Game-Based Training for Airline Pilots

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EXECUTIVE SUMMARY

Game-Based Training for Airline Pilots


Photo by Steve Jurvetson [A]

Problem area

Flight simulators form the backbone of current airline training and have contributed significantly to the improvements in piloting skills and aviation safety. They allow ample skills training without the cost of real life training, and training under conditions which would be impossible or highly dangerous in real life. While simulations are very suitable for training aviator skills and procedures, they do not fully support the training needs of future pilots. In addition the highly automated flight decks of modern aircraft necessitate a shift in training needs towards cognitive flexibility and dealing with unexpected situations. Moreover, future pilots are part of the "digital generation" and have a different way of thinking and of information processing.

Description of work

The purpose of this report is to provide an introduction to game-based learning, and to identify the training needs and preferences of future pilots who are part of the "digital generation" as well as the shifting training needs for the highly automated flight decks of

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This report is based on a presentation held at the Simulation-Based Training For The Digital Generation conference at the Royal Aeronautical Society, London, UK, November 11-12, 2015.

modern aircraft. This leads to a perspective on how game-based training can be used effectively for (student) airline pilots.

Results and conclusions

Supplementing the current, highly regulated and standardised simulation-based training of airline pilots with game-based training may offer practical advantages in addition to training benefits. Game-based learning matches the learning preferences of future pilots, is highly suitable for the training of non-technical skills and offers a more flexible and scalable learning environment that may furthermore reduce training expenses. The body of knowledge on the topics in this report needs to be increased by way of academic studies along with professional experiences. Collaboration between training providers and research communities is warmly recommended.

Applicability

Training providers in the aviation domain are not yet convinced that game-based learning can be effective. The ideas about game-based training put forward in this report may encourage them to at least consider it in the process of training method selection for future training for airline pilots and other aviation professionals, especially for non-technical skills.

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Summary

For decades high fidelity simulators have been used in aviation training; they allow ample skills training without the cost of real life training, and training under conditions which would be impossible or highly dangerous in real life. While simulations are very suitable for training aviator skills and procedures, they do not fully support the training needs of future pilots.

The highly automated flight decks of modern aircraft necessitate a shift in training needs towards cognitive flexibility and dealing with unexpected situations. Moreover, future pilots are part of the “digital generation” and have a different way of thinking and of information processing. The highly regulated and standardised simulation-based training currently used in Airline Training Programs fails to accommodate these needs. One possible method to supplement simulation-based training can be game-based learning. While supporting 21st century skills such as critical thinking, collaboration, and problem solving more easily, games are also more flexible in timing and location of training.

Games are not a one size fits all solution to training objectives that are not sufficiently covered by simulator training. The game environment, mechanics, and play need to fit to the training objectives. Design of game-based training requires a good understanding of game principles as well as aviation training needs. Apart from their inherent and perhaps unique training potential, games are a good match with the skills, attitudes and expectations of the new generation of “digital native” airline pilots.

This paper provides a literature review on game-based learning and an overview of relevant experiences with game-based learning. This leads to a perspective on how game-based training can be used effectively for (student) airline pilots.

Content

1 Introduction

Flight simulators form the backbone of current airline training and have contributed significantly to the improvements in piloting skills and aviation safety [1]. Since flight simulators were introduced in 1910 they have undergone continuous refinement as the technology and training requirements change in line with aviation developments [1, 2]. Similarly as the knowledge and technology for training and education is developed, this will also offer opportunities for changes and improvements in airline training programs.

Since the introduction of the "fourth generation" of airliners in the late 1980's – aircraft with automated systems and flight envelope protection – the automation has continued to evolve, becoming more integrated and increasingly forming the basis for normal operations. In current operations it will be perfectly normal for a flight crew to leave the automated systems to move the fuel around the aircraft during a flight to optimise the weight distribution, or to engage the autopilot to fly the route from the flight management computer from shortly after take-off up to arrival in the destination area. This increased amount of automation in the cockpit has caused a shift in the requirements for pilots. While they may use the automated systems on the aircraft most of the time, relying on the systems for the routine operations on the aircraft, it is always the pilot that will need to intervene should a problem with the systems arise. The fact that these systems are so incredibly reliable actually means that pilots are very rarely subjected to a situation where they must intervene manually. Additionally, situations may arise which are unclear or ambiguous, in which case the crew must be able to assess and decide on the most appropriate course of action. A recent European study – Man4Gen [3] – has investigated the competencies, and specifically the cognitive skills, that may be required in addition to the manual skills to operate the aircraft in these unexpected situations. The results of the initial experiments in this project indicate that non-technical skills such as decision making and problem solving, as well as leadership and workload management contribute to effective handling in an unexpected situation.

In order to accommodate these training needs, it is worth considering additional training concepts to complement simulation-based training, particularly concepts that can be applied to the training of non-technical skills. Game-based learning is a method that is being studied and applied in various different fields, and may offer advantages to relying on simulator-based training alone. Training benefits of game-based learning have been acknowledged in relation to widely accepted instructional concepts, such as situated learning [4], increased intrinsic motivation [5], experiential learning [6] and deep learning [7].

Additionally, game-based learning offers practical advantages that warrant consideration in a training environment such as making mobile learning and "on demand" training possible in a wider context. Games are not new to the aviation world – "Flight Simulator" is perhaps one of

the most recognisable examples of an aviation game – but their value within a training program is still being examined. These factors are currently leading not only to research studies, but to the introduction of game-based concepts in the aviation industry as well, such as the Skyboard collaborative decision making game [8]. However, it is too early to draw any operational conclusions.

When looking at the future of aviation training, it is fitting to consider the needs of the future personnel, and not just how aircraft are developing, and the new methods and concepts that the training world offers. The International Civil Aviation Organisation predicts that there will be an increased demand for personnel in the aviation industry in the coming years [9]. This "Next Generation of Aviation Professionals" is being recruited now, and so will be made up of people who entered the work force in the late 1990's and at the start of the millennium. When we consider the airline pilot training, it is these people who will be going through initial and recurrent training programs, and will be trained for command in the coming years. It is therefore valid to consider their needs when we are investigating concepts to support their training.

In this paper we will introduce game-based learning. We will look at why the next generation of aviators may benefit from it and we will compare it to standardised simulation-based training. We will look at the differences as well as the similarities. In the subsequent section we will address the implications of the use of games in the (recurrent) training of airline pilots and provide directions for future research.

2 Game-based learning

One of the training methods to be considered as an alternative or addition to simulation-based training is game-based learning. Game-based learning is one of the terms that are applied for the use of games for education and training purposes. Other terms for the same concept are "serious gaming" and "education games". In addition, gamification and edutainment are sometimes lumped together with game-based learning. Although both can be used within a training or education setting, they are in fact different concepts. Gamification is the application of game playing elements to other areas of activity [10], while the term Edutainment indicates any form of entertainment that is designed to teach something [11]. This paper will focus on game-based learning.

Central to game-based learning is gameplay. Play has an important role in human development. This has long been acknowledged for the development of young children. They acquire many essential competences and develop important social structures by means of play [12, 13, 14]. Nor is it a new perspective on the acquisition of more adult competences. The use of wargames as

military exercises has been dated back to at least the Roman Empire [15] and role playing has been long integrated in training such as for sales and communication skills [16].

Table 1: Selection of family features for games [18].

Game mechanics	Gameplay	Game materials
Goals	Fun	Playing board
Rules	Challenge	Game pieces
Rewards	Mystery	Dice
Feedback	Chance	Playing cards
Constraints	Skills	Score cards
Competition	Fantasy	Game console
Social interaction	Winning/losing	Avatar
Cooperation	Success/failure	Instructions
Score	Control	Timer
Levels	Curiosity	
Narrative	Strategy	
Events	Tactics	
Surprises	Practice	
Sensory stimuli	Flow	
Situational realism	Bluffing	
Patterns	Exploration	
Time restrictions		

Conclusively defining a concept such as game is impossible [17]. There is not one specific feature that is common to all games. Going through many groups of games, similarities will come up, but also disappear. Wittgenstein characterized these similarities as family resemblances, and all games as a family. Family resemblances for games include rules, goals, challenge, and more (Table 1).

Game-based learning uses games with defined learning outcomes, which have been designed to balance gameplay with subject matter and the player's ability to transfer this to the real world [19]. In this paper we will refer to these games as "serious games". Game-based learning is found in the overlap between learning and games (Fig. 1). The technical aspects, or simulations, should be distinguished as a third, essential part of game-based learning [20]. Although game-based learning in the current perception often uses digital games, it can in fact use any type of game, including analogue games.

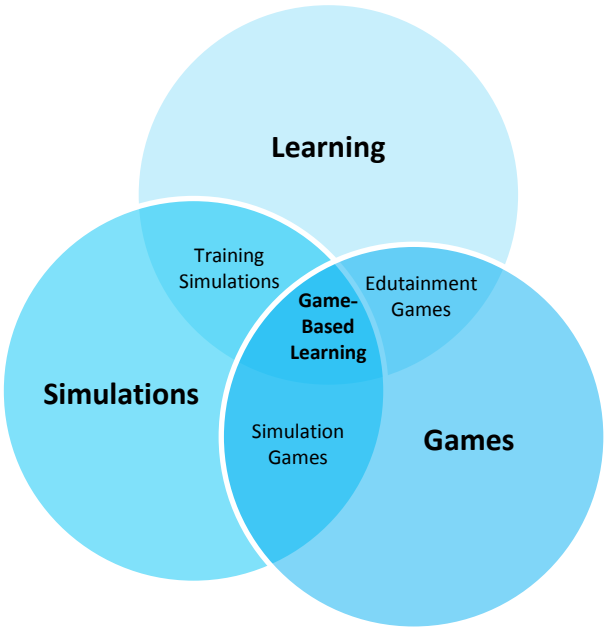

Figure 1: Game-based learning at the intersection of Learning, Games and Simulation [20].

The idea behind game-based learning is that the combination of gaming and learning (and simulation) is beneficial for training effectiveness. In many serious games, learning and entertainment have not been well integrated [21]. This imbalance leads to games that lack in either, or both, entertainment and learning quality. The fun of a game can be affected by overly explicit learning objectives, while the lack of firm learning principles may lead to a game that is fun to play but does not teach [23]. This raises the question whether the game should be designed basically as an instructional tool or as an entertainment game. Opinions vary, as Michael and Chen [23] advocate that learning should be leading, while Zyda [24] and Prensky [25] emphasize the fun part of gaming.

Good design of game-based learning seems to require a balance between game design and instructional design, based on learning theories [26]. However, more knowledge on the effects and interactions of game, instructional and player variables within serious game design is needed, to allow serious games to fulfil their full potential [21, 26].

Interest in game-based learning and serious games has seen a significant growth in recent years, in both commercial industry and the scientific community. The development of serious games has seen an exponential growth, from only a few in the 1950's and 1960's, to almost 200 in the 1980's and over 1200 in the 2000's [27]. The global market for game-based learning products and services totalled $ 1.8 billion in 2014, and is estimated to grow to almost $ 5 billion by 2019 [28].

There has also been a steep increase in the amount of serious games studies between 1990 and 2009 [29]. Most of these studies addressed the question whether serious games are, or can be, effective for learning compared to traditional instruction [30]. Several studies have found

evidence of a positive effect. Meta-analysis [31] revealed that serious games lead to better learning and retention, but it was found that learner motivation was not enhanced as a result of games. Another meta-analysis [32] showed that there is no significant evidence that serious games are more effective than other methods. Serious games studies are strongly heterogeneous in design, making meta-analysis a difficult task [33].

Other topics in serious games research include evaluation of instructional features in games, game-based pedagogy [30] and assessment, and some work has been done on models for the classification and design of serious games [22, 34]. These topics were found in only small numbers of studies, therefore more research on these topics is needed to move towards a pedagogically justified design of serious games including more knowledge on the relationships between pedagogy, learning and game mechanics [28].

The aviation domain generated relatively few studies of game-based training in comparison to e.g. the medical sector or crisis management. Baker et al. [35] have presented possibilities to use a PC simulation game for crew resource management training and Gopher et al. [36] have shown an improvement in flying skills of pilots that trained cognitive and attentional skills in a low (physical) fidelity entertainment game. Chittaro [37] investigated how a serious game could be used to improve aircraft passengers' attitude and behaviour with respect to personal safety in aircraft evacuations. He found that just playing the serious game for a few minutes resulted in a significant increase in the user's knowledge and self-efficacy. More recently, it was found that that playing a board game in a competitive and collaborative mode has a positive effect on collaborative decision making among airport stakeholders [8]. There has also been an experiment in which an entertainment combat game was used in a regular military CRM recurrent training. The game was played while instructors observed the players to note relevant behaviours that connect to the behavioural markers of the CRM skillset [38]. This illustrates that game-based learning is not necessarily a standalone learning method, it may not always be effective without instructors.

In a serious game the learning usually takes place unconsciously [39]. The learner does not receive direct instruction and may not be aware he is learning while playing the game. This is a contrast with traditional training methods in which the transfer of knowledge is explicit and learning goals are clear. Combining gameplay with a debriefing session, to make the learning explicit by reflecting on it, adds to the learning effect of the game [40]. Generally, the learning effect of a game is attributed to an increase of intrinsic motivation in learners, leading to higher attention and longer time on task [41]. The increased motivation may be a result of learning in meaningful context and learning by doing [42]. Improved learning may also be the effect of social aspects, collaboration and competition [43] and of improved retention and transfer [18].

3 The urge for gaming

The increasing use of highly automated aircraft affects the pilot tasks, roles and responsibilities in the cockpit and thus changes the competence requirements for future pilots. By the year 2030 necessary pilot competencies are expected to include operational monitoring, visualization, vigilance and originality. They need to be able to fully take over from the automated systems at any time, having a clear total picture of relevant elements of air traffic and able to come up with unusual or clever ideas [44].

In addition to the manual skills to operate the aircraft these non-technical, cognitive skills will be indispensable to handle unexpected situations adequately. Several of these skills are part of the 21st century skill set, such as collaboration, problem-solving, decision making and creativity. Through an extensive meta-analysis [45] a number of skills have been identified that are acknowledged as essential 21st century skills (Table 2). Video games can be beneficial to the training of these types of skills [46, 47, 48]. Several researchers of game-based learning have asserted that 21st century skills can be trained very well by using games [48, 49].

Table 2: Summary of 21st century skills [45].

21st Century skills	
Collaboration	Learning to learn
Communication	Self-direction
ICT literacy	Planning
Social and/or cultural skills, citizenship	Flexibility and adaptability
Creativity	Risk taking
Critical thinking	Manage and solve conflicts
Problem-solving	Sense of initiative and entrepreneurship
Develop quality products/Productivity	

Moreover, the aviation professionals that are being trained now are considered to be part of the Millennial Generation [50]. This generation has spent their entire lives surrounded by and using digital technology, making it an integral part of their lives. At this time the early Millennials have already found their way into the work force, while the later Millennials are just now finishing up their education. Prensky [25] called this generation the “digital natives”, contrasting them to older generations of “digital immigrants” who have had to learn to adopt digital technologies at a later age. Millennials have specific preferences for learning, work and communication (Table 3). They are believed to have different thinking patterns as they are used to receiving information really fast, multitasking and parallel processing. They prefer graphics to text, want non-linear access to information and thrive on immediate satisfaction. This group of learners may benefit from a move away from traditional teaching methods which generally use lectures to transfer information into the heads of students [51]. Using digital technology would be an appropriate method to educate them [25].

This implies that other, more appropriate and modern training methods should be considered in order to utilize the full potential of Millennials. Ultimately this means that traditional training programs may need to be adapted in order to fit the preference of this new generation.

Table 3: Millennial preferences/expectations for learning, work and communication [52].

Learning	Work	Communication
Teamwork	Positive colleagues	Positive
Technology	Challenge	Respectful
Structure	Respect	Respectable
Entertainment	Learn new knowledge & skills	Motivational
Excitement	Friendly environment	Electronic
Experiential activities	Flexible schedule	Goal-focused
	Good salary	

Several scholars agree that game-based learning is a highly suitable training method for imparting 21st century skills to the gamer generation [49, 53], also known as the Millennials or Digital Generation. It provides a match to many of their learning preferences.

This may give succour to the idea that game-based learning is only for a young male audience, who are stereotypically seen as the most avid gamers. In fact, statistics show that the average computer game player is 35 years old, with 44% of them being over 36 years of age. Also, 44% of computer game players are female [54]. And in terms of money, more money is spent on game-based learning for corporate training than for primary education [28].

Research shows that not only young participants with gaming experience appreciate and enjoy game-based learning, but also older participants and those without gaming experience or who are initially resistant, enjoy playing games [38, 55]. Serious games are also being used for rehabilitation [56] and improvement of cognitive health of the elderly [57].

4 Game-based learning and simulation-based training

Since flight simulator training was standardized in the 1970's its use has led to great cost savings and the reduction of training aircraft accidents [58]. Flight simulators offer training possibilities that would be too dangerous or all together impossible in the actual aircraft. The use of simulators also allows greater numbers of pilots to be trained in the same period of time. During flight simulation a pilot can fully focus on the task at hand without distractions. Exercises can be repeated until the task is mastered. Flight simulators are very well suited to train aircraft

operations and flight procedures. They prepare a pilot for all types of scenarios that may occur during actual flights and which may be almost impossible to survive in real life. A pilot will also be able to practice to react to challenges during flight, allowing him to learn how to handle the unpredictable.

Nowadays simulations are widely used, for military and civil training purposes. Gaming is sometimes said to be used widely in military settings, but most of these games are PC based simulations with relatively few game features. It is not uncommon for simulations to be confused with games. In effect, they are closely related to games and have many common features [17], such as situational realism, goals, surprises, or skills. In a training context simulation and games both offer a safe environment in which a learner is allowed to make mistakes and to retry. They both allow training under conditions that are impossible in real life and they are both cheaper and safer than real life training. Also, both games and simulations use (electronic) technology, can be exciting, entertaining and challenging and provide interaction in an experiential setting. With these traits they both match the learning and working preferences of the Millennials audience.

But there are also considerable differences. Several of the differences identified by Petroski (Table 4) relate to fidelity; the degree to which the game or simulation environment resembles the target environment [59]. Flight simulators usually have a very high fidelity. For instance, dials and switches resemble the actual aircraft and the simulated aircraft behaves accurately according to the actions taken by the pilot.

One of the advantages of lower fidelity is in the cost of development. With a less complex environment a game is cheaper to produce than a high-fidelity simulator. But low, or even zero fidelity games may also increase the focus on certain training objectives [59] and thereby improve learning. Zero fidelity for example motivates professionals to take part in engaging activities within an environment that is highly abstracted from the real task and systems. This allows for new learning possibilities, but effective design requires a good balance between the gameplay and learning objectives. However, abstract games are certainly not a panacea for all training goals.

Table 4: Differences between game and simulation [60].

	Game	Simulation
Amount of story	Storyline and background information can be minimal as learners may be engaged in playing almost immediately.	More detailed storyline and background information needed to support situational analysis.
Point of view	Experienced in a third-person point of view, detached from the consequences.	Experienced in a first- or second-person point of view that creates more attachment to the consequences.
Type of situation	Can be centred on a fantasy environment with little direct storyline attachment to real life.	Is often built around a real-life scenario that often includes realistic portrayals of environments and characters.
Interaction required for decision making	Action-based interaction with keyboard keys and mouse controls is the primary activity.	Scenario-based interaction with multiple-choice, branching decisions as the primary activity.
Information or rules	Gameplay is governed by rules. The more the learner understands the rules, the more he can achieve goals in the game.	Simulation play is governed by information. The more information the learner has, the better he can make decisions.
Linear or nonlinear process	Learners can progress in a nonlinear fashion.	Learners are required to make decisions within a more linear process.
Changing rules or situations	New or changing rules, more difficult challenges, or different scenes can change game play from level to level.	New situations, variables, and environments can change from scenario to scenario.
Type of feedback	Feedback is immediate through scoring and level completion. Failure is indicated by the inability to continue in the game.	Feedback is delayed based on decision branching. Success or failure is indicated by evaluating the outcome(s) of decisions.

5 A gaming perspective for aviation training

Young pilots and future pilots are part of the digital generation. Digital and engaging learning environments fit to their generation as well as to the professional profile. Simulators match many of their needs and preferences. However, simulator training is highly regulated and playful, inquisitive learning in a simulator is not encouraged. Even the strong learning-from-failure principle is not popular in aviation training, perhaps for good reasons, but taken these instructional constraints together, simulators are used as if they were the real thing. The total history of aviation training has worked towards that, and with success. The majority of pilot competencies can be trained using the simulators in this highly structured way. The majority, but not all.

Good insight in flying and in a particular aircraft may be difficult to reach by standard e-learning or formal simulator training. Airbus acknowledged this and recently launched an A350 transition course that stimulates pilots to discover the new aircraft and to experience the flying characteristics before putting the automatic systems on [61]. This kind of "discovery learning" is related to the "sandboxing" approach in game-based learning and as such, it is adding more game features to simulator training.

Game features can easily be added to simulator training or e-learning. However, we do not advocate adding game features to simulators just for the sake of making learning more attractive. Game features, such as competition, could also induce unwelcome behaviour (e.g. by flying at the speed limit, rather than maintaining a safe operational margin to the limit), which could potentially lead to negative transfer. The choice of game features that might be added to simulator training effectively depends on the training objective, the learning phase, and the instructional strategy.

Other training objectives may not be easily trainable in a realistic simulator environment at all. Many of the 21st century skills may benefit from a zero-fidelity setting, providing a safe environment for training high-level flexible skill sets. The training of non-technical skills in military CRM for example, proved to work very well for air force pilots engaging in a commando (army) game [38]. For the pilots this is a zero fidelity environment that nevertheless required most of their relevant non-technical skills. When the use of the game was demonstrated to a group of real commando soldiers, their reaction was quite different. To them this was not a zero fidelity game in which they could refresh teaming skills. They saw a very incorrect simulation of their personal jobs, in which they could not apply their regular tasks and procedures. NLR has applied this principle of using a different task and goal setting successfully to other professional training matters, for example in the Train Game, a railway oriented game for air traffic control supervisors.

As the increasing automation will rely more and more on 21st century skills, zero fidelity games have the potential to play a considerable part in future airline pilot training. For airline pilots, such zero fidelity games may be useful in qualification training as well as continuation training, focusing on skills such as SA, team coordination, and workload management, or on knowledge such as Shared Mental Models. The game mechanics and features need to be consistent with relevant aspects of the real task, environment and situations, but in an abstract way. When this is carefully done, transfer to the real environment is feasible [59]. An example of this is using a game of a power-plant simulation to train and exercise the "Problem Solving & Decision Making" and "Workload Management" competencies. An experiment in the EU Man4Gen project demonstrated how the competencies in this desktop game could be trained and affected the performance of the crews in a similar way to that in a full-flight simulator scenario [62]. Carefully designed desktop-based abstract games can be used to train general competencies that are

required for airline pilots, and thereby free up valuable full-flight simulator time for the training of competencies within the flight context, or those that are flight-specific.

While game-based learning provides high potential for aviator skills that may be difficult or expensive to train in simulators, many of its principles and effects have not yet reached full maturity and validity. Also, rough notions of training media selection – which training tool to use for which objective using which instructional strategy – are available, but may need considerable refinement to ensure training will be optimally effective and efficient. The same applies for insight on how to blend media and sequence training events over time.

As a final remark, we would like to stress that, while academic studies are important to increase the body of knowledge on these topics, professional experiences are equally vital. Careful explorations of game-based learning by training providers can further guide the limited amount of academic studies. Collaboration between training providers and the research communities may speed up progress and is warmly recommended.

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