**Developing and Piloting a Serious Game to Educate Children about Over-The-Counter Medication Safety**

**Abstract**

**Objective**

Misuse of over-the-counter (OTC) medications among children is a growing public health and medication safety problem. Serious games are increasingly being used to foster healthy self-management behaviors and decision-making among children. We developed and pilot-tested using a serious game to educate children about OTC medication safety.

**Methods**

Students (aged 15-17) ata public school serving grades 6-12 in Western Pennsylvania were recruited to play the game. Open-ended questions were asked following gameplay to obtain participants’ feedback about ease of play and additional changes that would be needed to improve the game. Gameplay was video recorded using a screen recording software to observe participants’ behaviors while playing the game. Participants OTC medication safety knowledge was assessed before and after gameplay using pre/post questionnaires.

**Results**

All the participants liked the game, reporting that it was easy to navigate and fun to play. Gameplay screen recordings revealed at least three areas that would need to be redesigned for the game to be more engaging and effective. Seven out of the 9 participants (78%) changed their answer to at least one question on the OTC medication safety post-test survey compared to their pre-test answers. There was an increase in the percentage of correct answers in the post-test survey for questions asking about correct dosing and active ingredients. Three responses remained unchanged and the percentage of correct answers for the post-test survey decreased for questions about the drug facts label and side-effects.

**Conclusion**

This pilot suggests that a serious game may influence participants’ knowledge and attitude about OTC medication safety. Further research is needed to examine the potential of using serious games to teach children about safe medication use and negative consequences of inappropriate use.

**Introduction**

Throughout the past decade, the use of serious games as interventions to improve health outcomes has increased.1-5 Serious games can be defined as digital games that are used for other purposes than solely entertainment.6 There are several genres of serious games, such as games for health, games for health-behavior change, and learning games.14 Serious games have been used to change behavior,3, 6-16 knowledge,3, 8, 9, 16-18 attitude,3 physical ability,3, 8, 17 cognitive ability,3, 8 health,3, 7- 9, 17, 18 and mental wellbeing.3, 8, 17 Most serious games used as interventions have shown positive outcomes in previous studies despite the category of the serious game or the outcomes that were measured.10, 19, 20 Consequently, serious games have been growing in popularity in both the video game industry and academic research.5 Although video games are popular among young people,11 little research exists on how to develop serious games tailored to children.21 Serious games should be developed for children due to their easy access to cell phones and video game consoles.11 A survey with individuals aged 8-18 years reported that 86% possessed computers at home and 83% had a video game console.12 Additionally, children, both boys and girls, commonly play video games with a survey of adolescents aged 12-17 years reporting that 97% play video games (99% boys and 94% girls).12 Therefore, serious games are convenient and accessible interventions for children.15 Furthermore, serious games will keep children engaged since they combine the fun of video games with the seriousness of achieving behavior change or health outcomes.6, 15, 16, 22, 23

Serious games have been used in healthcare as interventions to foster behavior change.3, 6-16, 24 A systematic review by Hieftje and colleagues found that interventions using electronic media can improve health and safety behaviors in young people where 17 out of 19 studies showed at least one statistically significant effect on behavior change outcomes, such as an increase in fruit and vegetable consumption, increase in physical activity, improvement in asthma self-management, and practicing street safety skills.7 A systematic review of serious games used as interventions for health improvement in randomized controlled trials by Rahmani and Boren8 revealed that educational games have shown success in increasing patient knowledge about diseases, such as cancer,25, 26 and changing eating habits.27-29

Little research has been conducted on the use of serious games as interventions to improve medication safety. Previous studies have used serious games to improve disease self-management, such as asthma7, 30, 31 or diabetes7, 12, 24, 30, 32, 33 but none have assessed medication use or medication safety. Medication adherence has been measured in previous studies using serious games as interventions for self-management of chronic diseases, such as cancer, and was shown to increase in adolescents and young adults who played the game.25 Developing a serious game to educate children about medication safety and change their medication taking behaviors is a novel idea in the games for health category.

Self-medication with over-the-counter (OTC) medications is common among children.34-39 Research shows that self-medication begins around the age of 11 years old.35  By the age of 16, almost all children have reported self-medicating with OTC medications.35 This high self-medication rate is concerning due to children’s limited medication knowledge.35-37, 40-43 Children have several knowledge gaps and misconceptions about OTC medications, such as the perception that they are safe and that acetaminophen and Tylenol are not the same medication.36, 37 Consequently, there has been an increase throughout the past decade in Poison Center calls and emergency department visits due to overdoses of OTC medications by children.44, 45 There is an urgent need to educate children about OTC medication safety since they receive little medication education from healthcare providers or through school.41, 43 Therefore, we developed a serious game (Alchemy Knights) to educate children about OTC medication safety, assess their medication knowledge through a pre-test and post-test, and examine their OTC medication use behaviors during gameplay. The purpose of the study was to develop and pilot a serious game that leverages game mechanics, interactions with non-player characters (NPC), and use of potions as metaphors for OTC medications to educate children about OTC medication safety and positively influence their medication use behaviors. The game is a traditional adventurer serious game in which the object is for players to use potions (analogous to OTC medications) to manage their health. Players must choose the correct potion and dosage to remain active in the game.

**Materials and Methods**

*Game Conceptualization, Design, and Development*

The lead pharmacist researcher assembled a multidisciplinary team of experts in medication safety, educational research, clinical simulations, game design, development, and implementation to develop the game. The team included three pharmacy faculty members, three game developers, and another faculty member with extensive industry experience in educational software design, learning technologies, IT project management, and information systems architecture design. The research team met bi-weekly over a one-year period to discuss the goals of the game, content, design principles, game mechanics, and steps for pilot-testing, all of which was documented in a shared game playbook. The game playbook was critical to clearly describe overarching concepts that influenced game design, learning objectives and changes made based on feedback early in the iterative development process.

*Game Design Elements*

The serious game (Alchemy Knights) was designed such that educational outcomes that drive transformation of behavior were built into the game, such as enhancing the participants’ ability to identify unsafe medication use practices and negative health consequences, informing the participants on basic aspects of medications including the importance of active ingredients, dosage schedules, and the harm of taking multiple medications that interact. For example, as players worked through the game story, they were required to utilize various types of potions to achieve their health goals. These potions were explicitly analogous to medications in real life used to treat specific symptoms, just as medications are only to be used for specific health indications. Within the game, the medications build up in the players’ character system as represented by the toxicity bars that fill as the character consumes them, just as a medication can build up in a person’s body in real life. If these bars reach a maximum level, they will cause negative and unwanted health effects such as making the character sick, much like medications can cause adverse effects when taken at too high of a dose. These toxicity bars within the game were designed to decrease in a similar manner as the amount of medication would decrease when it is eliminated from the body after a specific period (functioning like a half-life of a drug). These potions within the game were also designed to interact with each other (like drug-drug interactions) if used inappropriately and highlight medication side effects. Figure 1 is a screenshot of the game depicting features such as the toxicity bars and the instruction manual for using the potions.

A non-player character (NPC), the Master Alchemist, was designed to communicate with the player directly through dialogue and indirectly through a potion book which provided further instructions to guide the player through the game. These interactions with the Master Alchemist were analogous to the opportunity to communicate with a pharmacist about appropriate use of medications. The Master Alchemist was readily available to inform the participant during gameplay about the active ingredients in each potion that allow it to work, how much of each potion is safe to use and how often, and how the potions may interact if taken together (Figure 2). Combination potions were intended to represent combination medications, requiring the player to understand the active ingredients to prevent accidental misuse.

Three major revisions or iterations of Alchemy Knights were completed. Each version of the game was reviewed by members of the research team and student volunteers (potential end-users) to ensure that the storyline and game metaphors (alchemy, potions) were easy to understand from an educational perspective and translated to real-life situations. Each revision of the game was tested on multiple platforms including Windows, MacOS, web browsers (WebGL), Android, and iOS. We discovered that due to the nature of the game and the virtual world that the player must navigate, users preferred to play the game on larger screens instead of smartphones. Thus, study participants played the game on laptops during the pilot testing sessions.

*Participant Recruitment and Data Collection*

We recruited children aged 15-17 years old from a public school in Western Pennsylvania that served grades 6-12 to pilot test the game. The public school was designated as a science and technology academy for high school students. Two pilot testing sessions were conducted within a period of two weeks in February 2018. Three types of data were collected. First, open-ended questions were asked following game play to obtain participants feedback about the game such as ease of play and improvements that could be made for further development of the game. Second, gameplay was video recorded using a screen recording software to examine the participants’ behaviors while playing the game. Third, the research team developed a pre-test and post-test medication use questionnaire to assess the participants’ knowledge and observe any changes in perspectives made after playing the game (see Appendix). The questionnaire was multiple choice and included questions regarding OTC medication dosing, active ingredients, drug facts labels, side-effects, perceptions of safety, and demographics (age, sex, ethnicity, and race). Participants initially completed the pre-test questionnaire, played the game on a laptop uninterrupted for 15 minutes, and then completed the post-test questionnaire. Study participants received a $20 incentive. This study was approved by the Pittsburgh University Institutional Review Board.

*Data Analysis*

Open-ended post-test survey responses were analyzed using content analysis. The gameplay video recordings were visually reviewed by our research team members to identify in-game experiences that players may have found difficult such as teleportation, conversation with Master Alchemist, and battle scenes. Any in-game activity that took players more than 3 times to succeed (for example, it took a player 3 or more attempts to engage the Master Alchemist in a dialog) were marked for future revision and redesign. We examined activities and interactions with NPC such as periods of inactivity, decisions made within the game, number of times the player had to restart the game, mouse cursor movement, mouse clicks, collisions with in-world objects, amount of time spent in “conversations” with the Master Alchemist, amount of time spent reading instructions, number of times the player opened the potion book, number of times each potion was consumed, and number of “overdoses” for each potion. Lastly, we sought to assess participants OTC medication knowledge through a pre-test and post-test and examine their OTC medication use behaviors during gameplay. Survey data were analyzed using descriptive statistics and the number of pilot testing participants was used as the denominator for the reported percentages. Differences in survey responses before and after playing the game were analyzed using a paired two sample for means t-test in Microsoft Excel. The alpha value was set to 0.05 with differences considered significant if P < 0.05. This analysis was performed to establish possible trends in the data even though the sample size failed to achieve power.

**Results**

A total of nine students participated in the pilot test of the game. As shown in Table 1, most of the participants were male (56%), non-Hispanic (89%), White (67%), and had taken a medication within the past 6 months (78%). The participants’ mean age was 16 years old.

Overall, all the children liked the game and thought it was fun to play and easy to navigate, however they offered suggestions for changing the game and reported some challenges which were consistent with the review of the gameplay screen recordings. Some of the students wanted to keep playing the game after the pilot testing period was over. A few students found it challenging to stay alive during gameplay. Students recommended that a virtual store be added to game where they could buy more potions and other items. Additionally, a few children preferred playing the game using hot keys or WASD keys instead of a mouse. Participants also reported that they did not understand the role of the non-player character (NPC) of the Master Alchemist nor did they frequently interact with this character in the game.

The pilot-test revealed opportunities for the research team to improve the game. Gameplay screen recordings revealed at least three areas that would need to be redesigned for the game to be more engaging and effective. Most players (6 out of 9) had difficulties identifying the mechanism for communicating with the Master Alchemist. For 5 players it took at least 3 tries to initiate dialog, and 1 player was not able to communicate with the Master Alchemist. Five out of nine players had initial issues with navigation (moving within the game using the computer mouse, teleporting, evading enemy NPCs). These players spent on average the first 3 minutes of gameplay experimenting with navigation and motion mechanics. Three out of nine players who reported having had little experience with action/adventure genre of video games experienced difficulties with multitasking when the game required the player to move, fight, and consume potions at the same time. Finally, while reviewing gameplay screen recordings, we noticed that 4 subjects experimented with deliberately overdosing their game character using the potions, presumably to see what happens. However, after deliberately overdosing the knight gameplay character (on average 2 times), the player stopped and started to use potions appropriately. While we are hesitant to make any specific claim as to why the participants reverted to using the potions as indicated, it appeared that players realized that misusing potions resulted in adverse effects that negatively affected game play. In other words, a game character who took too much of a potion was too slow to move and fend off the enemies. Additional formative research that involves further user testing through focus groups, interviews, and surveys with the target audience would contribute important insights on viability, acceptability, and comprehension. Such research would elucidate problems participants encountered when playing the game, effective ways to overcome the problems, whether they understood what they were being asked to do, ease of gameplay, bug testing to identify technical problems, and overall appeal of the game.

Seven out of the nine participants (78%) changed their answer to at least one question on the post-test compared to their pre-test answers. The percentage of correct responses increased for two questions after participants played the game (Figure 3), one about proper dosing (67% pre-test; 89% post-test) and the other about active ingredients (44% pre-test; 67% post-test). The responses for three questions did not change after the participants played the game: (1) perceptions of medications being safe (89%), (2) appropriate medication use (100%), and (3) misuse (78%). Unexpectedly, the percentage of correct responses was lower for two questions after participants played the game: (1) a question about the drug facts label (100% pre-test; 89% post-test) and (2) a question about side-effects (100% pre-test; 78% post-test). All the participants provided a correct response for questions about the drug facts label, appropriate medication use, and side-effects before playing the game, which shows that they were knowledgeable about some aspects of medication safety before playing the game. However, prior to playing the game, only 44% of participants responded with the correct answer for the question about active ingredients and 33% of participants believed that taking more medication makes people get better faster, which suggests that these aspects of their medication safety knowledge needs to be improved.

**Discussion**

Children are an ideal population to use serious games since they often use computers, the internet, and video games.18 Furthermore, young people are usually more visually oriented than older populations and can easily manage multi-tasking.18 Traditional approaches to medication education often lack the ability to motivate and engage children. There is increasing evidence that educational games offer instructional tools capable of engaging children while teaching and reinforcing knowledge and skills.46 The elements and mechanics of games, rather than a game itself, can be used across various domains to influence the motivation of participants as they engage in processes such as self-management of medications. Many common game design principles have been applied in educational contexts throughout the literature, which include goals and challenges, rapid feedback, freedom of choice, freedom to fail, and abstraction.46 Serious games have been widely used with various populations to improve health outcomes, showing positive effects.10, 19, 20 Serious games have been used with children in particular to improve diabetes, asthma, and cancer self-management, adoption of healthy lifestyles, street safety practices, and disease knowledge.3, 6, 8, 9, 16-18

Overall, study participants found the game to be fun and expressed interest in playing the game after the pilot testing session. These findings are consistent with previous research demonstrating that children and adolescents are accepting of using serious games as learning tools. Games offer children a low-risk environment in which decisions and actions are executed, and the failure to successfully solve a problem allows the learner to identify gaps in knowledge or skills while applying creative solutions over iterative learning attempts.47-51 The child is free to experiment and explore within the setting of the game, and the interactions that lead to learning are executed at the child’s own pace.48, 50, 52, 53 The child has the option to repeatedly play the game, and thus engage in iterations of practice that continuously reinforce their knowledge and skills.48, 50, 52, 53 Successful completion of a task can be accomplished through various approaches and the child can select their own sub-goals within larger objectives such as learning about a medication or improving their health of improving their health.48, 50, 52, 53

These elements of game design are critical for engaging children across various instructional contexts and domains of learning. We included these key concepts in our own design elements for Alchemy Knights to teach children about responsible use of OTC medications. Our overall aim was to not only teach children about these critical medication use concepts, but to also produce a game that was engaging enough to encourage dialogue between children and healthcare providers, particularly pharmacists, in real life. Future improvements need to be made to the game since study participants reported that they rarely interacted with the Master Alchemist in the game, who represents the pharmacist and child-pharmacist interaction. Other improvements that will be made to the game include incorporating a system whereby the player can replenish their potions reinforcing real-life experiences of purchasing more OTC medications as needed. Future research can explore the use of gameplay results as baseline information to facilitate medication use discussions between children and pharmacists. This would provide opportunities for pharmacists to initiate interactions with children and reinforce the importance of about safe and appropriate use of OTC medications.

Study findings showed an increase in medication safety knowledge for some questions after playing the game. The use of a serious game can potentially increase medication safety knowledge for children and adolescents, which is consistent with previous studies that used serious games to improve knowledge about chronic diseases such as diabetes, asthma, and cancer.3, 8, 9, 16-18. Consequently, the use of a serious game might foster behavior change in children and adolescents, which is consistent with prior research where serious games increased the adoption of healthy lifestyles, chronic disease self-management, and street safety practices.3, 6-16

A small sample of students were recruited which limits the statistical validity and clinical implication of the study findings. These results may not be generalizable to all high school students in the U.S. due to our small sample size and selection of students who played video games and attended a science and technology academy. In addition, long-term knowledge retention and behavior change were not measured, as that was not the purpose of the study. We were not able to use in-game data capture mechanisms for every interaction between the player and the game. Rather, we performed visual analysis of game play screen capture which may be subjective and open to interpretation by the research team. Student responses may also be attributed to educated guesses due to the low number of participants and questions on the post-test survey. Future research should examine the theoretical contributions this game-based learning approach for medication safety using rigorous qualitative and quantitative assessments of gameplay by a larger number of students.

In summary, serious games are an innovative and engaging approach for children to learn about safe and appropriate medication use. The results of this pilot study could be used in the future to refine this game, as well as other serious games developed to promote medication safety. Most existing games for health and behavior change mostly focus on mainly disease management with little emphasis on facilitating effective medication use. Study findings indicated that the use of the serious game, Alchemy Knights, may influence adolescent-aged children’s knowledge about OTC medication safety regarding correct dosing and active ingredients. Overall, study participants were accepting of the game and found it enjoyable to play, which suggests that game-based learning may be an acceptable approach to medication education for children. Further research is needed to examine the potential of using educational games to teach children about safe medication use and negative consequences of inappropriate use. Serious games can be developed to help children understand the positive and negatives aspects of medication use and unsafe behaviors.

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**Table 1.** Participant characteristics

|  |  |
| --- | --- |
| Participant Characteristic | N (%), N= 9 |
| Sex |  |
| Male | 5 (56%) |
| Female | 4 (44%) |
| Age |  |
| 15 | 2 (22%) |
| 16 | 4 (44%) |
| 17 | 3 (33%) |
| Ethnicity |  |
| Hispanic | 1 (11%) |
| Non-Hispanic | 8 (89%) |
| Race |  |
| White | 5 (56%) |
| Black or African American | 3 (33%) |
| Asian | 2 (22%) |
| American Indian and Alaska Native | 1 (11%) |
| Have you taken a medication within the past 6 months? |  |
| Yes | 7 (78%) |
| No | 1 (11%) |
| I don’t remember | 1 (11%) |
| Do you play games? |  |
| Yes | 8 (89%) |
| No | 1 (11%) |

\*One participant did not provide a response for race and more than one race could be selected