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Evaluating a Summative Feedback Option for an Industrial Virtual Learning Environment

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2023 | 34

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Abstract

Virtual learning environments (VLEs) have been rapidly emerging as a powerful tool for education and training. One of the primary modes that VLEs use to promote learning is feedback. Although feedback is known to advance training experiences toward achieving learning outcomes, very little work has been undertaken to isolate and measure the learning impact of immediate, summative, or reflective feedback. This study aims to evaluate the learning effect summative feedback has on industrial training via a VLE. Responses were collected from three groups (with 10 participants each) who played the same fire extinguishing scenario with different feedback features – no post-play analytics, includes only post-play analytics, and includes post-play analytics with summative feedback. The participants in each group also completed pre- and post- questionnaires. Data from both questionnaires and game analytics were compared to evaluate the impact of the summative feedback. According to the findings, the group of participants who used the ADE virtual reality fire safety application with in-game analytics and summative feedback demonstrated a greater degree of change in their responses on the post-test survey compared to the group who played the application without in-game analytics. In conclusion, the use of in-game analytics and summative feedback

appeared to have a positive impact on the participants' learning outcomes and their ability to gain new knowledge through the application.

Keywords:

virtual reality environment; VLE; virtual training; feedback; simulator training

Contents

1 Introduction

The utilization of virtual learning has experienced tremendous growth at 60% annual rate (Machover,1994) and virtual reality technology has made a significant impact not only on the gaming industry but across various other industries as well. Virtual reality offers a multitude of benefits for learners, including the provision of a safe and controlled learning environment that allows for immersive, hands-on simulation experiences. This technology enables learners to engage in in-depth learning experiences that are difficult to replicate in traditional classroom settings. By utilizing virtual reality, learners can explore and practice new skills and knowledge in a risk-free environment that mimics real-world scenarios, thus enhancing their overall understanding. (Hu-Au, 2021)

To be effective, virtual learning environment pedagogy strongly recommends the use of feedback, both immediate and post-play (Charles et al. (2011). Immediate feedback happens while the user is engaging with the virtual training scenario, while post-play feedback is typically in the form of informative panels that appear in the virtual setting after the player has completed the training exercise—often referred to as the in-game analytics. These panels usually display a score for each of the areas that are evaluated in the training scenario.

In-game analytics serve a multitude of purposes in video games and other applications, including educational ones. These analytics are leveraged to gain insights into player behavior, identify areas for improvement, and optimize game design (Canossa et al. 2013). Additionally, in-game analytics can be utilized as a tool for learning and skill development. The problem, however, with displaying in-game analytics as scores to the player at the end of their training exercise is that it only provides information on what they did correctly or incorrectly. In-game analytic scores alone do not supply deeper reasoning about their incorrect actions nor provide information to the player on how to correct their behavior. This study sets out to show whether more informative summative feedback could have a positive impact on knowledge acquisition among practical trainees in a virtual learning environment.

The objective of the study is to compare the post-test results of three groups of trainees who completed a virtual training scenario in fire response. One group received no analytics; the second group only received a display of their in-game analytics after completing the training scenario; while the third group received a display of the in-game analytics together with an explanation on why they received the penalties in the areas where they did not succeed. Throughout this thesis, the term summative feedback system is used to refer to the group that received both analytics and explanations.

Chapter 2 of the thesis presents the theoretical framework surrounding post-play feedback and some of the investigative work carried out by others in this area. Chapter 3 describes the research prototype used in this study and Chapter 4 explains the research design. The research protocol is followed by an extensive description and discussion of the study results in Chapter 5, followed by Chapter 6 which concludes this thesis.

2 Literature

This study aims to assess how the use of summative feedback in a virtual reality learning environment for industrial training impacts the overall learning experience compared to the use of in-game analytics scoring display panels. This chapter provides a short overview of three studies (Seaton et al. 2018; Yousef et al. 2014; Hauge et al 2014) into post-play feedback.

A study conducted by Seaton et al. (2018) demonstrated the effective integration of learning analytics into an educational game. The findings revealed that players could greatly benefit from receiving information about their in-game performance, enabling them to identify areas for improvement by analyzing their gameplay habits and their impact on performance. To facilitate this, the study introduced a visually engaging dashboard that presented players with insightful data regarding their performance. The data visualization tool employed in the research provided players with valuable insights. For instance, it revealed that players exhibited relatively lower performance levels during morning and daytime sessions, whereas their performance gradually improved towards the evening. Consequently, the study demonstrated that the data visualization tool effectively aided players in recognizing the optimal times for engaging in the game. These findings highlight the significant advantages of integrating effective data visualization techniques and learning analytics into educational games.

The impact of game-based learning on student motivation has been highlighted by study conducted by Yousef et al. (2014) . This study aimed to explore the benefits, challenges, and overall effects of using games to enhance student engagement and participation during the learning journey. The findings of this research revealed that game-based learning has a profound and positive impact on students' motivation levels, understanding of concepts, and long-term retention of newly taught information. The study emphasized the crucial role of motivation as a vital element in the teaching and learning process. Building upon these valuable insights, we have incorporated the study's findings into the

development of our post-test survey, which enables us to assess the players' motivation level effectively.

Finally, the study by (Hauge et al (2014) explored the integration of serious games and learning analytics to enhance the evaluation of player behavior, gaming performance, progress, learning outcomes, and game quality. The study by Yousef et al (2014) revealed the significance of establishing a connection between the educational objectives of the game and the data that can be observed within the game. Furthermore, it emphasized the importance of incorporating support for data collection during the game's design phase.

Based on this short literature review, it is clear that player's competence in serious games has been studied and there have been studies trying to find the best tools to ensure player competence in serious games. However, limited research has been conducted to compare the influence of in-game analytics presented together with summative feedback systems on player' knowledge acquisition. This research study on summative feedback has the capacity to fill a notable gap in the current understanding and knowledge base.

3 Prototype Description

ADE Oy, a Finnish based company specializing in making and implementing virtual learning environments for hands-on training purposes, has developed an immersive virtual reality application called "ADE Hot Work" that is specifically designed for fire safety certificate training. This utilizes VR technology to create a realistic and engaging environment where learners can experience and practice hot work fire safety. With its interactive gameplay, ADE Hot Work offers a highly effective and efficient training experience for individuals and professionals seeking to enhance their knowledge and skills in fire safety procedures.

3.1 ADE Hot Work Application

Ade’s cutting-edge learning environment has been designed to provide users with practical experience, enabling them to acquire in-depth knowledge and make informed decisions about fire responses in a safe and controlled setting. By utilizing this innovative platform, users can gain certification and develop their skills to confidently handle challenging scenarios requiring fire response in real-world settings.

The Hot Work fire safety application is aimed at preparing players to obtain the European Hot Work certification in fire safety. The application adheres to official fire safety standards and regulations, and effectively simulates real-life fire safety situations while ensuring the safety of players.

To achieve this, the application has been designed in accordance with several fire safety guidelines and laws, such as the CFPA guidelines, 5900 SFS, Occupational Safety Act, Insurance Act, and Fire Protection Act. The application features a tutorial, along with five distinct training episodes, all of which are developed to meet the highest standards of fire safety training.

ADE Hot Work Training Episodes are:

- Fire Escape:
  In this scenario, the player will find themself trapped in a room where cardboard boxes have caught fire. The player's mission is to escape the building unharmed and as quickly as possible. Figure 1 shows a screenshot of the fire escape part of the application.

Figure 1. Fire escape scenario in Hot Work Application.

- Reporting:
  In this situation, the player is required to recognize and assess potential hazards and dangers present within an industrial setting to ensure safety measures are in place. Figure 2 shows a screenshot of the reporting part of the application.

Figure 2. Reporting scenario in the Hot Work Application.

- Fire Hose:
  In this scenario, the player is required to showcase their ability to extinguish a fire using a fire hose. Figure 3 shows a screenshot of the fire hose part of the application.

Figure 3. Fire Hose part of the Hot Work Application.

- Fire Blanket:
  In this scenario, the player is required to exhibit the proper utilization of a fire blanket for extinguishing a fire. Figure 4 shows a screenshot of the fire blanket part of the application.

Figure 4. Fire Blanket part of the Hot Work Application.

- Fire Extinguisher:
  In this particular scenario, the player employs a fire extinguisher to effectively extinguish a fire. Figure 5 shows a screenshot of the fire extinguisher part of the application.

Figure 5. Fire Extinguisher part of the Hot Work Application.

The HTC Vive Pro virtual reality headset and its controls were utilized to play the ADE Hot Work application, which offers a distinctive feature of using a physical fire extinguisher controller (Figure 6 Fire extinguisher controller). in one of its game sections. This controller adds an extra layer of authenticity to the training experience by mimicking the use of a real foam fire extinguisher. Weighing a few kilograms, the controller's usability closely replicates the actions needed to operate a fire extinguisher in a real-life scenario, including removing a safety pin and precisely aiming the moving nozzle at the right spot. It's worth mentioning that the fire extinguisher controller was specially designed and provided by ADE.

To engage in ADE Hot Work, the following equipment is necessary:

- A PC with exceptional CPU and GPU capabilities
- A VIVE Base Station for precise tracking and spatial awareness
- An HTC VIVE Pro VR Headset for an immersive virtual reality experience
- ADE Fire Extinguisher to ensure safety measures are in place.

Figure 6. Fire Extinguisher Controller.

As part of the research project, two new versions of the Hot Work application were developed, in addition to the existing version that was already available. The original version of the application (see Figure 7 for an example of the in-game analytics) included in-game analytics, while the second version was designed without any in-game analytics. The third version of the application provided summative feedback. Both these new versions were created solely for the purpose of research. The ADE Hot Work virtual reality application was developed using the Unity Game Engine. Additionally, other versions of the application were customized within the Unity Game Engine specifically for this study. In the version of the application without in-game analytics, the scoring scripts from the backend were adjusted and modified. Meanwhile, in the version

of the application with summative feedback (see figure 8 for an example of the summative feedback), a feedback system was incorporated into the final score scene. This feedback system was designed to deliver proper instruction such as how to properly use fire hose or fire blanket. This study employed summative feedback to effectively educate participants on appropriate responses in various situations, such as demonstrating the correct usage of a fire blanket to minimize the risk of injuries.

Figure 7. In-game Analytics.

Figure 8 Summative Feedback.

4 Research Protocol

4.1 Research Design

In this study, the impact of summative feedback in a virtual reality learning environment was explored using a quantitative research design. The study compared three different versions of the ADE Fire Safety app, with varying features. One version included in-game analytics, another version excluded in-game analytics, and the third version included both in-game analytics and summative feedback.

The study involved thirty participants who were divided into three groups, with each group playing a different version of the application. Prior to playing the application, all participants completed a pre-test survey, followed by playing the game, and then completing a post-test survey.

The purpose of the study was to evaluate the effect of summative feedback in a virtual reality learning environment. The study aimed to provide insight into whether summative feedback could enhance the effectiveness of virtual reality learning environments, and potentially improve learning outcomes.

4.2 Participants

One of the major challenges faced during this research project was recruiting participants for the ADE fire safety application testing. The testing was conducted in a virtual reality space reserved exclusively for this purpose, over a period of two weeks. To overcome this challenge, twenty participants were selected from the game development course at Turku University of Applied Science.

During the first week, half of the participants were assigned to play the ADE fire safety app with in-game analytics, while the other half played the application

without analytics. In the second week, we randomly selected an additional ten participants from the ICT study program at Turku University of Applied Science.

In both weeks, all thirty participants participated in pre-test and post-test surveys to gather data on their experience with the ADE fire safety application. All participants were university students at Turku University of Applied Science.

Overall, we were able to successfully recruit and test 30 participants in our experiment, despite the initial challenge of finding suitable candidates.

4.3 Data and Data Collection

Participants from three groups were involved in a study that utilized an ADE virtual learning application. The first group played the application with in-game analytics, which collected data during their gameplay and displayed the results of their actions back to the players. The second group played the application without displaying the results back to the players. Their actions were still recorded to understand their behavior in specific situations. The third group played the application with both in-game analytics and summative feedback about their actions displayed back to them at the end of the scenario. Data were collected from both the in-game analytics and gameplay recordings.

All participants from the three groups also completed pre- and post-test surveys to examine any differences in their knowledge before and after playing the application. The data collected from in-game analytics and gameplay recordings provided valuable insights into the participants' interactions with the virtual learning application, while the pre- and post-test surveys helped to understand any changes in their understanding of how to respond to fire situations following the gameplay experience.

4.4 Data Analysis

The study aimed to evaluate the effect of summative feedback on virtual learning environments by comparing the data collected from game analytics, pre-test and post-test surveys (Figure 9). The collected data were then imported into Excel and analyzed through descriptive statistics and ANOVA to draw meaningful insights about the impact of summative feedback on learning outcomes in virtual environments.

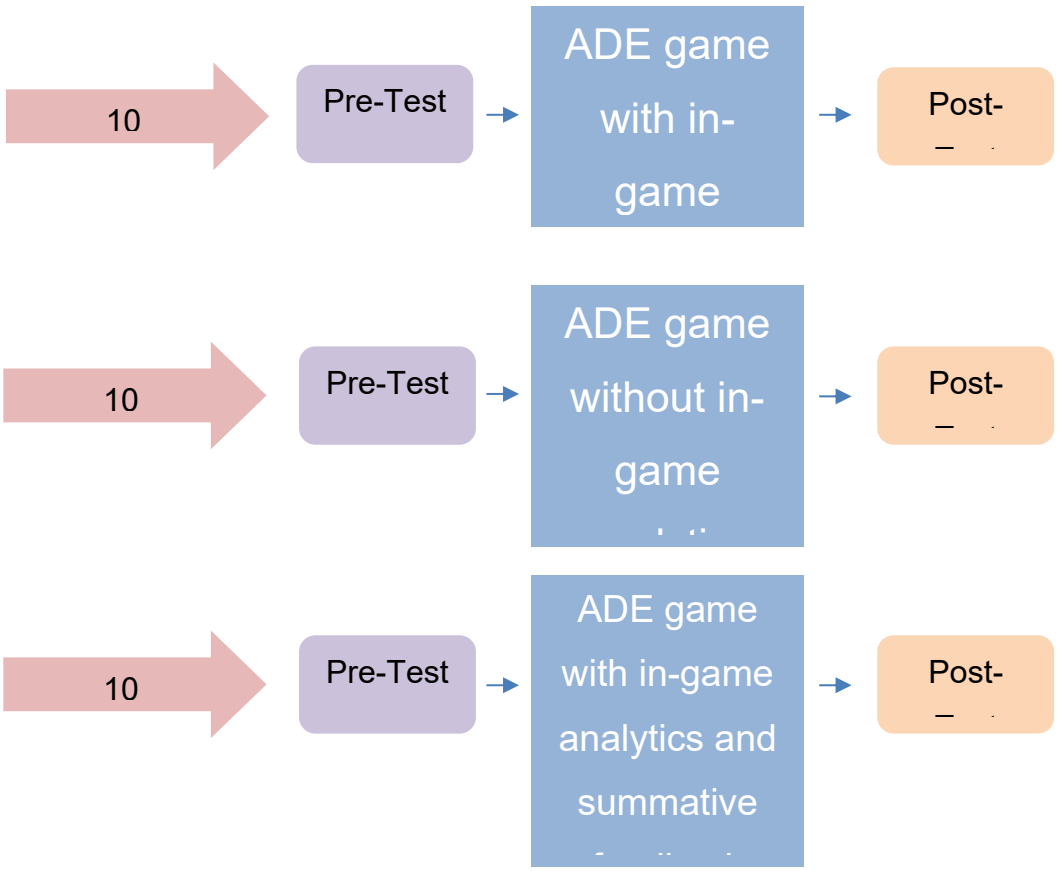

Figure 9. Research design to compare the impact of different post-application feedback arrangements.

5 Results and Discussion

In this study, three distinct participant groups were involved in a test. Group 1 played the application with in-game analytics. Group 2 played the application without any post-play analytics. Group 3 played the application version with both in-game analytics and a summative feedback system displayed back to them at the end of the scenario.

The ADE Hot Work certification program is specifically developed for individuals who wish to acquire the European Hot Work Certificate. In a research study, students from Turku University of Applied Sciences participated in the certification process. To understand their level of understanding on the topics of Virtual Reality and Fire Safety, a pre-test survey was conducted. The pre-test survey also served to establish whether the groups were homogenous in terms of their prior VR experience and fire safety knowledge.

Question 1 of the pre-test questionnaire reveals that in the first group of participants, 40% reported being involved in the development of virtual reality applications, while 50% reported having some previous experience with virtual reality. Only 10% of the participants in this group reported having no prior experience with virtual reality. In the second and third groups of participants, 60% of individuals from both groups reported having tried virtual reality before, while 10% reported never having used virtual reality prior to participating in the study. Table 1 summarizes the results of pre-test questionnaire question 1.

1. How familiar are you with Virtual Reality?
    a. I am part of a VR application development team
    b. I have my own headset at home and play regularly
    c. I often use VR
    d. I have tested it a few times
    e. I have never used it before

Table 1. Pre-test questionnaire results show VR familiarity.

	Pre-Test		Pre-Test		Pre-Test	
	Without In-Game Analytics		With In-Game Analytics		With Summative Feedback	
a	4	40 %	2	20 %	2	20 %
b	1	10 %	1	10 %	-	-
c	-	-	-	-	1	10 %
d	4	40 %	6	60 %	6	60 %
e	1	10 %	1	10 %	1	10 %

According to question 2 on fire safety knowledge, 80% of participants from the group without in-game analytics, 70% from the group with in-game analytics and summative feedback, reported having some knowledge of fire safety. In contrast, 10% of participants from both the groups without in-game analytics and summative feedback reported receiving formal training in fire safety. On the other hand, 30% of participants from the group with in-game analytics reported having received formal training in fire safety. Table 2 shows the result of the pre-test questionnaire question 2.

2. How much knowledge do you have about fire safety?
    a. I am a volunteer fire fighter
    b. I have received training in fire safety
    c. I have some knowledge
    d. I have no knowledge about fire safety

Table 2 Pre-test questionnaire results on fire safety knowledge.

	Pre-Test		Pre-Test		Pre-Test	
	Without In-Game Analytics		With In-Game Analytics		With Summative Feedback	
a	-	-	-	-	-	-
b	1	10 %	3	30 %	1	10 %
c	8	80 %	7	70 %	8	80 %
d	1	10 %	-	-	1	10 %

The next three questions in the pre-test indicated that all three groups had similar levels of experience with fire safety equipment and VR usage. The survey findings indicate that a significant number of participants demonstrated insufficient knowledge and experience in the field of fire safety. This was particularly evident in their understanding and familiarity with fire safety equipment. The groups appeared to be homogenous across their prior VR experience and fire safety knowledge, making that the data can be compared across the three different groups without participant bias.

3. Have you ever used a Fire extinguisher?
    a. Yes
    b. No
4. Do you know how to use a fire hose from a fire cabinet?
    a. Yes
    b. No
5. Have you ever used a fire blanket?
    a. Yes
    b. No

5.1 Comparison before and after playing ADE Hot Works Application

The questions below were included in both the pre-test and post-test surveys. This section highlights the changes in participants' responses after the play session, as we compare their answers from the pre-test to those in the post-test survey. The following tables display the distribution of responses, before and after a test, across various answer options for the participants. The subsequent tables provide detailed explanations of the information presented in the tables.

The following table illustrates the modifications made by three groups of participants to their initial responses. Based on the data provided in the table, the findings indicate that when participants engaged in the application without

in-game analytics, around 50% of them made alterations to their responses when completing the post-test questionnaire. In contrast, among those who had access to in-game analytics, approximately 40% of participants modified their answers. Notably, in the Summative feedback group, only 30% of participants changed their responses.

The right answer for this question is Trigger the alarm when you see a fire in your workplace. According to the findings of the pre-test survey conducted outside the game analytics group, 60% of the participants selected option C as their answer. In the post-test survey, only 20% of the participants chose the correct answer. See Table 3 for the data results regarding fire in our workplace part in the application.

In contrast, within the game analytics group, 50% of the participants consistently selected the correct answers in both the pre-test and post-test surveys. According to the summative feedback received, 60% of the participants responded correctly to the questions in the pre-test. However, there was a significant improvement observed in the participants' performance in the post-test survey, with 90% of them selecting the correct answers.

Summative feedback demonstrated a notable enhancement in the selection of the correct answer when comparing with and without in-game analytics groups. The correct option is option C.

1. What would you do first, when you see a fire in your workplace? (Please select only ONE answer)
    a. Try to put the fire out
    b. Try to exit the area
    c. Trigger the alarm

Table 3. Results on fire in your workplace part of the application.

	Pre-Test		Post-Test		Pre-Test		Post-Test		Pre-Test		Post-Test	
	Without In-Game Analytics		Without In-Game Analytics		With In-Game Analytics		With In-Game Analytics		With Summative Feedback		With Summative Feedback	
a	4	40 %	4	40 %	3	30 %	3	30 %	2	20 %	1	10 %
b	-	-	4	40 %	2	20 %	2	20 %	2	20 %	-	-
c	6	60 %	2	20 %	5	50 %	5	50 %	6	60 %	9	90 %
	50 %				40 %				30 %			

Percentage indicates how many participants changed their answers for this particular question in post-test.

The below table outlines a set of multiple-choice questions that require respondents to rank the given options in a specific order. The task is to determine the most appropriate sequence in which the listed items should be performed. This question is related to the Fire Escape training section. The right combination is “badc”. Based on the data presented in the table, it is evident that a higher proportion of participants belonging to the in-game analytics group demonstrated an improvement by changing their answers to the correct ones. However, it is noteworthy that the summative feedback group exhibited the highest percentage of participants who initially selected the correct answers in the pre-test compared to other groups. See Table 4 for the combination’s answers data.

2. When there is a fire, in what order should the things listed below be done?
    a. Rescue people at risk
    b. Alert others about the fire
    c. Inform the fire department
    d. Leave the building

Table 4. Combination answer data for question 2.

Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Without In-Game Analytics	Without In-Game Analytics	With In-Game Analytics	With In-Game Analytics	With Summative Feedback	With Summative Feedback
bdca	dbca	badc	b - - -	cbad	c - - - -
bcad	bcad	bacd	badc	badc	badc
cbad	cbad	bcad	badc	bcad	badc
cbad	badc	bcad	bacd	badc	badc
bcad	d - - -	bcad	b - - -	badc	badc
badc	bdca	bacd	badc	bacd	badc
abdc	abdc	dbac	dbac	badc	badc
bcad	bcad	bcad	bcad	bcad	bcad
abdc	adcb	bcad	bcad	bacd	badc
abcd	a - - -	dabc	bdca	badc	badc
60 %		70 %		40 %	

The post-test survey reveals a greater shift in response among the participants who were exposed to in-game analytics compared to those who were not, as well as those who received summative feedback. According to the data presented in the table (Table 5), there has been a significant increase in the participation of the in-game analytics group. Specifically, the participation rate has surged from a mere 10% to a noteworthy 60%. This indicates a substantial growth in the number of individuals actively engaged in the analytics group within the gaming environment.

3. When you notice some bottles of highly flammable liquid on the floor, you should…

a. Move them away from the fire
b. Cover them with fireproof material
c. Get away from that area immediately
d. Move them and cover them with fireproof material
e. Immediately warn others to not go near the area where the bottles are

Table 5. Data for question 3.

	Pre-Test		Post-Test		Pre-Test		Post-Test		Pre-Test		Post-Test	
	Without In-Game Analytics		Without In-Game Analytics		With In-Game Analytics		With In-Game Analytics		With Summative Feedback		With Summative Feedback	
a	1	10 %	2	20 %	3	30 %	1	10 %	-	-	3	30 %
b		0 %	2	20 %	2	20 %	2	20 %	3	30 %	5	50 %
c	2	20 %	-	-	2	20 %	1	10 %	3	30 %	-	-
d	4	40 %	5	50 %	1	10 %	6	60 %	3	30 %	1	10 %
e	3	30 %	1	10 %	2	20 %	-	-	1	10 %	1	10 %
	50 %				70 %				60 %			

The following question aimed to assess knowledge regarding strategies for escaping a room, specifically in the context of the Fire Escape game scene. In this scene the player was placed in a room where the highly flammable material is placed in the middle of the room.

In the Fires Escape scene, the player's initial objective was to interact with the fire alarm button. Once activated, the player proceeded to exit the room through the door, with the option to close it behind them. They then had the opportunity to warn others about the danger, evacuate the building using the emergency

exit route, and guide the fire department to the scene. Option B is the accurate response. The data indicates that there are no significant alterations in the correct answers among the summative groups. However, within the in-game analytics groups, there is a slight modification in the participants' answers. See Table 6 for the result for the question 4.

4. When exiting a room while there is a fire inside, you should first…

    a. Shout for help
    b. Close the door
    c. Trigger the alarm
    d. Find where the fire extinguisher is

Table 6. Data on exiting room part of the application.

	Pre-Test		Post-Test		Pre-Test		Post-Test		Pre-Test		Post-Test	
	Without In-Game Analytics		Without In-Game Analytics		With In-Game Analytics		With In-Game Analytics		With Summative Feedback		With Summative Feedback	
a	-	-	-	-	-	-	-	-	-	-	-	-
b	6	60 %	3	30 %	2	20 %	4	40 %	3	30 %	3	30 %
c	2	20 %	3	30 %	6	60 %	5	50 %	6	60 %	7	70 %
d	2	20 %	4	40 %	-	-	1	10 %	1	10 %	-	-
	40 %				50 %				40 %			

The following survey question pertained to the Fire Hose exercise in the application, and the correct combination was determined to be "dbca" (Table 7). Among the participants who did not have access to in-game analytics, 40% of them selected the correct combination. In contrast, among the participants who had access to in-game analytics, 30% of them chose the correct combination. Lastly, among the participants who received summative feedback after playing the application, 20% of them correctly identified the combination.

6. When operating a fire hose, in which order should the things below be done?

    a. Open the hose nozzle valve
    b. Get into position to extinguish the fire
    c. Aim the hose at the fire
    d. Open the main wall/cabinet valve

Table 7. Data on operation fire hose combination.

Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Without In-Game Analytics	Without In-Game Analytics	With In-Game Analytics	With In-Game Analytics	With Summative Feedback	With Summative Feedback
dabc	dabc	dbac	dbca	dbac	dcba
c - - -	dabc	a	dcba	dbac	dabc
dbac	dbca	-	dbca	dbca	dbca
dbca	dbac	dbca	dbca	dbca	dabc
dbca	-	abcd	dabc	bdca	dbca
bdca	dbca	dbca	dbac	dbac	dbca
dcba	dbca	-	cadb	dbca	dbca
dbca	dbca	dabc	dabc	dbac	dabc
bcda	dbca	dbca	dbca	dbca	dbca
dbca	dbca	dbac	dbca	dbca	dbca
70 %		70 %		60 %	

Interestingly, the question concerning fire safety in the workplace yielded an intriguing result. Surprisingly, none of the participants in the in-game analytics group provided the correct answer in both the pre-test and post-test assessments. However, there was a slight improvement in the post-test performance of participants from both the in-game analytics group and the summative group, as they demonstrated a higher number of correct answers. See Table 8 for the data on question 8. The correct answer is B

8. When there is a fire in the workplace, you should first concentrate on…
    a. Putting out the fire
    b. Getting yourself to safety
    c. Alerting others about the fire
    d. Removing highly flammable materials away from the fire

Table 8. Data on fire in the workplace.

	Pre-Test		Post-Test		Pre-Test		Post-Test		Pre-Test		Post-Test	
	Without In-Game Analytics		Without In-Game Analytics		With In-Game Analytics		With In-Game Analytics		With Summative Feedback		With Summative Feedback	
a	1	10 %	4	40 %	2	20 %	1	10 %	2	20 %	1	10 %
b	2	20 %	5	50 %	-	-	-	-	4	40 %	5	50 %
c	4	40 %	1	10 %	5	50 %	5	50 %	3	30 %	3	30 %
d	3	30 %	-	-	1	10 %	2	20 %	1	10 %	1	10 %
	60 %				60 %				30 %			

Question 10 addresses the appropriate time to contact emergency services in the event of a fire. The given table indicates that there are slight differences in the correct answers between the group without in-game analytics and the group with in-game analytics. However, there is a significant improvement in the correct response rate among the summative group. Table 9 shows the changes in correct answer.

10. When should you inform emergency services (call 112) about the fire?

a. Once you are safely outside the building
b. Once you know that nobody else has called them yet
c. As soon as you notice the fire
d. Immediately after triggering the alarm

Table 9. Data for question 10.

	Pre-Test		Post-Test		Pre-Test		Post-Test		Pre-Test		Post-Test	
	Without In-Game Analytics		Without In-Game Analytics		With In-Game Analytics		With In-Game Analytics		With Summative Feedback		With Summative Feedback	
a	6	60 %	7	70 %	3	30 %	4	40 %	6	60 %	9	90 %
b	-	-	-	-	-	-	-	-	-	-	-	-
c	2	20 %	2	20 %	1	10 %	1	10 %	-	-	-	-
d	2	20 %	1	10 %	6	60 %	3	30 %	4	40 %	1	10 %
	10 %				50 %				50 %			

The survey results indicate that among participants who did not have access to in-game analytics, 60% of them selected incorrect answers in the pre-test survey. However, during the post-test, 30% of these participants managed to choose the correct answers. Surprisingly, among the participants who had access to in-game analytics, a significant 80% of them initially chose incorrect answers in the pre-test. However, during the post-test, 40% of these participants were able to switch to the correct answers. On the other hand, among the participants in the summative feedback group, 40% of them initially selected wrong answers in the pre-test. Nevertheless, all of these participants corrected their answers and chose the right options during the post-test. The correct combination of responses observed across these groups is "bdac". See Table 10 to check data on operating fire extinguisher.

13. When operating a fire extinguisher, in which order should the things below be done?

a. Aim the hose at the fire
b. Remove the safety pin
c. Squeeze the extinguisher trigger
d. Get into position to extinguish the fire

Table 10. Data on operating fire extinguisher.

Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Without In-Game Analytics	Without In-Game Analytics	With In-Game Analytics	With In-Game Analytics	With Summative Feedback	With Summative Feedback
bdac	bcac	dabc	bdac	badc	bdac
dabc	dbac	abdc	abdc	dabc	bdac
badc	badc	bdac	-	bdac	bdac
dabc	bdac	dbac	bdac	bdac	bdac
dabc	-	badc	bdac	dabc	bdac
dbac	bdac	bdac	bdac	bdac	bdac
bdac	bdac	bdac	-	bdac	bdac
bdac	bdac	dbac	bdac	dabc	bdac
dbac	bdac	dbac	dabc	bdac	bdac
bdac	bdac	bdac	bdca	bdac	bdac
60 %		80 %		40 %	

The results of the post-test surveys indicate that participants, who did not have access to in-game analytics, modified their responses by an average of 46%. Interestingly, participants who had access to in-game analytics made slightly more changes, with an average modification rate of 49%. These two groups exhibited similar levels of response modification, showcasing a close resemblance in their behavior. On the other hand, participants belonging to the summative feedback group displayed a notably lower average modification rate of 38%. This finding suggests that this particular group made fewer adjustments to their answers compared to the other two groups.

This study also compared the results of the post tests of the three groups by means of a one-way ANOVA test. Table 11 shows the results of each group's 10 participants for the 14 post-test knowledge questions. The group with no analytics scored 6,3 out of 14 on average, while the groups with analytics and the summative system scored 6,5 and 8,6 respectively.

Table 11. Post-test results - Number of correct answers put of 14 knowledge questions.

	NO analytics	ONLY analytics	Summative system
User 1	5	9	6
User 2	5	7	9
User 3	5	5	10
User 4	7	8	7
User 5	4	6	7
User 6	8	8	7
User 7	6	3	10
User 8	8	6	9
User 9	9	5	10
User 10	6	8	11
Average	**6,3**	**6,5**	**8,6**

The ANOVA test had a p-value of 0,01056. At a 0,05 level of significance, this means we can reject the null hypothesis that the average scores of all 3 groups are equal. To determine the groups that were significantly different from one another, a Tukey pairwise post-hoc test was conducted. The results of the Tukey post-hoc tests are shown in Table 12.

Table 12. Tukey Test results to determine which groups were significantly different.

Treatment pairs	Tukey HSD Q-stat	Tukey HSD p-value	Inference
NO analytics vs ONLY analytics	0,3651	0,9000	Insignificant
NO analytics vs SUMMATIVE system	4,1992	0,0165	* p<0.05
ONLY analytics vs SUMMATIVE system	3,8341	0,0300	* p<0.05

The Tukey data analysis shows that the groups with no analytics performed the same as the group who had only analytics. The summative feedback system

group, on the other hand, had significantly different scores from both the no analytics and analytics only groups.

According to the findings of this study, the survey data suggests that the in-game analytics system exhibits a greater influence on participants, making them more inclined to modify their responses and acquire new knowledge compared to other feedback systems.

According to the survey data, the group that did not have in-game analytics showed an average percentage of changes in answers in post-test surveys of 48%. On the other hand, the group that had in-game analytics demonstrated a slightly higher average percentage of changes, with 50%. Lastly, the group that received summative feedback had a lower average percentage of changes in answers, measuring at 38%.

In the provided table, the group utilizing in-game analytics exhibited the highest frequency of modifications in their post-test questionnaires compared to other participants.

Here are the key differences between the three test groups that would like to emphasize:

Participants in Group 1 of the test were assigned to play a version of the application without in-game analytics. At the conclusion of each section of the application, these participants were not provided with a score or a list of the choices they had made. Furthermore, at the end of their play session, participants in Group 1 were not shown their total score.

During the testing phase, Group 2 participants were engaged in playing a version of the application with in-game analytics. After completing each section of the application, participants were promptly presented with their individual scores for that specific section. Additionally, they were provided with a comprehensive breakdown of the positive and negative choices or factors that

contributed to their scoring. At the conclusion of the play session, Group 2 participants were able to view their overall score, which ranged from 0 to 500.

In the 3rd group of test participants, the application version they played with in-game analytics and also provided summative feedback. Throughout the game, after completing each section, participants were able to view their scores for that specific section. Additionally, they were presented with a list of positive and negative choices or factors that influenced their scoring, helping them understand the impact of their decisions. At the end of the play session, participants were shown their overall score on a scale of 0 to 500. Moreover, they received feedback on how to effectively accomplish the tasks in order to improve their performance.

Significant evidence indicates that individuals who belonged to the in-game analytics group demonstrated superior performance compared to other participants when it came to selecting the accurate answers in the post-test survey. The primary contributing factor to this notable achievement was the availability of in-game analytics scores.

All participants, regardless of their respective groups, were presented with the following question that required them to choose the correct answer from a set of four options.

Where should you aim the water spray when extinguishing a fire with a firehose?

a. In the middle of the fire
b. The area around the fire so it does not spread
c. Over the top of the fire so that it falls on the fire
d. At the base of the fire

According to the data collected by survey, the in-game analytics group exhibited a significantly higher percentage of alterations in their responses during the post-test survey compared to other groups. The use of in-game analytics greatly

impacted the participants' performance in both the pre-test and post-test surveys. Initially, only 50% of the participants correctly answered the questions in the pre-test. However, after utilizing in-game analytics, the success rate increased significantly to 70% in the post-test. This improvement clearly demonstrates the effectiveness of in-game analytics in enhancing the participants' performance.

Moreover, the summative feedback groups also indicated a positive trend in selecting the correct answers. While the improvement may be slight, it further supports the notion that in-game analytics and summative feedback positively influenced the participants' decision-making abilities.

In contrast, the group without access to any feedback systems experienced a decline in performance. Initially, they had a success rate of 70% in the pre-test, which decreased to 60% in the post-test. This decline can be attributed to the absence of any feedback mechanisms that could have potentially aided their decision-making process.

Overall, these findings highlight the significant impact of in-game analytics on participant performance, as well as the importance of incorporating feedback systems to foster improvement and enhance decision-making abilities.

6 Conclusion

This study aimed to assess the effectiveness of incorporating summative feedback options within an industrial virtual learning environment. In this study, summative feedback was compared to traditional in-game analytics and the modified version of the game which did not have any in-game analytics to understand the participants changes in the answers in post-test survey compared to pre-test survey.

This study presents evidence supporting the notion that the inclusion of traditional in-game analytics, such as scoring systems, significantly influences players' performance compared to games or learning applications lacking any form of in-game analytics. Specifically, participants utilizing in-game analytics displayed a greater inclination to revise their initial answers in favor of the correct ones.

Nevertheless, the results of an ANOVA test indicated that the impact of a summative feedback system on players exceeded that of in-game analytics. On average, the group without in-game analytics achieved a score of 6.3 out of 14, while the groups utilizing analytics and the summative system scored 6.5 and 8.6, respectively. This data suggests that while the presence or absence of in-game analytics yielded similar effects on the participants, the summative feedback system had a greater impact on their performance.

This study strongly advocates for the inclusion of summative reasons in the scoring analytics provided to users at the conclusion of their play-throughs. It strongly recommends hands-on training for VR application developers to incorporate these reasons into their development process.

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