
* Theory
* About
* Quit

View Certificate, About and Quit are one action buttons and are described as following:

* View certificate will display the mock diploma if it has been previously obtained
* About will show information related to the application
* Quit will exit the application

Theory will enter another menu where the user can select from a play list a video containing specific theory which interests the user, between these options: *Fire Triangle, Safety Items, Hazard Items, Evacuation* and *How to put off a fire.*

Start Training will enter in the first attempt of the first scenario.

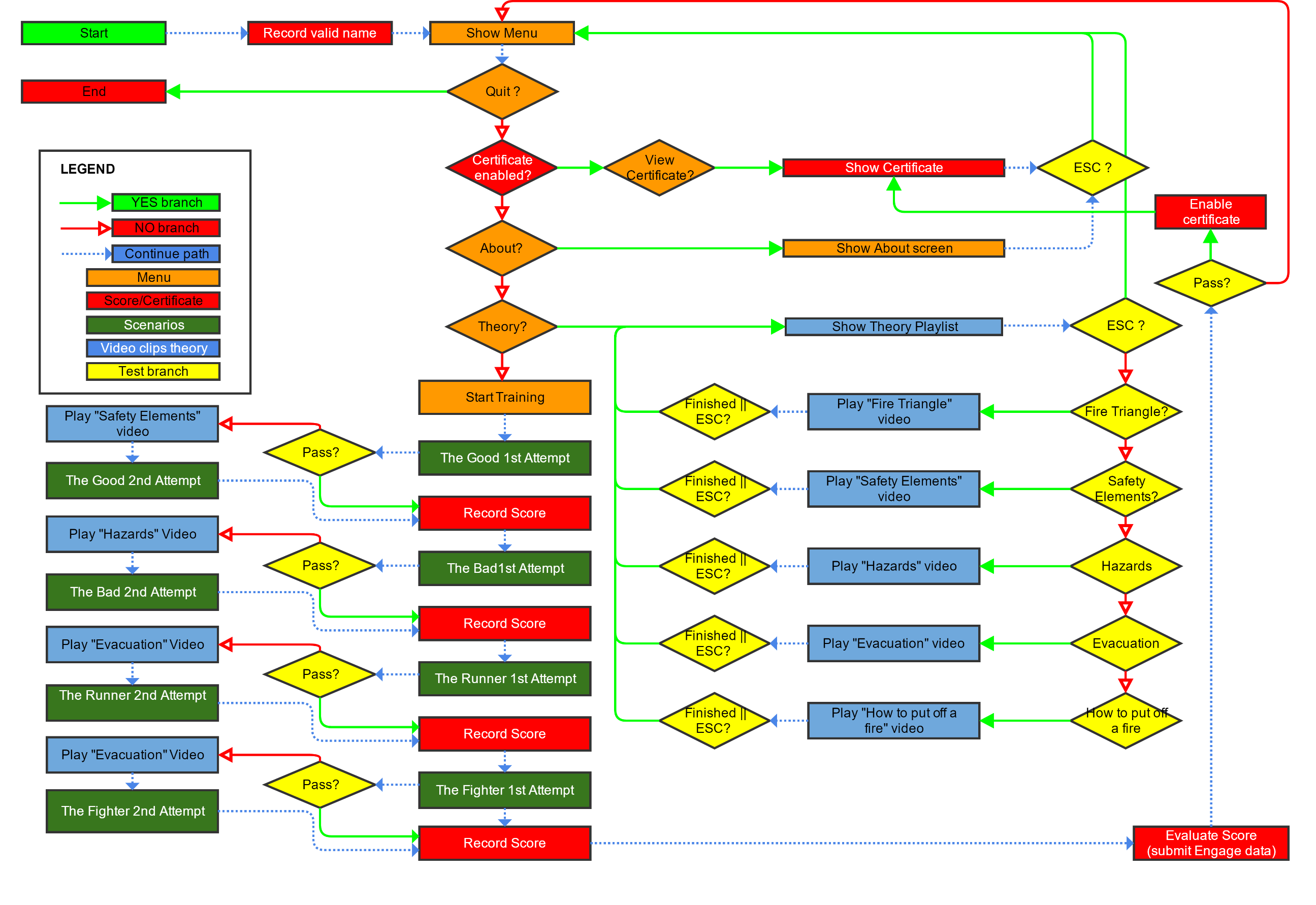
If the scenario is successfully completed, then the score will be recorded and the application will advance to next scenario.

If the scenario is failed, then the application will play the video theory related to the current scenario and then the second attempt of the scenario will be started. No matter of the outcome of the second scenario, the score will be recorded and next scenario will start.

The scenarios are linked this way: The Good -> The Bad -> The Runner -> The Fighter.

When the Fighter scenario will end (no matter if is the first or second attempt) the overall score will be evaluated, and a final score will be computed.

The result will be sent to Engage Assessment Engine. Finally based on the final score if it is above a specified passing limit, the Certificate will be issued containing the user’s name. The certificate will remain enabled and can be later reviewed from the main menu.



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