The effect of a serious game on aviation vocabulary acquisition

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ABSTRACT

Having proficiency in the standard aviation phraseology specified by International Civil Aviation Organization (ICAO) is of great importance for prospective pilots in communication with air traffic controllers and other pilots. The ambiguity in the standard phraseology could be a disaster for the flight crews. Serious thought, thus, has been given to the policy of improving precise communication in aviation. However, it remains unclear whether the serious game-based flight simulations can enhance the vocabulary intake of the learners who invest the majority of their time in studying the standard aviation phraseology. There is also a dearth of research pertaining to the association between serious gaming and aviation phraseology. The advancement of technology has exponentially expanded digital games and therefore began to be widely used in education. The current study thus sets out to investigate the effect of a serious simulation game X-Plane 11 offering an invaluable learning experience on aviation vocabulary acquisition. This investigation takes the form of quasi-experimental mixed-method research by retrieving convenience sampling (15 subjects in the experimental group, 15 subjects in the control group). The findings indicated that there was strong evidence of the positive effects of serious gaming on the learners' outcomes. Following the integration of the serious game, a significant increase in the medium effect size in the experimental group was recorded. This finding was also echoed by the majority of the interviewees who unanimously emphasized that the game was beneficial and motivating for language learning despite the minority challenges triggered by the level of language, hardware, and software types.

Key Words: *serious gaming, simulator game, vocabulary acquisition, aviation English.*

1 Introduction

A learning game is described as a set of entertaining activities which are designed with concrete rules to reach measurable results (e.g., scores and status) and combines the game mechanics (e.g., challenge and competition) with instructional objectives for the pursuit of intended learning outcome [1]. This definition embraces games for both digital and non-digital settings. Yet, recent trends have indicated growing attention in digital-game based learning [2]. Global Games Market Report highlights that there has been an exponential growth in the number of computer gaming users with 2.2 billion [3]. This interest has led to the increase in the amount of expenditure for games, which has reached 152 billion dollars, and it is estimated to be 196 billion dollars by 2022 [4]. Additionally, the users spend approximately seven hours per week on digital games [5]. Lately, researchers have shown an increased interest in gaming and began to focus on the integration of games into educational contexts. This is also verified by the number of articles published on this topic [6],[7]. The use of computer gaming in education involves a wide range of areas such as medical [8], military [9], language [10], and engineering [11].

Digital games are originally categorized as commercial-off-the-shelf (COTS) games that encompass games for entertainment and serious games for educational purposes [10]. While both are used in a learning context, the latter is more appropriate to deliver content knowledge [10]. Learning

best takes place when the instruction involves active participation, engaging tasks referring students' needs, experimenting, relevant contexts, and meaningful feedback with the affordances of digital media [1]. Serious games compromise most of these characteristics, and thus they are considered to be influential in training.

Specifically, a considerable literature has grown up around the theme of computer gaming integrated into language education, referred to as digital game-based language learning [7] largely due to the positive effects on reducing anxiety [1], improving motivation [12], increasing interactivity, enhancing productivity [13], and strengthening the cooperation [14]. Many digital games could be used in order to facilitate language learning. Gee [15] posits:

> "Good games have design features that are particularly relevant to language learning. They often use concentrated samples or situations where you present players or learners with many more instances of important cases in a short time than they would see in reality." (p.19).

A notable example of the COTS games is World of Warcraft (WoW) which is the most played massively multiplayer online role-playing game (MMO Population, 2021). WoW is considered to have great potential to practice a language with its distinct features for socializing in a proper server for the target language [16],[17],[18]. Some other COTS games, such as Everquest II, Ragnorak Online, and the SIMS, have been found useful to enhance the communicative competence of language learners [19].

2 Serious Gaming for Language Learning

Many get confused about the term *Serious Gaming* since it seems oxymoron with two contradicting words. Overall, serious games are described as games created for non-entertainment goals. Clark C. Abt [20] firstly proposed the idea that games might be more effective when designed with educational considerations. He further states, "We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement." (p.9). A broader definition was also provided by Michael Zyda [21], stating, "Serious games have more than just story, art, and software, however. (…) They involve pedagogy: activities that educate or instruct, thereby imparting knowledge or skill. This addition makes games serious" (p.26). Furthermore, serious games diverge from other digital materials in that they provide opportunities for users to be immersed in and experience a highly visual environment and get feedback based on their judgments. Chen and Hsu [9] put forward that serious games augment learning motivation and increase learning outcomes.

Serious gaming could be an ideal way of practicing in the target language. In a gaming environment, learners are able to carry out communicative goals that increase their productive capabilities. In addition, serious gaming will play an essential role in lowering students' affective filter with engaging tasks [15]. The association between serious gaming and language acquisition, however, has received scant attention in the research literature. Studies such as Johnson et al. [22] and Johnson [23] investigated the impacts of serious games on military students' language learning. Johnson et al. [22] developed a serious game to enhance communication in the target language. Then, he focused on the cultural knowledge of participants in the game. The game was designed as conversational simulations with non-human players. Also, *Conference Interpreter* as a serious game [24] was created to foster the ability to translate among languages by providing necessary vocabulary knowledge. Calvo-Ferrer (2017) has used the game on participants' vocabulary attainment. Those who played the game got significantly better results in the post vocabulary test. Moreover, Chen and Hsu [10] examined the effects of a serious game, *Slave Trade* on vocabulary and content knowledge regarding history. The findings showed that serious gaming offers a rich, engaging, and contextual learning medium. Students performed significantly better by playing the game during the treatment process.

A Flight simulator which is a device that "recreates an aircraft and its environment or any events where it flies" [25] is considered as a type of serious game with overlapping attributes including raising awareness, knowledge transfer, promoting behavioral change. Simulators are integrated into training including medical, military, etc., to lower the risks and increase the skills-

based knowledge. Visual realism is the key component of these games since improved reality effect is more likely to make trainees ready for overcoming the actual challenges in the field. As emphasized by Huet et al. [26], simulator-based training is a worthwhile alternative to traditional lecture-based instruction because it substantially reinforces experiential learning. Even this has been made compulsory with a new regulation by the Federal Aviation Administration [27]. Overall, serious games are considered ideal learning environments in strengthening learning abilities and a wide range of prerequisite skills prior to facing real-life problems. This paper thus attempts to investigate the impact of a serious game, *X-Plane 11* on prospective pilots' vocabulary acquisition. The experimental work presented here provides one of the first investigations into how a serious game affects aviation training. The research questions of the current study are illustrated below.

Research Question 1: Would the prospective pilots learn standard aviation phraseology by playing a serious game?
Research Question 2: What are the perceptions of the students toward the serious game and its appropriateness regarding learning vocabulary?

3 Serious Gaming and Constructivism

Constructivism is based on the premise that "the assumption that knowledge is constructed by learners as they attempt to make sense of their experiences. Learners, therefore, are not empty vessels waiting to be filled, but rather active organisms seeking meaning" [28], (p. 360). Serious games are capable of doing more than just bringing a splash color or entertainment to tedious learning practice. They transform a learning activity into a game-based instruction and significantly influence the learner's experience. The constructivist theory holds that the learner should build on and change their current mental process. The emphasis is on knowledge development instead of knowledge transfer. The power of serious games to aid in knowledge development stems from their ability to affect the learner's current mental process, drastically improves the learner's experience in order to integrate the experience in the game environment. There is a strong emphasis on learning tasks rather than lecturing. The ideas of constructivism, according to [29], involve personalized interpretation of knowledge everyone constructs as a result of their experiences. Active learning through interaction is also another aspect of the constructivist framework. Serious games value active learning strategies by providing user independence, and by scaffolding with meaningful and corrective guidance and feedback pertaining to individuals' performance throughout the game [30].

4 Methodology

The current study employed a quasi-experimental mixed-method research design that promotes both qualitative (interview), and quantitative (vocabulary test) approaches to gather necessary information accurately regarding the treatment process.

3.1. Participants

30 prospective pilot students enrolled in an aviation English course in a state university in Eastern Europe were recruited for this study as a non-random convenience sample. Of the initial cohort of 30 students, 28 were male and 2 female aged between 19 and 21. The results of the placement test prepared by testing experts of the publishing house providing materials for the institution showed that the English proficiency of the target sample was intermediate according to the Common European Frame of References for Languages (CEFR). This test is conducted every year in the school to screen the current English level of the students. They are also exposed to aviation English courses for three hours per week. The syllabus of the course was based on standard aviation phraseology in a wide range of subjects including parts of an airplane, runway incursion, flight rules, weather, and

communication with an air traffic control. These participants received approximately 2 years of general English as a foreign language prior to taking an aviation course.

3.2. Instrument

A flight simulator serious game called *the X-Plane 11* was selected for the current study. It was developed and released by Luminar Research company in 1998. The game has been updated with better graphics and more realistic functions since then. Most importantly, recent updates favored simulated real-world landscape on earth and massive multiplayer mode, which increased the immersion and the quality of user experience by underpinning the active involvement. It is one of the most sophisticated simulator games in which users are trying to become a pilot or practice a wide range of planes in different environmental conditions. It is worth emphasizing that X-Plane was initially developed to train prospective pilots for real-life challenges that they can encounter during the flight. Aviation English phraseology, however, is dominantly used in the game while providing auditory and visual instructions, requests, guidance, warnings, and emergencies. This offers a contextual and enriched aviation English practice for prospective pilots. They learn not only the basics of flying, parts of planes, control devices, a rich body of airports with hangars, jetways, a wide range of plane models but also the standard aviation phraseology required to get in touch with a nearby environment such as ground operation, tower, flight instruments. Flight simulators thus provide cost-effective and risk-free opportunities for prospective pilots in a real lifelike environment. Although X-Plane allows for professional use certified by the Federal Aviation Administration (FAA), the mobile for iPad version was utilized in the research due to its relatively reasonable pricing and convenient usage. X-Plane offers four different options to practice flying including flight school, challenges, freeflight, and massive multiplayer (see figure 1). It is highly recommended by the game for inexperienced users to complete the training scenarios in flight school in order to join flights in other options. In most cases, prospective pilots begin practicing by the Cessna 172 as it is relatively affordable and thus chosen for training. In this respect, X-Plane presents the initial training with the Cessna 172. In addition, flight school has 10 different scenarios (see Appendix 3) in order to develop skills to fly a plane by using proper systems in the vehicle. There is guidance throughout the flight school scenarios by suggesting what to do for the next step and how to keep the plane balanced. During the game, there is often a reminder text on the screen, which leads the prospective pilots. There are a few flight simulator games in the market. X-Plane, however, has unique features which are likely to address our needs and intended learning outcomes. In understanding the efficiency of the games for instructional purposes, Garris et al. [31] have proposed a set of attributes that a game must have in order to enhance learning. These attributes are capability, instructional content, learning outcomes, game characteristics, learning activity, and reflection. Garris [31] posits that educational games designed and built by considering these attributes possess a high potential to address learners' needs. They tend to be effective during the intervention. Table 1 below illustrates an overview of the X-Plane according to these attributes.

Figure 1. *X-Plane Flight Simulator*

Figure 2. *The cockpit of Cessna 172*

Table 1. *The features of the X-Plane 11 based on the Garris framework [31]*

Feature	Availability in X-Plane 11	Description
Capability	Yes	- High-quality graphics and visuals - Smooth frame rate - 3-D cockpits - A wide range of plane models - Allowing instrument flight - More than 13.000 airports with buildings, hangars, fuel, and pushback - Realistic weather and lightning

		- Tutorials - Massive Multiplayer - VR, Mobile and, IPad support
Instructional Content	Yes	- Training scenarios - Step by step learning - Instant feedback
Learning Outcomes	Yes	- Skill-based learning - Procedural knowledge
Game Characteristics	Yes	- Rules and goals - Challenge - Learner control - Scenario
Learning Activity	Yes	- Flight school mode - Assistive learning
Reflection	Yes	- Reflection during and after the flight - Scoring

As for the vocabulary test, the current study utilized pre-and post-test design to assess the vocabulary knowledge of the participants. They were asked to write down the Turkish correspondence of each word in the list (see Appendix A). Although there were many words appearing as auditory or visual input during the game, the target group is accepted as the keywords for standard aviation phraseology. All the aviation words taking place in the game were written down the list. In order to take an aviation English course, prospective pilots must have at least intermediate or B1 level English proficiency. For this reason, learners were already familiar with plain English, which we encounter in our daily life. Aviation phraseology, on the other hand, was new to them, and it was also the main objective of the course as part of our curriculum. Overall, 50 words were selected as essential for the prospective pilots. The participants took the test prior to the intervention, and later they had the same test with a different order after the game.

3.3. Interview

Semi-structured face-to-face interviews composed of 4 open-ended questions were conducted with 7 participants in order to gain insights into students' experiences and perceptions regarding the game. While the first and second questions were to solicit information for the game itself, the third and fourth were to see students' ideas about whether the game was beneficial for learning English vocabulary. A non-random quota sampling which offers exclusive sub-groups, was used in choosing the interviewees based on their English proficiency level accordingly high, middle, and low achievers. The quota sampling allowed researchers to select participants from each segment based on a certain amount. This assisted in understanding different level students' experience with the game better. The following questions were addressed during the interviews lasting approximately 10 minutes for each.

1. What are the pros and cons of the serious game?
2. What are the game characteristics you enjoyed more?
3. Did the serious game help you learn vocabulary?
4. Do you think the serious game could be used in an aviation course as a supplement to the syllabus? Why?

5 Procedure

4.1. Lecture-based classroom

Following the pre-test, students in the control group had in-class instruction regarding the target vocabulary. The instructor provided an oral explanation with the help of visuals through PowerPoint. A total of 50 essential aviation words were taught explicitly to 15 participants in 2.5 hours. At the end of the session, the students took the post-test to see the learning outcomes.

4.2. Serious game-based classroom

Following the pre-test, students in the experimental group did not receive in-class instruction. Instead, they completed *X-Plane 11* flight school mode comprised of ten different scenarios accordingly by means of an IPad (see Appendix 3.). They were exposed to 50 essential aviation words implicitly as visual and auditory input during the game for 1 hour on average. The game also provides guidance on how to fly and adjust the control panel. Students were able to draw meanings of the words while following the guidance and signs. At the end of each scenario, students received performance feedback as reported in the cards (see Appendix 2). Only two attempts were given to the participants. There were no students who could not make it at the second attempt. Throughout the game, one of the researchers was present to aid the participants in case they might need help. After that, 7 students with different proficiency levels, took the post-test and participated in the face-to-face interviews.

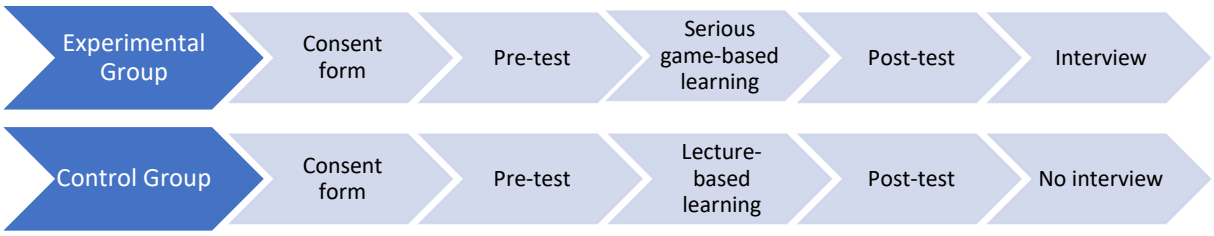

Figure 3. *Summary of the procedure*

6 Findings

The same post-test was conducted in order to understand the effect of the intervention on the vocabulary knowledge of the participants. Later, the collected data was examined through independent samples t-test in SPSS 23 (Statistical Package for Social Sciences). Additionally, the effect size was calculated to see the difference precisely.

Table 2. *Pre-test results of the serious-game based and lecture-based group*

Group	N	Mean	SD	t	df	Sig.
Experimental	15	31.73	11.68	.43	28	.66
Control	15	30	10.02			

Significant difference was not found in the first vocabulary knowledge test for the experimental group (M = 31.73, SD =11.68) and the control group (M = 30, SD = 10.02) conditions; $t(28)$ = .43, p = .66. It could be clearly understood from the pre-test results that experimental and control groups are quite similar to each other in terms of vocabulary awareness regarding aviation.

Table 3. *Post-test results of the serious game-based and lecture-based group*

Group	N	Mean	SD	t	df	Sig.
Experimental	15	73.33	13.21	1.73	28	.09
Control	15	64.67	14.17			

The analysis of independent samples t-test for the post-test demonstrated that there had been a significant difference for the experimental group (M = 73.33, SD = 13.21) and the control group (M = 63.67, SD = 14.17) conditions $t(28) = 1.74$, $p = .09$ with a medium effect size (d = 0.60). The findings showed that the use of serious gaming in the aviation English course significantly enhanced the vocabulary acquisition of the prospective pilots.

As for the qualitative findings gathered through semi-structured interviews, the researchers used Otter.ai to transcribe the interview recordings. Then, the transcript was analyzed and coded inductively through NVivo software which is a qualitative data analysis tool. Later, similar patterns in students' outputs were drawn as themes. 12 themes providing students' insights into learning aviation phraseology in the serious game were found in different categories. Table 4 below demonstrates the emerging themes with the number of appearances.

Table 4. *Themes*

Category	Themes	Number of Appearances	Examples
Advantage	Engaging	7	The game is pretty entertaining. I don't want to stop playing... Instead of a lecture, it is more like a game.
	Risk-free	5	You can try again when you fail... There is no risk when you make mistakes.
	Real lifelike	4	The visuals are close to real-life... I feel like I fly a real plane.
	Language learning	7	I prefer learning English while playing... I wish we always had games for lessons... I won't forget the words I learned in the game.
Disadvantage	Advanced speaking	3	The level of English was above our proficiency... I sometimes didn't understand the instructions.
	Insufficient guidance	2	I think the guidance was not enough... The guidance could have been more.
	Hardware challenge	2	I would prefer to play on a computer rather than iPad... It was harder to control the plane with the iPad.
	Compelling software	3	The game itself was demanding... It took some time to get familiar with the game... X-Plane 11 is complicated for beginners.
Game Mechanics	Immersive	6	I was immersed in the game because of using the iPad as a yoke of an airplane... The graphics made you feel like you were in the cockpit.
	Guidance	4	It is good for beginners to follow the guidance... Guidance leads you throughout the game, which helped me a lot.
	Feedback	4	There is always feedback based on your decisions... The alerts in the plane keep you awake before you lose control...
	Scoreboard	3	The game provides scores and points for your flight... I like the scoreboard as I can see my success during the flight.

7 Discussion

The present study set out to investigate the effect of the serious game *X-Plane 11* in the aviation English course. In addition, the learning perceptions of the prospective pilots toward the immersive simulation tool were examined qualitatively. The results, as shown in Table 3 and 4, indicate that there had been strong evidence of the positive effects of serious gaming on the learners' outcome. Following the integration of the serious game, a significant increase in the medium effect size in the experimental group was recorded. This finding was also echoed by the majority of the interviewees who unanimously emphasized that the game was beneficial and motivating for language learning despite the minority challenges triggered by the level of language, hardware, and software types.

The current study produced consistent results with the previous studies evaluating the integration of serious gaming into language learning environments (e.g., [32];[20];[10];[33], [34]). In addition, the results are in agreement with Boulaknadel and Fakhri's [35] findings indicating that serious gaming provides immersive and contextual language learning. The merits of serious gaming, as stated by the students, could be justified by the exclusive characteristics of the game that empowers the learning experience. High-quality visuals and graphics with interactive tasks, for instance, strengthen the students' positive feelings toward the game and thus get them to be immersed while playing. It could also be said that there is a direct interaction between the game features and the player since the player needs to understand the guidance and oral directions. In addition, students should follow the instructions in the game while keeping control of the plane, which was a real challenge for them. In this way, the tasks could be accomplished accurately.

The results further support the idea that serious games encourage meaningful learning and motivational concepts through adaptive challenge, clear goals, rewarding, and low-stake failure [36]. These components are consistent with well-known learning theories like flow theory. These types of games are appropriate to establish a learning environment where learners strive to work and view themselves in the role of the target job. The serious games allow learners to perceive the world in a number of ways that are primarily rooted in purposeful action and well linked with key issues of target objectives. Additionally, meaningful learning in a game occurs with the combination of learning activity, instructor role, curiosity, human engagement, general setting, and evaluation at the end of the performance, which fits well with the existing game in the research. It provides a satisfactory user experience for prospective pilots as well as language input during the pre-flight and en route. In this respect, Keller [37] emphasizes the importance of motivational design for meaningful learning by introducing the ARCS model that underscores attention referring user interest, relevance known as usefulness of the content, confidence meaning success expectation, and satisfaction. Whereas these attributes augment the intake of educational games, most simple games designed for entertainment are deprived of them. Therefore, the success of serious game-based intervention in the current study could be explained by the ARCS model of the game as well as meaningful situated learning. The affordances of serious gaming help students to be exposed to invaluable learning experiences such that students are actively involved in a real lifelike environment. This also lies in students' utterances during the face-to-face interviews. The qualitative data has shown that interviewees found the game engaging, risk-free, and real lifelike. These findings accord with earlier studies [7], [10], [31] on serious gaming that highlighted the simulated landscape, improved controls, and on-time auditory intervention in captivating learners' attention. Building such a learning environment is almost impossible for lecture-based instruction. Students in the control group, for example, could only see the word and visual representation with the teacher's lecture. They did not have a chance to build their own knowledge by experiencing the content deeply. The observed students' voices in interviews, in addition, could be attributed to the student-centered and constructivist learning opportunity. Students playing the serious game actively construct target knowledge while others are exposed to knowledge as passive observers. As emphasized by students, the aforementioned game mechanics pave the way for a learning environment in which students are in the center and invest their effort independently. Reinders [1] posits that integrating games into the learning environment support student autonomy and strengthens active learning. Some disadvantages, on the other hand, were uttered by interviewees, including the level of language, software, and hardware challenges. The use of the iPad for such a sophisticated and

complicated game is rare in the literature. Students were not familiar with such devices for learning content, and none of them had played this game before. That is why it was not surprising to see these complaints. Contrary to expectations, some students complained about the language of the game although their language proficiency was found intermediate. This inconsistency may be due to the dominance of aviation phraseology in the game since they did not meet these words in advance. This was an extra cognitive load as they were making efforts to comprehend ongoing vocabulary. The results have shown that this was not a barrier for the study. This instead forced them to learn it in order to pass the scenarios.

The results also corroborate the ideas of Hanandeh, Abdullah, and Harun [38], who suggested that serious gaming is an excellent solution in order to increase students' achievement since it allows learners to practice affordably without any risk. Moreover, Nisansala et al. [39] state that serious gaming offers cost-effective solutions for aviation training since aviation is one of the riskiest areas which requires a considerable amount of investment to train the prospective pilots. According to FAA, mental and physical factors considerably impact aviation safety. The majority of the injuries or casualties are the result of these factors. There is not even one percent possibility to make mistakes while flying a real plane. Otherwise, it might cause the death of the pilots and passengers. Advanced technology, however, enhances the learners' buy-in due to authentic scenarios such as flight mechanics, cockpit, and external effects such as weather, plane type, airport, etc. Using the iPad as a yoke also augmented the reality effect of the learners and provided intense sensations because the sensitivity of the relationship between the plane and the control of the yoke was pretty high and adjusted to real properties. A notable example of this is the first training plane, Cessna 172, having low weight compared to other aircraft, which makes it compelling to control during the flight. That is why using a rudder while taking off or landing is usually necessary. This characteristic is reflected precisely in the game. Furthermore, the systems and indicators in the cockpit are fully integrated and activated. The prospective pilots are thus responsible for all the controls pertaining to the success of the flight, although there is intense guidance and feedback in the flight school mode.

Concerning the relationship between vocabulary acquisition and serious gaming was also related to the assistive guidance provided by the game in the flight school training. Possibly, students had challenges at the beginning due to being a newbie to the game. In addition, training is designed initially to prepare prospective pilots for the real flight experience rather than flying on their own by randomly experiencing the process. That is why it is necessary to provide explicit feedback and instruction for the ongoing tasks. This is in line with the assumption that the zone of proximal development that refers to the learner's competency to favorably accomplish tasks with the help of more competent people [40] exists throughout the flight school. Additionally, Wass and Golding [41] state that instructors should give assignments that are hard to do alone but could be completed with assistance. More demanding tasks could further be assigned for the independent involvement. This instructional framework is reflected in the current serious game because the scenarios are getting harder, and assistive guidance is available during the training prior to the independent flight experience.

8 Conclusion

This paper has argued that serious gaming could be a remedy for the difficulties that prospective pilots go through in studying the standard aviation phraseology. The qualitative and quantitative data evidently support our hypothesis regarding the effectiveness of serious gaming. The empirical findings in this study provide a new understanding of integrating serious gaming into education. The study adds to the existing body of literature that simulator-based serious gaming enhances learners' vocabulary acquisition. The results yield practical implications for both English as a Foreign Language (EFL) and English for Specific Purposes (ESP) courses such as aviation, engineering, nursing, etc. Simulator-based serious games offer affordable and risk-free opportunities for the learners and increase the achievement rate. Also, sophisticated technological affordances provide an immersive and engaging learning experience. Specifically, the iPad flight simulator game emerged as a reliable tool due to strong sensations with higher immersion. This work, therefore, should be seen as a pioneering attempt

to redesign aviation English courses with serious gaming and bring authentic and contextualized materials into a classroom environment.

The study has limitations that need emphasizing. A note of caution is due here since the sample size could have been larger, although there has been a significant difference between the groups. Furthermore, excluding the general English words might affect the results since students are also exposed to these words during the game. To develop a full picture of the effect of a serious game on language learning, additional studies evaluating the comparison among the computer, iPad, mobile phone, and virtual reality will be needed.

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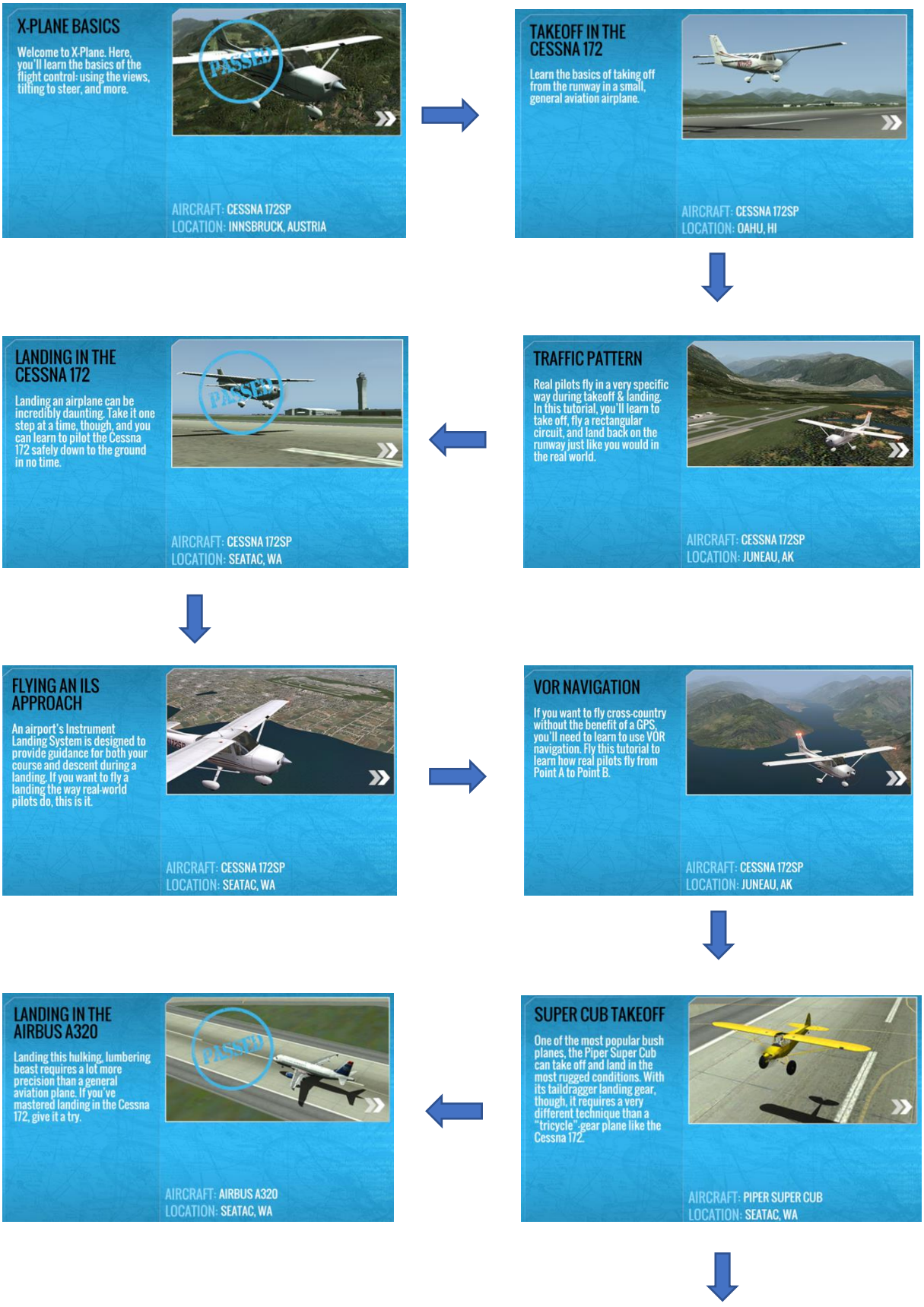
Appendix 1. *Vocabulary Test*

1. Advance
2. Aft
3. Aileron
4. Altimeter
5. Altitude
6. Approach
7. Ascend
8. ATC
9. Brake
10. CDI
11. Clearance
12. Crosswind
13. Cruise
14. Departure
15. Descend
16. Disengage
17. Drag
18. Flap
19. Frequency
20. Fuselage
21. Gate
22. Head
23. Hold
24. Horizon
25. ILS
26. Land
27. Line up
28. Magnetic compass
29. Maintain
30. Monitor
31. Pitch
32. Propeller
33. Pushback
34. Rotate
35. Rudder
36. Runway
37. Stall
38. Steer
39. Suspend
40. Tachometer
41. Take off
42. Taxi
43. Throttle
44. Thrust
45. Tilt
46. Upwind
47. Velocity
48. VOR
49. Wind
50. Yoke

Appendix 2. *Performance assessment of the scenarios.*

Appendix 3. *Flight school scenarios in the experimental group*

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AIRCRAFT: F-4 PHANTOM II
LOCATION: GRAND CANYON
HELICOPTER BASICS
Forget everything you know about flying... this is a whole new world. In this tutorial, you'll learn the fundamentals of taking off and controlling a helicopter.
AIRCRAFT: SIKORSKY S-76
LOCATION: OAHU, HI