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Cleared for take-off: Game-based learning to prepare airline pilots for critical situations

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Chapter 7

Conclusions and discussion

In this chapter, we will conclude our research by answering the three research questions and the problem statement. We will start by answering the research questions in Section 7.1. Armed with these answers, we will address the problem statement in Section 7.2. Finally, in Section 7.3, we will discuss the limitations of our research and give an outlook on future work.

7.1 Answers to the research questions

In the subsections below, we will summarise our findings and answer the three research questions. RQ 1 will be answered in Subsection 7.1.1, RQ 2 in Subsection 7.1.2, and RQ 3 in Subsection 7.1.3.

7.1.1 Answer to research question 1

In Chapter 3, we focused on RQ 1.

RQ 1: *How should a serious game be designed to support competency development effectively?*

From our interpretation of the literature, we identified three main requirements for serious games for competency development.

1. The game is playable and attractive.
2. The game supports learning.
3. The instructional elements address competency development.

To meet the three main requirements, the design of a serious game for competency development necessitates the application of (1) game design, (2) serious game design, and (3) instructional design.

In Chapter 3, we elaborated on each requirement and the type of design needed to meet the requirement. We identified and described six characteristics that should be incorporated in a serious game and its environment to support the development of

competencies by playing that game. We then identified eleven elements for gameplay and ten elements for learning. We combined these elements into a series of sixteen elements to be used in our SG4CD model (see Figure 3.9 on p. 49). The SG4CD model identifies the three parts of a serious game that contribute to the development of competencies. The model distinguishes (1) game elements, and (2) elements for learning (serious elements and instructional support elements), which are connected to the characteristics of (3) competency development.

The most important characteristic of competency development is the use of authentic learning tasks. The learning tasks in a game, especially a zero-fidelity [192] game, need to match actual job tasks based on competencies, task characteristics, and working conditions (see Figure 3.5 on p. 44).

With our model, serious games for competency development can be designed in a more structured way. We have applied our SG4CD model, including the model to generate authentic learning tasks, by using it in the design of our serious game *Shuttle to Mars* (see Chapter 5).

7.1.2 Answer to research question 2

In Chapter 4, we reported on the explorative study to answer RQ 2.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

Considering the possible outcomes of a serious game, we decided to distinguish two types of outcomes, namely (1) the learning effect, and (2) the gameplay experience. The research question was split into two subquestions to reflect both types of outcomes.

RQ 2a: *To what extent does the voluntary play of a serious game affect the learning effect?*

RQ 2b: *To what extent does the voluntary play of a serious game affect the gameplay experience of the player?*

To answer RQ 2a, we measured the learning effect of a serious game by comparing scores of a pre-test with those of a post-test. In an ideal situation, playing a serious game would result in learning, and the learning would lead to a distinct improvement in test performance. We expected voluntary use of the game to lead to a greater improvement (i.e., more learning).

However, there was no difference between pre-test and post-test scores. Playing the game did not lead to better test scores. This was found, regardless of whether playing the game was voluntary or mandatory. Therefore, we may conclude that the *CloudAtlas* game that we used in the studies has no learning effect. This may be caused by the quality, playability, difficulty, or even graphical design of the game as well as by the questions in the test.

Our findings did not allow us to answer RQ 2a conclusively. In all studies performed, we did not find substantial differences between the voluntary and mandatory groups. Therefore, we believe that the influence of voluntary play on the learning effect will be at

most quite small. We did find that after an obligatory minimum of playtime, players also remain in the game voluntarily for a longer time. This increases the total time spent in the game, which in turn may improve the learning effect.

To answer RQ 2b, we looked at the participants' enjoyment, engagement, and their opinion about being obliged to play. In our studies, we found that voluntary play does not influence the gameplay experience. Mandatory players do neither report a lower enjoyment or engagement, nor do they have strong negative feelings about the obligation. Moreover, they actually play longer than the voluntary players. We did not find evidence that the voluntariness of gaming, highly rated by many game theorists and practitioners, is essential in order for the game to be engaging and fun. On the contrary, our findings indicate that participants with a stronger obligation play as long and as well as participants who were free to play the game. Also, they enjoy the game equally.

With the answers for the subquestions, we will now answer RQ 2 as a whole.

RQ 2: *What is the effect of voluntary play on the outcomes of a serious game?*

The findings in our experiments (see above) indicate that voluntary play does not have a substantial effect on the outcomes of a serious game. The mandatory playing of a serious game is just as much fun as playing it voluntarily. Mandatory gameplay does not appear to ruin the enjoyment and engagement in the game. This statement challenges the assumption of many game design theorists and practitioners that games need to be played voluntarily in order to be engaging, fun, and effective [26, 69, 89, 133, 135, 160].

7.1.3 Answer to research question 3

In Chapter 6, we reported on the small-scale qualitative study aimed to answer RQ 3.

RQ 3: *To what extent do airline pilots accept a game to develop essential competencies for critical situations?*

The starting point for RQ 3 was that effective training is based upon a positive reaction of the participants [105]. Without a positive reaction on the first level of training evaluation, it will be difficult to reach the upper levels of improved behaviour and organisational change.

The participants were not enthusiastic about the gaming quality of the beta version of the *Shuttle to Mars* game that they had to play, but they did respond to gaming positively. Hence, we conclude that with the envisaged improvements to the game (see Subsection 5.5.2) and embedded in the initial training for airline pilots, the game has the potential of providing a positive and effective experience.

From the study as it was now, we may conclude that airline pilots are positive about the innovative approach of using a game for training the essential competencies.

7.2 Addressing the problem statement

Now that we have answered the research questions, we can address the problem statement.

Problem statement: *To what extent can a serious game be used to train airline pilots to act adequately in critical situations?*

Below, in Subsections 7.2.1 and 7.2.2, we will address the problem statement by the two perspectives outlined in Chapter 1: (1) the suitability of games to train competencies, and (2) the acceptance of game-based learning by airline pilots. Then, in Subsection 7.2.3, we will give our answer to the problem statement, followed by our conclusions in Subsection 7.2.4.

7.2.1 The suitability of games to train competencies

Serious games are predominantly used for knowledge acquisition [22, 38]. Our goal was to determine whether serious games can also be used for competency development. The SG4CD model (see Chapter 3 for more details) identifies the game elements and the serious (instructional) elements that should be implemented in the game to support competency development. The model shows that a serious game can support all characteristics that are needed for competency development.

We designed and developed our *Shuttle to Mars* game to study the actual use of a game for training competencies (see Chapter 5 for details). The pilots that played the *Shuttle to Mars* game (see Chapter 6) were critical about the quality of the game. Despite their criticism, they were confident that less experienced and aspiring pilots can develop their competencies with a game.

Our findings show that using a serious game development model does not guarantee an effective game within a short time span and with only a few iterations. Designing and developing good games for training takes time and patience, and more iterations than usually available in a research setting.

From our findings, we may conclude that a serious game can be useful for training competencies. Hence, it should be possible to design a serious game that contains the instructional support as well as incorporates the characteristics needed for competency development. Furthermore, according to our findings, the pilots who have participated in our small-scale study are confident that a game may contribute to acquiring and strengthening competencies. However, they believe that the *Shuttle to Mars* game is not successful in this and may be more appropriate for novice pilots.

7.2.2 The acceptance of game-based learning by airline pilots

For some time already, serious games are being used in various areas, such as the military, the health sector and education [20, 135, 188]. In aviation, and specifically the training of airline pilots, there have not been many projects on the use of serious games. This is due to legislation and unfamiliarity. As airline pilots are still mostly unfamiliar with GBL, part of our research focused on determining their reaction to and opinion about GBL.

The pilots involved in our experiments had a favourable opinion about the use of games for training, including the ones who indicated they did not play games very often. In general, airline pilots are open to GBL as a training method, and it does not seem to be problematic for the ones who are less positive. Our findings confirm that GBL is promising for a group of users such as airline pilots, that may be open-minded but somewhat sceptical.

Moreover, from our study on voluntary play in serious games, we found that voluntariness does not have a significant effect on the motivation and willingness to play a serious game. The enjoyment remains, even when a player is obliged to play the game. Hence, voluntariness is not necessarily imperative for GBL.

All in all, we believe, based on our findings, that there may now be reasons to apply serious games in the training for airline pilots.

7.2.3 Answer to the problem statement

Combining both dimensions, we will now address the problem statement (reproduced below) as a whole.

Problem statement: *To what extent can a serious game be used to train airline pilots to act adequately in critical situations?*

From our investigations, as guided by the three research questions, we may conclude that a serious game can be a viable training method for airline pilots to develop the competencies they need in critical situations. We come to this conclusion based on our three main findings.

First, we have shown that a serious game can be used to develop competencies (see Chapter 3). All characteristics required for competency development can be supported in a serious game. In the *Shuttle to Mars* game, aimed at the development of the competencies needed in critical situations (see Section 5.1), the participants were able to recognise these competencies in the gameplay.

Next, we found that both pilots and instructors are open to serious games for training purposes (see Chapter 6). Thus, they were motivated to play the game.

Finally, our study on the effect of voluntary play showed that a serious game can be played mandatorily without adverse effects (see Chapter 4). Therefore, a serious game can also be effective for pilots who are less inclined to accept GBL as a training method.

However, from the current research, we cannot draw any conclusions about the extent to which a serious game can be successful in the long run in training airline pilots to act adequately in critical situations.

7.2.4 Conclusions

From the work described in this thesis, we draw four conclusions.

1. The SG4CD model connects game design with competency development.
2. Mandatory gameplay in a serious game does not ruin the enjoyment and engagement.
3. Designing an effective serious game is a great challenge.
4. Airline pilots are willing to accept game-based learning as a training method for competency development.

7.3 Limitations and outlook

In our research, we were limited by two factors: (1) the difficulty of game design, and (2) the number of participants available for our studies. In Subsections 7.3.1 and 7.3.2, we will discuss these factors. In Subsection 7.3.3, we will look at three topics on which future research should focus. Finally, in Subsection 7.3.4, we will look ahead at the future of GBL for airline pilots.

7.3.1 The difficulty of game design

In our studies, we used two serious games which were designed by the researchers and developed by students.

Both games that we used, *CloudAtlas* and *Shuttle to Mars*, proved to be unsuccessful games. The games contained elements of successful games, but they did not reach their potential. Players were not positive about the gameplay. Admittedly, they did not have an overall negative opinion about the games, but neither one of the games triggered the players to keep playing.

Moreover, we did not succeed in creating games with a positive learning effect. In the *CloudAtlas* game, the fact that we did not find a learning effect may have had two causes. It may have been a result of (1) the game design, or (2) the quality of the tests.

With our *Shuttle to Mars* game, we aimed to measure the player experiences. However, we used a beta version of the *Shuttle to Mars* game, which did not have the quality for which we were aiming. The participants in the study found the quality and size of the game insufficient for training purposes. Therefore, we may conclude that our game in its current state is not able to train the competencies effectively.

If the game is to be the subject of further research, improvements will need to be made. A serious game for this purpose should be well designed, and the competencies must be activated correctly. The game design should be reconsidered and improved. Preferably, an experienced game designer should be consulted to make the game playable and attractive. The development of the game should be redone using a more modern visualisation to have a larger appeal to the players, and all elements that were designed need to be implemented. Furthermore, the game should offer a larger number of situations in which the learner can use and strengthen his competencies.

7.3.2 The number of participants

In all four experiments in our study, we had difficulties recruiting a sufficient number of participants.

For the three experiments with the *CloudAtlas* game (see Chapter 4), we recruited through social media, through institutions for higher education and flight academies. Through all three channels, we were able to recruit participants, but in none of the experiments, we had the number of participants that would have given sufficient power to the analyses. Moreover, not all participants in the first and second experiments about voluntary play belonged to the target group of our overall research. In Experiment 1, none of the participants was involved in aviation and only a few of the participants of Experiment 2 were enrolled in aviation-related studies.

For the experiment with the *Shuttle to Mars* game (see Chapter 6), we recruited through connections with Dutch airlines. As we were specifically looking for young airline pilots with little experience, the number of eligible participants was relatively small. In addition, the participants needed to be available in a specific period to attend two meetings and play the game. All in all, only a small number of pilots could participate.

As a result of the small number of participants, our results are not reliable and need to be interpreted carefully. Furthermore, we can neither generalise our findings to the entire population of airline pilots, nor to the players of serious games in general.

7.3.3 Outlook

With the work presented in this thesis, we have laid the groundwork for the implementation of GBL in aviation in general, and for the use of a serious game for the development of essential competencies in critical situations specifically (see Section 5.1).

For future work, the *CloudAtlas* game and the *Shuttle to Mars* game should be re-designed to overcome their shortcomings.

Now that we have shown that there is support for the use of serious games for the training of airline pilots for critical situations, future work should focus on determining (A) learning effect, and (B) creating blended learning environments, to optimise the learning effect [134]. Furthermore, further research should address (C) transfer of learning [212], (D) determining the validity of the SG4CD model and (E) determining the power of the serious game mechanics. The five topics will be discussed briefly below. Moreover, the effect of voluntary play remains of interest.

A. Determining the learning effect

The learning effect of a game can be measured in two ways: (1) within the game, using game results and game data, and (2) outside the game, using test results.

Development of the competencies within the game should lead to an improvement in game results. Analysis of game data, such as reaction speed, optimal prioritisation, and correct answers, will provide information about the improvement.

Subsequently, development of the competencies in the game should lead to improvement in test results outside the game. Players should perform better on the test than non-players, and the post-test should show an improvement over the pre-test.

B. Creating blended learning environments

GBL is not necessarily a stand-alone training method. Once a learning effect is determined, this effect may be strengthened by combining GBL with other training methods [46, 134]. For example, GBL may be implemented in a curriculum together with lectures and discussions. First, during a lecture prerequisite knowledge can be shared and explained by a teacher. Next, the game can be played, followed by a group discussion about strategies and results. A blended approach using both GBL and other training methods may lead to better results by strengthening the learning effect.

C. Determining transfer of learning

The development of competencies in a game should lead to improved behaviour outside the game, i.e., in the work environment.

The transfer [212] of the learning effect from the game to the actual working environment can be assessed with a quasi-transfer test by observing the participants during flight simulator scenarios. Pilots who have the essential competencies to act adequately in critical situations should show specific behaviour indicative of those competencies. They should be able to respond faster to the situation and provide better solutions. In the simulator, this behaviour can be assessed by an examiner.

We would expect to see an improvement in the participants' performance as a result of the game. Furthermore, we would expect to find a difference between the performances in the simulator of participants who have played the serious game and participants who have not. This would indicate a positive, transferable learning effect of the serious game. To examine this effect, data coming from the game and surrounding activities should be combined with assessments made by the examiner in the simulator.

Ideally, such research is set up as a random controlled trial comparing the effect of a serious game with that of the currently typical training on a topic. However, making a valid comparison is difficult, as the competencies we have identified as essential in critical situations are not being covered in one training in particular, but they are addressed over several courses. Moreover, if such a training were available, ethical questions may arise about withholding the most effective alternative from a group of participants.

D. Determining the validity of the SG4CD model

The validity of the SG4CD model introduced in this thesis has yet to be proven. When the Shuttle to Mars game is redesigned for further research, we suggest using the SG4CD model to guide the connection between the game elements and competency development. In addition to testing the redesigned game for learning effect and transfer of learning, the game may be used to test the validity of the SG4CD model.

E. Determining the power of the serious game mechanics

Finally, an interesting topic of research will be the separate serious game mechanics to determine which mechanics were successful, which were not and why. Such scrutiny may

lead to insights into the question of how to improve the serious game mechanics, which in turn may contribute to improving the success of serious games designed specifically for learning.

7.3.4 The future of game-based learning for airline pilots

With the outcomes of our work and those of future research, game-based learning may become an effective and validated training method for aviation. We expect it to become a standardised training method that will be a part of initial and recurrent training for airline pilots. We consider game-based learning for aviation to be *cleared for take-off*.

"Ladies and gentlemen, welcome on board. We are preparing for take-off and expect to be in the air soon. We ask that you please fasten your seat belts at this time and secure all baggage underneath your seat or in the overhead compartments. Thank you and enjoy your flight."

