Imperial College London

Final report for MEng/iBSc Group Project

ADdictive: Gaming Away Atopic Dermatitis

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Contents

1 Abstract

Atopic dermatitis (AD), commonly referred to as eczema, is a skin disease that affects up to 5% of the adults and 25% children worldwide. However, current public awareness of the causes of the disease and the modern treatment protocols are lacking. To address this issue, four different educational games were developed, delivering information about the important aspects of AD mechanisms and treatment. These include the role of the skin barrier in the disease pathology, the reasons why proactive therapy is superior to reactive therapy and the role of topical emollients and topical corticosteroids in the treatment of the AD. The games were made publicly available at the website 'simmer.io' and showcased during Imperial Festival 2018. Surveys with questions testing the understanding of the various aspects of AD and proactive therapy were distributed to the players before and after the game, and the impact of the games on their knowledge was assessed. Despite the small sample size, the games have proven to be an efficient tool to raise awareness of AD and to deliver key messages about the pathology and treatment of the disease.

2 Acknowledgements

We would like to thank our supervisor Dr. Tanaka for her endless patience and continuous support throughout the project year. With her assistance, we received extremely encouraging and constructive feedback from within the Bioengineering department and outside. We would also like to acknowledge the work of the former students of Dr. Tanaka, as their work on eczema was the foundation for our project. Similarly, the previous X-ema game created by previous undergraduates of the department provided a proof of concept for our own project. Furthermore, we would also like to extend our gratitude to the Bioengineering department and PhD students, Harley Day and Guillem Hurault, who helped us make the showcase of the project during Imperial Festival 2018 happen. Special mention goes to Dr. Radcliffe for helping us to source the hardware and promotional materials for the festival.

Thank you to all that played and tested our games and helped us improve them. Special thanks to Professor Hywel Williams from the University of Nottingham, Goldie Putrym as well as to Dr. Stevens-Smith.

Additionally, we would like to thank Unity, the gaming platform, which has made this possible with its amazing tutorials and extensive community.

3 Introduction

Atopic dermatitis (AD) commonly known as eczema, is a common skin condition, characterised by dry, pruritic skin and can significantly affect the quality of life of individuals affected by it [9]. This chronic and relapsing inflammatory skin condition affects all age groups, but in particular children, of which up to 25% are affected worldwide[9]. Unfortunately, there is no known cure for AD. When an AD flare up occurs, the skin becomes more pruritic, inflamed and sometimes infected. The condition is kept under control using topical emollients, to improve the barrier function of the skin and consequently prevent flare ups from occurring[17]. Emollients are used as frequently as twice a day on both lesional and nonlesional areas. Depending on the severity, topical corticosteroids are also used to decrease the associated symptoms. The application of corticosteroids is regular until all lesions have mostly cleared. Further application of corticosteroids depends on the patients' treatment plan. Table 1 summarizes the different treatment plans.

Table 1: Comparison between the two types of treatment for AD.

	Reactive therapy	**Proactive therapy**
Description	- The conventional management of AD. - Corticosteroids are applied only during a flare up. - This has been shown to deliver sub-optimal results [15].	- The current recommended management of AD. - Focuses on preventing flare ups from happening by aiming to reduce subclinical inflammation [19]. - Corticosteroids are used regularly, even in periods without obvious symptoms.
Method	- Anti-inflammatory therapy is stopped after lesions have mostly cleared.	- Depending on severity, long-term low dose intermittent application of anti-inflammatory therapy to the former affected area is required [15].
Area of medication	- Anti-inflammatory therapy is only used on a "needed basis"- only at location where flare ups occur [15].	- Anti-inflammatory therapy to the former affected area [15].
Frequency of medication	- Anti-inflammatory therapy is stopped after lesions have mostly cleared.	- Anti-inflammatory "minimal therapy for minimal eczema" usually twice a week following an intensive period [19].

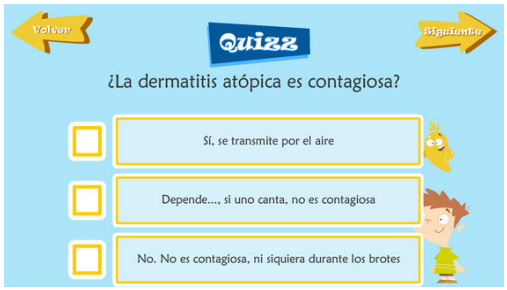
Due to the condition's relapsing nature, adherence to proactive therapy is paramount for its management, as it induces and keeps the condition in the asymptomatic non-active phase [19]. Currently, proactive therapy is often associated with low patient adherence, with only a 40% adherence to five day treatment courses among children with AD [11]. This is due to the time consuming nature of topical treatments, the lack of understanding about the disease and the medication used, leading to corticosteroid phobia, as well as disinterest and lack of urgency to regularly apply the treatments during the non-active phase [13 16].

Therefore, there is a clear need to raise awareness of medical professionals - especially dermatologists - and the public, with a special focus on children, about the condition itself and the benefits of proactive therapy. One of the main objectives of our project is to introduce and enhance patient knowledge of proactive therapy hence encouraging patient adherence.

Studies have shown that early follow up appointments, text message reminders, and educational workshops increase patient compliance to the treatments [4]. However as AD is mainly a disease affecting children, the increasing of adherence should be done in a more engaging way, which would be best achieved by using interactive tools such as educational games. Video games engage the player as they encourage the element of learning [10 7]. Games contain complex rules and game mechanics, which are "constructs of rules designed for interaction with the game state" [2]. The player must learn and manipulate these to achieve their goals [8]. Embedding elements of teaching lessons within these gameplay mechanics produces educational games. In various subjects, these have been successful as teaching aids or research activities [6].

Several educational games on AD have already been developed. The Winter Game by the Foundation of Atopic Dermatitis and Alex y Glupi by a Spanish developer (Figure 1) emphasized the daily precautions to prevent itchiness. However, neither mentions the mechanism of the disease nor explains proactive therapy [1 12]. Another game, called X-ema, developed by Imperial undergraduates in 2015 explores some mechanisms of AD and the importance of proactive therapy [3]. However, some significant downfalls such as repetitive gameplay and redundant wordiness were identified.

(a) X-ema



(b) Alex y Glupi

Figure 1: Screenshots of a maze level in X-ema and Alex y Glupi.

These preliminary findings, and the X-ema project files, allowed us to define the project to create an educational game which focuses on the pathogenesis behind AD and the importance of proactive therapy with optimal dosing and schedules. In particular three lessons will be emphasized:

- Emollients should be taken frequently
- Corticosteroids should be taken following the treatment plan
- Treatment needs to continue even in the absence of symptoms

An educational game on AD can be made easily accessible to the target audience, be it patients, caregivers, academics, or the general public, with a low time commitment required. Such a project can also promote the use of educational games to disseminate the applications of a solid scientific approach in an intuitive and engaging way.

4 Methods

4.1 General Design Principles

It was found that a good educational game carries an intrinsically integrated message meaning that the message is delivered as a core concept of the game, a "just-in-time" and "on-demand" method of message delivery, an appropriate design of difficulties among levels according to user skills development, and the clear goal(s) of the game[7 8 6 14].
To apply these elements into our game design, all of our games were tailor-made such that game setup, players' actions and winning/losing conditions corresponds to relevant concepts in AD mechanism or treatments. Through a multi-level system, we aimed to deliver our lessons gradually as the players progress through the game, rather than deliver all the lessons simultaneously. This has been shown to be effective in other educational games[6]. In order to maintain player engagement, the games were designed in such a way that the difficulty increases with levels and thus the players' expected skills and experience, making them more challenging yet not overwhelming, as shown in Figure 2.

4.2 Development Platform Choice

The project was developed using the Unity Engine. This platform was chosen as it was free to use for non-commercial purposes. The game was developed in C#, using the Unity's extensive library of pre-built functions, and Unity's built-in game assets. The platform was also compatible with different operating systems, and could build versions of the games for computers, the online game hosting platform we used ('simmer.io'), and the mobile phones.

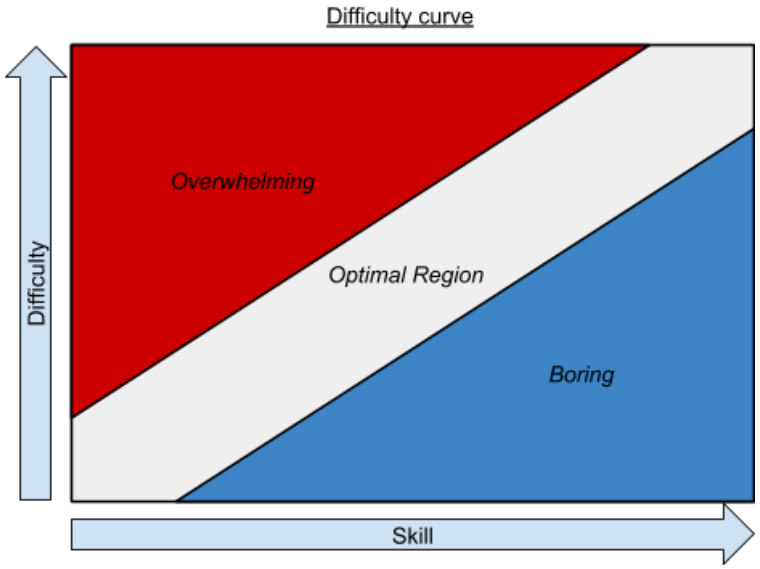


Figure 2: Difficulty curve, illustrating the relation between skill and difficulty in relation to the players needs.

4.3 Specific Game Designs

Four games were proposed to cover different age groups and different learning outcomes.
Short gameplay videos are available in the Appendix 4.

Skin Square
Target age group: 12+

Skin Square took inspirations from the "Pretentious Game" series by Keybol. In these games the player solves puzzles using the given text conveying the story of the game, and providing hints to the solutions.

In the Skin Square game, players follow the Skin Square character, who is diagnosed with AD as the game progresses. The puzzles represent the difficulties of an AD patient adhering to treatment. The text, representing the character's thoughts, provides the educational component. Character is relatable to AD patients as it follows the character's process of learning about the disease, the medication, and the importance of adhering to the proactive therapy treatment plan.

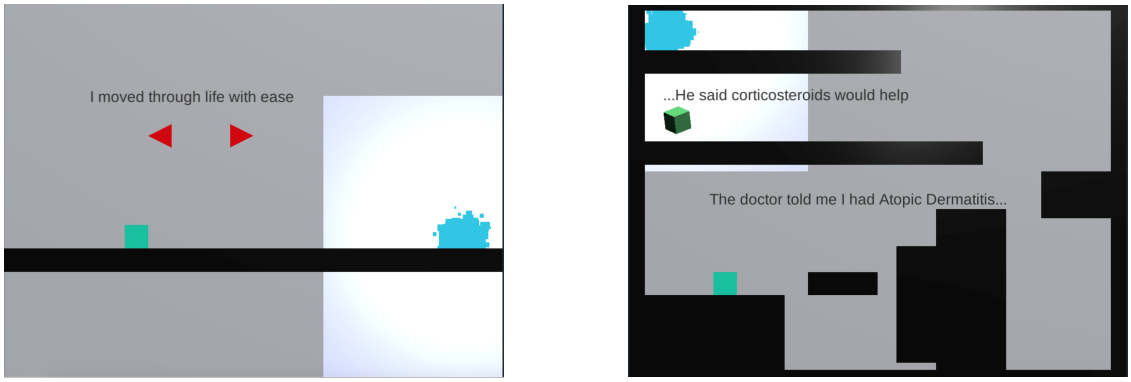


Figure 3: Gameplay of Skin Square. The player (cyan-green cube) needs to reach the exit point (blue pixelated cloud), using the text as hints.

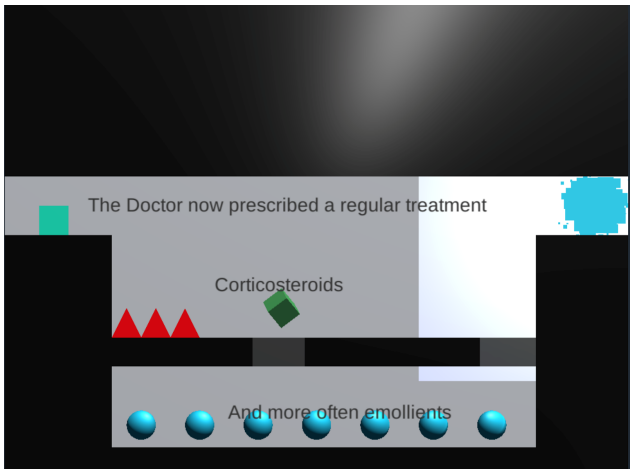


Figure 4: In this level of Skin Square, the player need to take the corticosteroid (green cube), and the emollients (blue spheres) before they can jump onto the exit platform. This teaches that taking medications according to the treatment schedule would help the patient achieve their goal, which is recovery.

Skin Sphere
Target age group: 12-18

Skin Sphere is a maze-based game that introduces the player to the different types of treatments in proactive therapy for AD as well as factors that increase the likelihood of flare ups. Players control the movement of the Sphere to reach the exit point before the health bar, decreasing over time, reaches zero. A threshold in the health bar indicates the occurrence of a flare up. This is represented by the health bar dropping instantaneously to a low value and character turning red and moving slower, increasing the difficulty of reaching the exit point. As the game progresses different concepts are introduced. This progression is shown in the Figures 5-7.

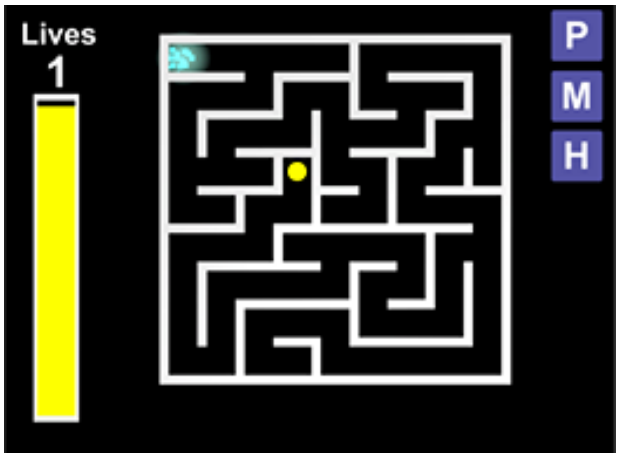


Figure 5: A Skin Sphere level with exit point (blue pixelated cloud) and health bar (yellow bar on the left). The player (yellow sphere) needs to reach the exit point before the health bar drops to zero.

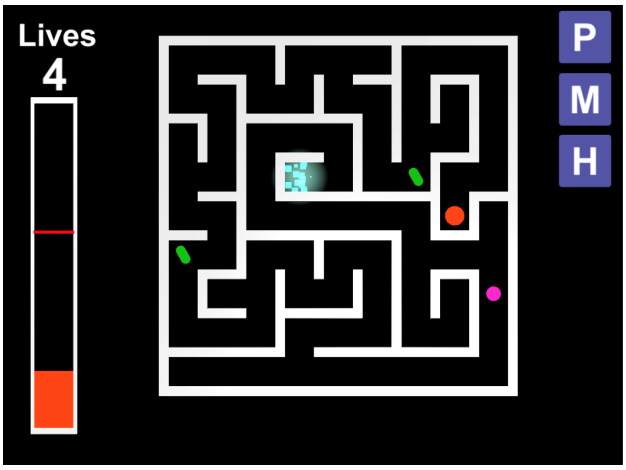


Figure 6: A Skin Sphere level where a flare up has occurred (health bar is below red line threshold). Emollients (pink dot) and corticosteroids (green capsules) have been introduced. The player (red sphere due to flare up) can use them to raise the health bar out of the flare up state. This represents proactive therapy inducing and maintaining the asymptomatic state.

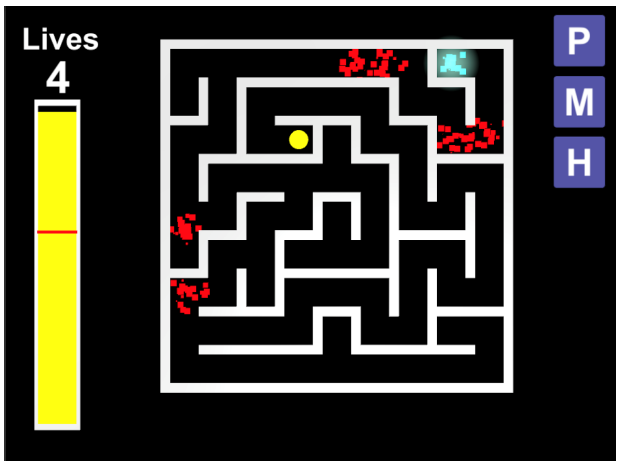


Figure 7: A Skin Sphere level with pathogens (red pixelated clouds) present. They will cause decrease in health bar.

Whack-a-Flare
Target age group: 6 – 12

Inspired by Whack-a-mole, the goal of the game is to educate players on the different treatment for AD depending on the severity of their condition and to prevent people from overusing strong treatments.

The playing field represents the skin, which turns red to trigger generation of flare ups (moles). The hammer represents the application of treatment. The player is required to use corticosteroids of two different potencies and emollients (different hammers) to stop flare ups of different severities and keep the skin healthy to gain points. As the use of incorrect medication potency can lead to low effectiveness of the treatment or exacerbation of the symptoms, the incorrect use of hammers results in point deduction. For each level, the player has a limited time to reach a minimum score to pass, and the levels are organized with increasing difficulties, reflecting different severity of real-life AD symptoms.

The hammering is a representation of applying treatment onto the skin. The player is required to stop the flare ups of different severities by applying the corticosteroid of appropriate potency and keep the skin healthy using emollients to gain points. As the using the incorrect medication potency contributes to the exacerbation of symptoms in real life , the incorrect use of hammers results in point deduction. For each level, the player has a limited time to reach a minimum score to pass, and the levels are organized with increasing difficulties, reflecting different severity of AD symptoms in reality.

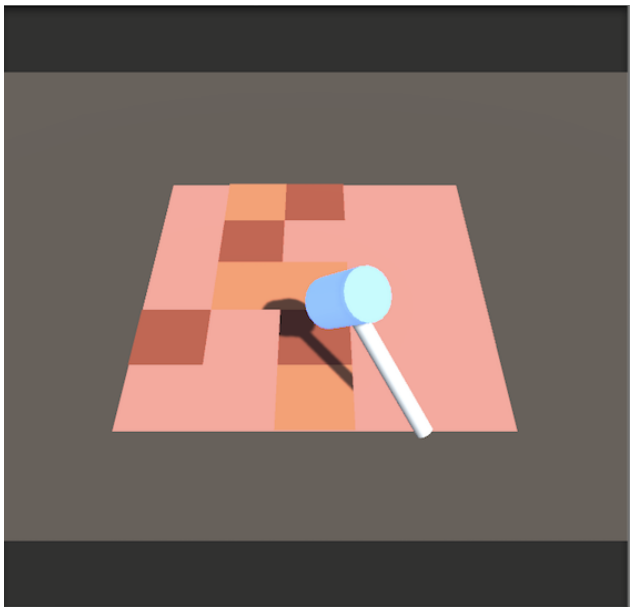


Figure 8: Screenshot of Whack-a-Flare. Different colours of patches represent different severities of flare ups, and using the correct hammer, which represents different medication, is essential in achieving a high score.

Skin Defense
Target age group: 16+

Skin Defense aims to explain the disease mechanism of how eczema progresses in a patient. It is a tower defense game, where pathogens (environmental stressors) act as “invaders” to the skin while the player deploys white blood cells as “towers” to defend the skin from inflammation. Two parameters called “immune tolerance” and “skin barrier integrity” are used. “Immune tolerance” refers to the number of pathogens that the skin barrier and the immune responses can tolerate without causing inflammation, while skin barrier integrity refers to the ability to prevent the penetration of pathogens by the skin barrier. The player

loses when the skin barrier integrity drops to zero. Pathogens breaking through the skin (reaching the endpoint) reduces immune tolerance, causing flare up when it reaches zero. Skin barrier integrity drops consequently, representing how flare ups damage the skin barrier [18]. If pathogens are prevented from breaking through the skin barrier, the flare up will eventually subside and skin barrier integrity recovers over time. However, after given number of flare-ups, the maximum immune tolerance decreases, making flare-ups more likely to occur. This represents allergic sensitization [5] .

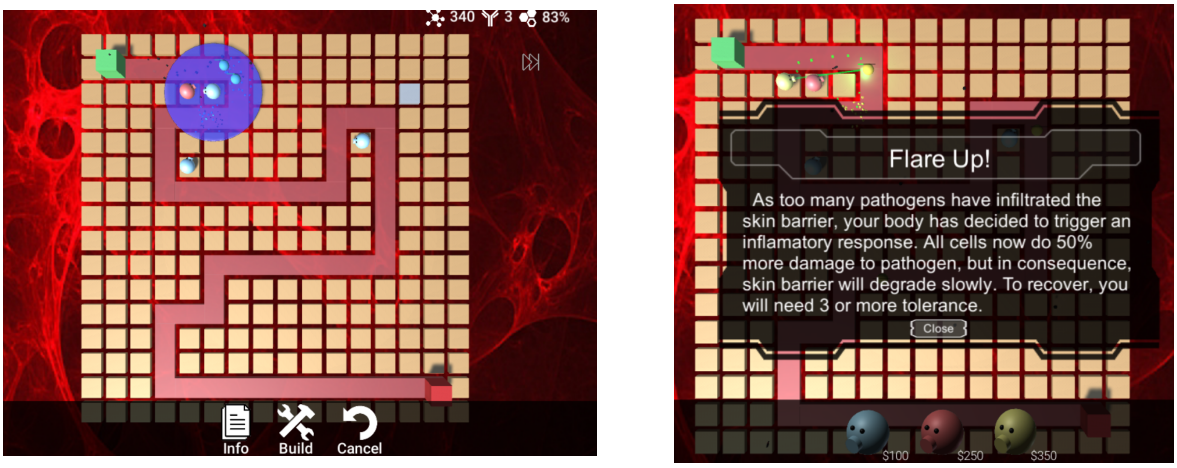


Figure 9: Screenshot of Skin Defense. Pathogens spawn at the green cube and moves towards the red cube along the pink path, which represent the skin barrier. Players select white blood cells in the menu and build them on the nodes to defend against the invasion. A flare up message indicates too many pathogens have passed through the skin barrier.

4.4 Evaluation

To evaluate on the effectiveness of the games in conveying their messages, the games were distributed among peers and some AD-related researchers for feedback. Moreover, the games were showcased during Imperial Festival 2018. Visitors were invited to play the games and were asked to fill in a survey before and after the session. The responses of pre-game and post-game surveys were compared to evaluate the effectiveness of the games as an educational tool.

Different surveys were prepared for each game, containing multiple choice questions. They each shared general knowledge questions on AD, such as its definition, as well as questions tailored to the relevant concepts in each game. The players' ages were recorded so that data analysis could be achieved for various age groups. Detailed survey questions and results for each game are attached in the Appendix.

The number of correct answers were recorded as scores and normalized by the total number of questions in each survey. The 95% confidence interval of Student t-distribution was used to analyze the statistical significance of the data.
The data was analyzed in three ways:

- Pre-game and post-game score differences across three age groups
- Pre-game and post-game score differences across four games
- Pre-game and post-game score differences in specific questions

This segmentation was used as it shows the overall educational benefit of the games, reveals the ability of the games to deliver their specific message, and demonstrates the appropriate age range in which the games could be suitable.

4.5 Summary

Table 2: Summary of the four different educational games on AD.

Game title	Learning outcome	Specifications	Target audience	Game platform	Average playtime
Skin Square	- Acquire intuitive understanding of AD proactive treatment plan - Understand that inflammation exists even without AD symptoms	- Puzzle based platform game - Split in 2 level packs - Macro & micro scale - Story based - Educational messages provide hints to puzzles	- AD patients - Caregivers - Age: 12+	Desktop	15 min
Skin Sphere	- To appreciate the need for treatment even in the absence of AD symptoms - To highlight the negative role of the pathogens - Demonstrate how the flare ups increase the required treatment dosage	- Pacman based - Macro-scale - Trying to avoid pathogens - Discrete maze levels - Flare ups negatively affect the player	- AD patients Caregivers Age: 12-18	Desktop	10 min
Skin Defense	- To understand the mechanism behind a flare up in AD - To understand how - the immune system responds to external triggers - To appreciate the importance of the skin barrier	- Tower defense based - Micro-scale - Trying to avoid pathogens from invading the skin - Multiple levels varying in difficulties, simulating real-life inflammations - Player loses when skin barrier strength falls to zero	- General public - Age: 16+	Desktop	15 min
Whack-a-Flare	- To use appropriate treatments for various severity of flare ups - To realize the importance of regular application of corticosteroids - To learn the effects of different treatments on the skin	- Whack-a-mole based - Macro-scale - Player eliminates flare ups ("moles") with treatments ("hammer") - Three levels based on severity of flare ups	General public - Age: 6-12	Desktop	5 min

5 Results

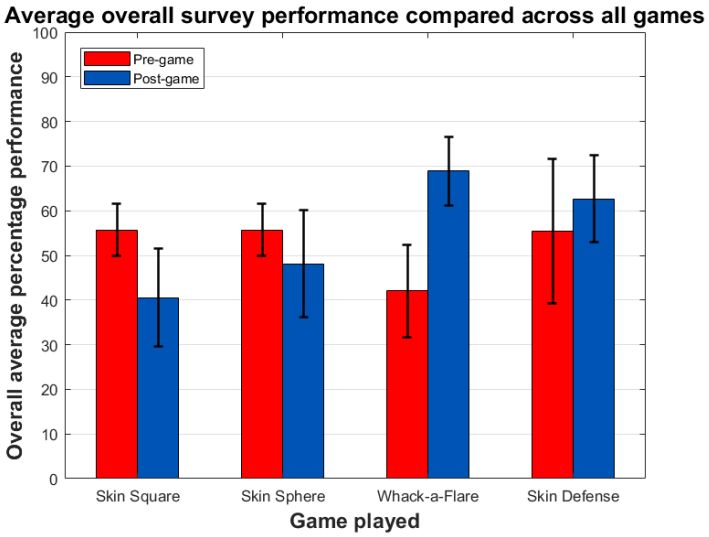


Figure 10: The overall ASP in surveys across all games before and after playing a game, sample sizes are as in Tables 7 and 8 in the Appendix.

The overall average survey performance (ASP) was determined as the average percentage of the correct answers of the individual players for all games. As shown in the Figure 10, Skin Square has the worst overall performance, showing a 15% drop in number of correct answer, while Whack-a-Flare has the best overall performance, showing a significant, 27% increase in the average performance. However, the confidence intervals demonstrated by the error bars suggest that this drop is not significant.

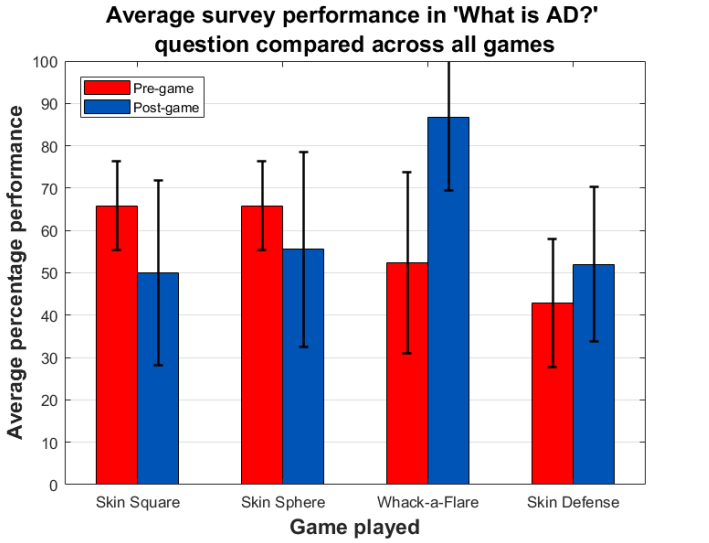


Figure 11: The ASP in the survey question 'What is AD?' across all the games before and after playing a game, sample sizes are as in Tables 7 and Table 8 in the Appendix.

Figure 11 shows the performance in the question "What is AD?", for which the subject had to choose from the following options:

1. **'A long term skin condition that causes skin to become red, itchy, dry and cracked.'**
2. 'An allergic skin condition where it reacts to pathogens by becoming inflamed and infected.'
3. 'A skin condition caused by trauma to the skin.'
4. 'Don't know/Not answered'

The bolded answer is correct. The performance in this question improved significantly for Whack-a-Flare, by 25%, and also improved for Skin Defense by 10%. The performance decreased after playing Skin Square and Skin Sphere by 15% and 10% respectively.

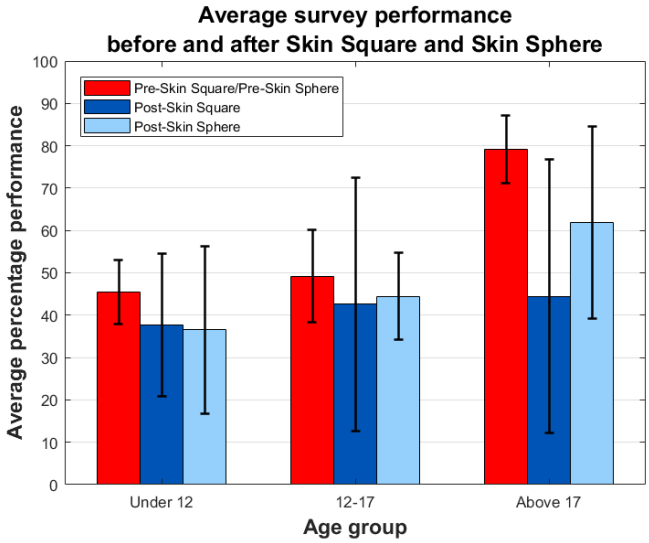


Figure 12: The comparison of ASP before (red) and after playing Skin Square (dark blue) or Skin Sphere (light blue) across different age groups, sample sizes are as in Table 7 in the Appendix.

Figure 12 shows there is no significant difference in both the age group of "under 12" and "12-17". However, there is a much greater drop in performance for "above 17". Performance after playing Skin Square is 34% worse and that after playing Skin Sphere is 17% worse for that age group, reflecting possibility that the questions are too difficult.

Figure 13 shows the ASP after playing the Whack-a-Flare improves in all age groups after playing the games. Performance after playing Whack-a-Flare is significantly better across all age groups. There is a 29% improvement for "Under 14", a 31% improvement for "14-18", and a 26% improvement in "Above 18" age group.

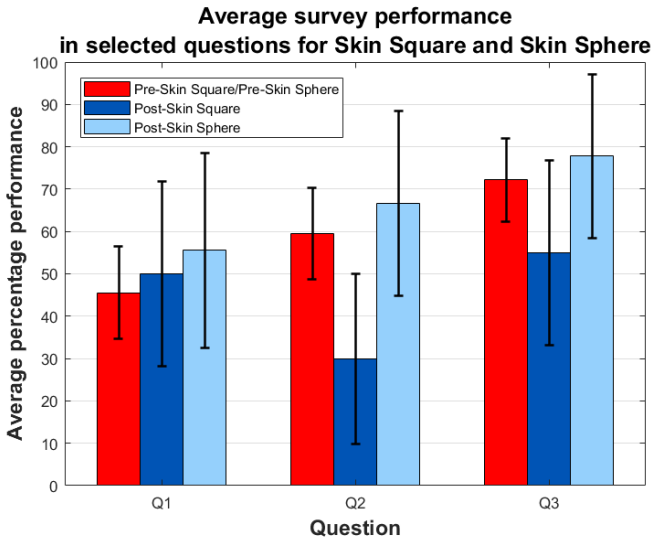


Figure 13: The comparison of average performance before and after playing Whack-a-Flare across different age groups, sample sizes are as in Table 8 in the Appendix.

Figure 14 shows the ASP after playing the Skin Defense improves by 10%, while the improvement after playing the game is marginal for the other age groups

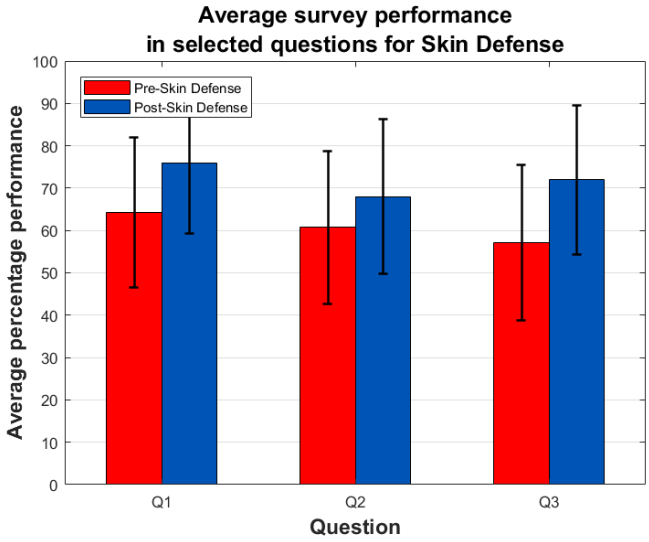


Figure 14: The comparison of average performance before and after playing Skin Defense across different age groups, sample sizes are as in Table 7 in the Appendix.

Results for specific messages

To investigate the ability of the games to educate players on the most important aspects of the AD, we examined the ASP in specific questions that embodied the key messages they were to deliver.

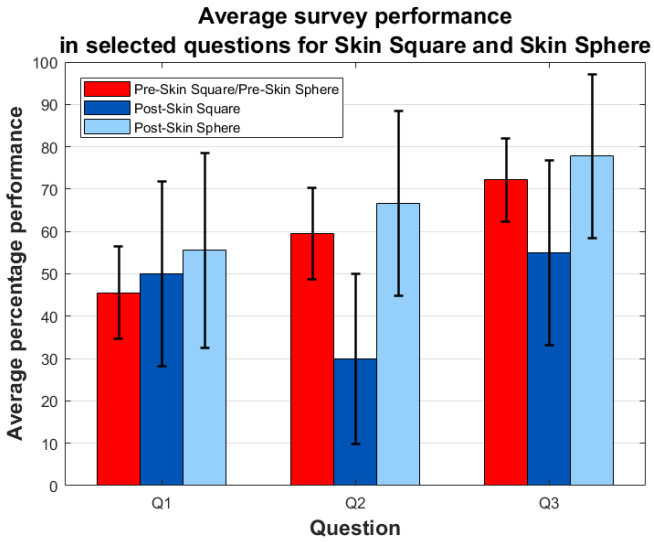


Figure 15: The average performance in the selected questions before and after playing Skin Square or Skin Sphere, sample sizes are as in the Table 7 in the Appendix.

The key questions for Skin Sphere and Skin Square were selected as follows:

Q1: What is the role of corticosteroids in treating AD?

- It is an antibiotic
- **It suppresses inflammation**
- It moisturizes and protects the skin
- It numbs the itching sensation
- Don't know/Not answered

Q2: Which treatment is used specifically to keep the skin barrier healthy?

- Corticosteroids
- **Emollients**
- Don't know/Not answered

Q3: "Taking corticosteroids become more important during the flare ups."

- **Strongly agree**
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree
- Do not know/ Not answered

Figure 15 show that the performance in the Q1 increased after playing both Skin Sphere and Skin Square by 10% and 4% respectively. The performance in Q2 and Q3 increased by 8% and 6% respectively for Skin Sphere. However, ASP in Q2 and Q3 after playing Skin Square exhibits drops by 30% and 18% respectively.

The key questions for Whack-a-Flare were selected as follows:

Q1: Should AD treatment be taken even when there are no symptoms?

- **Agree**
- Neither agree or disagree
- Disagree

Q2: Which one is a stronger agent?
- Emollient
- **Corticosteroid**
- Don't know/Not answered

Q3: What happens when one applies too much emollient?
- **Nothing happens**
- Skin burst
-More flare ups
- Don't know/Not answered

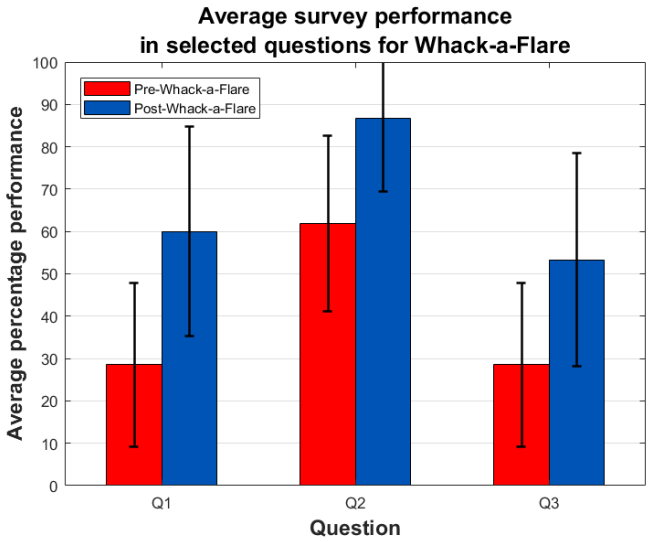


Figure 16: The average performance in the selected questions before and after playing Whack-a-Flare, sample sizes are as in Table 8 in the Appendix.

Figure 16 shows the performance in all the questions increased significantly after playing Whack-a-Flare compared to the performance before playing the game by 32%, 25% and 25% respectively.
The key questions for Skin Defense were selected as follows:

Q1: What is the role of the skin barrier?
- **Skin barrier prevents bacteria from entering the human body.**
- Skin barrier produces the immune cells that fight pathogens.
- Skin barrier involves synthesis of vitamin E in the skin.
- Don't know/Not answered.

Q2: What happens if too much bacteria passes through the skin barrier?
- All Bacteria are killed by immune cells.
- The skin barrier becomes itchy.
- **The accumulation of immune cells causes inflammatory response and the AD flare-up.**
- The accumulation of Bacteria causes allergic sensitization.
- Don't know/Not answered

Q3: Is it more difficult to recover from a flare up after the Allergic Sensitization occurs?
- Yes, it is more difficult to recover.
- No, it is easier to recover.
- There is no effect on therecovery.
- Don't know/Not answered.

Figure 17 shows the ASP in all the questions increased after playing Skin Defense, when compared to the ASP before playing the game, by 12%, 8% and 14% respectively.

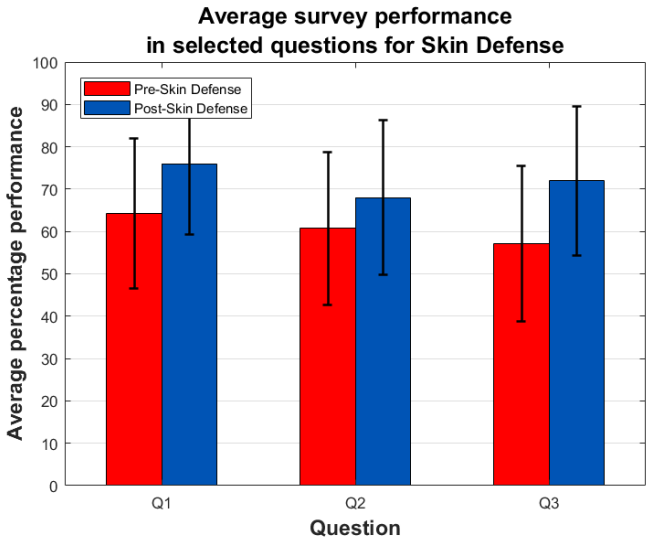


Figure 17: The average performance in the selected questions before and after playing Skin Defense, sample sizes are as in Table 7 in the Appendix.

6 Discussion

The results from Imperial Festival show an overall improvement in the post-game survey answers when compared to pre-game surveys. Although the general trend seems to indicate an increase in knowledge, in majority of cases these differences were statistically insignificant. Figures 10-17 show most pairs of pre- and post-game survey results possess one set of error bars (at 95%) which include the mean of the other set, indicating that the difference in the results is insignificant. Although statistically insignificant, these results were still encouraging and identified many weaknesses and possible improvements in the games. It is also possible that the questions in the surveys were not optimal for determining fully what the player learned during the games. Table 3 shows the questions with significant change in performance after the games were played.

Table 3: Parameters that showed a significant change between pre- and post-game surveys.

Parameter	**Game**	**Change between pre- and post-game survey (%)**	**Figure**
ASP overall	Skin Square	-15	10
ASP overall	Whack-a-Flare	+27	10
ASP in the question 'What is AD?'	Whack-a-Flare	+35	11
ASP in the age group 'Under 14'	Whack-a-Flare	+27	13
ASP in the age group '14-18'	Whack-a-Flare	+30	13
ASP in the question 'Which treatment is used specifically to keep the skin healthy?'	Skin Square	-29	15
ASP in the question 'Should AD treatment be taken even when there are no symptoms?'	Whack-a-Flare	+31	16
ASP in the question 'Which one is a stronger agent?'	Whack-a-Flare	+25	16

Table 4: Feedback on each game derived from survey results.

Game	**Feedback from survey results**
Skin Square	The overall performance of players in the survey decreased after playing the game. In particular the game was unable to explain the different roles of emollients and corticosteroids in AD treatment.
Skin Sphere	The overall performance of players in the survey decreased after playing the game.The game was effective in delivering the key messages about the needs for treatment even without apparent symptoms.
Whack-a-Flare	From Table 3, it can be seen that Whack-a-Flare was particularly effective in increasing the player's overall performance in the survey. In particular, the game was effective in teaching the nature of AD, increasing the number of correct answers for the question "What is AD?". The game was able to deliver its key information about the importance of proactive therapy, as well as the need for appropriate medication strength and effects of different types of medication. The game also appears particularly effective in educating players aged from 14-18.
Skin Defense	The overall performance of players in the survey increased after playing the game. In particular, players were able to correctly answer the question "What is AD?". Skin Defense delivered its key informations about the role of skin barrier, pathogens, and the inflammation in the onset of the AD. The results also suggest Skin Defense is more effective in delivering its message to players above the age of 17.

During Imperial Festival it was found that actual age groups able to play the games were younger than expected, therefore in the future we need to adjust the level of difficulties for each age group accordingly.

The decreased performance of Skin Square and Skin Sphere players in the post-game survey could be due to the games presenting the effects of treatments and flare ups in a more abstract nature. This lead to a degraded link between the AD treatment concepts taught and the gameplay mechanics representing them. This would need to be compensated by increasing explicit connections between the concepts and gameplay for the player.

The two games that showed an increase in correct answers for the question "What is AD?" was Whack-a-Flare and Skin Defense. This is interesting as Whack-a-Flare had tutorials that used fewer technical terms, while Skin Defense was the only game which focused on AD pathophysiology and did not have a specific message about proactive therapy. Thus, it was likely that the other games focused on the details of their own key messages about proactive therapy, and failed to establish a foundation of the nature of AD for the players in the early stages of the game.

The survey result contains several limitations arising from the environment of Imperial Festival. The disturbances created a non-ideal learning environment. The queue, as well as neighboring exhibits also lead to visitors rushing and being unable to finish the surveys. These factors suggested that visitors were not engaged with the games and its tutorials, and may not have answered the survey questions as well as they could. Furthermore, as limited numbers of visitors were able to play the games over the festival due to a lack of computers available, the sample size for all surveys (average of 26 responses per survey) was too small for an accurate conclusion to be made.

Table 5: Qualitative feedback from players and scholars.

Game	**Qualitative feedback**
Skin Square	The game was reported to be too difficult, referring to levels in which low lighting or design meant the player's skill and patience was more important than their puzzle-solving skills. This contradicted the game's appeal as a puzzle game.
Skin Sphere	Players were unable to progress very far into the game as the time limit for each level was often too short. This was exacerbated by the procedural maze generator occasionally generating a level that was impossible to complete. Still, most agreed that the game is a rewarding experience.
Whack-a-Flare	Players found the tutorial section very text heavy and were unable to remember all the gameplay mechanics. The majority found the game appealing, especially the young players.
Skin Defense	Players found the game challenging and entertaining. However, many found the instructions and tutorials needed to be clearer. These people struggled to start the level and deploy a white blood cell and thus were unable to play the game without guidance.

Player feedback stated that a common fault was that the gameplay controls were unintuitive and unrefined. This was particularly evident for Whack-a-Flare and Skin Defense. Feedback also suggested that the terms used in Skin Square were too technical, especially for younger players. In addition, the term "atopic dermatitis" was confusing to many players as the condition was more commonly known as "eczema" in the UK. This supported the survey results which showed that the messages were not clear enough and players tended to get confused after playing the game.

Table 6: Potential improvements to the game design, based on survey results and qualitative feedback.

Game	**Potential Improvements**
Skin Square	The level of difficulty may be reduced by reducing the complexity of the levels, and emphasizing the puzzle-solving aspect of the game. The terminologies in the game may be switched to more commonly used phrases.
Skin Sphere	The procedural maze generation algorithm may be expanded so that the complexity of the mazes can be controlled, and there will not be mazes that are impossible to complete generated. We may also introduce a mouse-control mechanism to make navigating the maze easier for players.
Whack-a-Flare	The controls may be be modified to be simpler and easier to use. Players also need to be informed they can quit the game to try another game. There is also a lot of potential for graphical improvement to attract the attention of young children.
Skin Defense	The gameplay instructions need to be clearer. An in-game video tutorial could be implemented. In addition, more features, like allowing the players to modify the path through the skin barrier for the pathogens, and introducing more types of white blood cells/pathogens, can be implemented to make the game more entertaining and complex.

Table 6 shows the potential improvements specific to each game corresponding to the weaknesses identified in Tables 4-5. In general, the player controls could also be modified to be smoother and more intuitive. The tutorial for these controls and the gameplay mechanics also need to be expanded and modified to be more concise. The games also need to devote an initial section to providing a foundation of general knowledge on AD to provide context for the proactive therapy concept taught in the games. Furthermore, the project should aim at the increasing of the accessibility of the games. Mobile versions of the games would

allow players to access the games at any time, supporting the appeal of these games. Skin Sphere is particular is also suitable as a virtual reality game, allowing the player to place themselves in a 3D version of the maze. Moreover, the graphical designs of the games may be enhanced to improve their appeal.

7 Conclusion

The results obtained from the developed games were extremely mixed. Skin Defense and Whack-a-Flare seem to have been successful in educating players on AD Skin Square and Skin Sphere were less successful in relaying our intended learning objectives. Nevertheless, the relatively low absolute performance in the pre-game surveys justify the need for more educational games or other interactive resources for AD patients to increase patient adherence to treatments. Despite the mixed statistical results, the qualitative feedback received was overwhelmingly positive. Therefore, to further our aim to provide an educational platform on AD and its treatment for patients and the general public, we plan to extend the development of the games based on the survey results and feedback, adjusting the level of difficulty and improving links between the gameplay mechanics and key messages. We would also like to develop the mobile versions and, potentially, a virtual reality version of the games, increasing the accessibility and engagement of the players.

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9 Appendix

9.1 The overall survey numbers

Table 7: The number of responses received from surveys, within each age group, for Skin Square, Skin Sphere and Skin Defense.

Game	Pre- or post- game	Number of responses from age group				Total
		Under 12	12-17	Above 17	'Prefer not to say'	
Skin Square/ Skin Sphere	Pre	40	17	22	0	79
Skin Square	Post	10	6	4	0	20
Skin Sphere	Post	7	4	7	0	18
Skin Defense	Pre	15	7	5	1	28
	Post	14	4	7	0	25

Table 8: The number of responses received from surveys, within each age group, for Whack-a-Flare. This surveys for this game used a different spread of ages from the other games as the target audience was younger.

Game	Pre- or post- game	Number of responses from age group				Total
		Under 14	14-18	Above 18	'Prefer not to say'	
Whack-a-Flare	Pre	9	5	6	1	21
	Post	9	2	4	0	15

9.2 Game developed by former students (X-ema)

The information about the game developed as a part of the Group Project conducted under the supervision of Dr Reiko Tanaka in academic year 2015/2016 can be found at `http://eczemagame.blogspot.com/`

9.3 Example survey for Skin Square and Skin Sphere pre-game

The survey that was provided to the participants of the Imperial Festival before playing Skin Square or Skin Sphere.
It is also available to all the players of the game who would like to test their knowledge before playing.
The survey can be found through following link:
`https://docs.google.com/forms/d/1PoHttfZYJiQlaPyT8iyzWI60j81K4eyCzdslyKtQUc4/edit`.

9.4 The link to our games

The games that we developed can be played at the research website of our supervisor, Dr Reiko Tanaka, at the URL address `http://www.bg.ic.ac.uk/research/r.tanaka/resources.html`.

9.5 The video previews of the games

Video previews of the short gameplay videos of all four developed games can be found at
`https://www.youtube.com/watch?v=Ar-JBKZUJcM`.

9.6 The list of abbreviations used

Table 9: Table of Abbreviations used.

Abbreviation	**Meaning**
AD	Atopic Dermatitis
ASP	Average Survey Performance

9.7 Distribution of the tasks across the group members

Table 10: Distribution of project workload within the group.

Task	**Description**	**Details**	**Group member**
Level design and storyboarding	- Define the theme of the game - Design the gameplay mechanics - Design the physical layout - Prepare narrative story	Skin Square	Nathaniel
		Skin Sphere	Nathaniel, Panagiotis
		Skin Defense	Matthew, Miroslav
		Whack-a-flare	Kathy, Elina
Unity programming	- Program gameplay mechanics - Adhere to the programming conventions - Test for bugs and glitches - Incorporate or remove emergent behavior	Skin Square	Lucas
		Skin Sphere	Nathaniel, Panagiotis
		Skin Defense	Matthew
		Whack-a-Flare	Ling, Kathy
Research on scientific background	- Investigate the appropriate scientific concepts - Provide the underlying scientific justification if needed - Choose the concepts for the game lessons - Check that game delivers the target message	AD biomedical background	Panagiotis, Elina