Evaluating the efficacy of “MIApp”:A serious game to deliver health education to adolescents about meningococcal disease.

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Abstract

Background: Meningococcal disease (MD) is a severe, vaccine-preventable infectious disease that can be life-threatening. This study evaluated the efficacy of the Meningococcal Infection Awareness, Prevention and Protection app (MIApp), a serious game to deliver health education for adolescents about MD.

Objective: This study evaluated the efficacy of the Meningococcal Infection Awareness, Prevention and Protection app (MIApp), a novel serious game to deliver health education for adolescents about MD.

Methods: Participating high school students (Years 7-10) from six secondary schools across metropolitan Western Australia completed a pre- and post-intervention questionnaire to measure primary outcomes. The findings were compared to changes in an active control (comparison) group that received an in-class educational presentation about MD transmission and protection.

Results: Of the 788 participating high school students, the median post-intervention correct score in both the MIApp and control cohorts was 14/16 (87.5% correct responses), compared to the median pre-intervention correct score of 6/16 (37.5% correct responses), representing a significant ($p<0.01$) increase in MD knowledge. Improvements were retained in both groups three months after the initial intervention, demonstrating the efficacy of MIApp to deliver health education about MD transmission and protection.

Conclusions: Participating adolescents considered this digital game more enjoyable than a presentation. Serious games represent a constructive tool to help teachers impart knowledge about risk-avoidance behaviours, vaccination uptake, and early symptom identification of MD.

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Original Manuscript

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Keywords: Serious games; meningococcal disease; immersive digital applications; health promotion

Introduction

An estimated 94% of Australian teenagers are smartphone users, with research showing that 82% of teenagers frequently use these devices for digital gaming [1]. Digital technologies have led to a generation with new ways of thinking, learning, and interacting with each other [2]. Game-based learning occurs through “an environment where game content and gameplay enhance knowledge and skill acquisition, and where game activities involve problem-solving spaces and challenges that provide players/learners with a sense of achievement” [3]. In the school environment, digital games are increasingly considered a constructive learning tool to captivate and intrinsically motivate adolescents’ engagement [4-6]. The concept of ‘serious games’ generally refers to those digital games that intend to provide meaningful learning whilst simulating real-world scenarios that are typically aligned to educational standards [7-9]. Research suggests serious games can promote active learning, build knowledge, engage and motivate students, support higher-level thinking and increase learner independence [10]. Further studies have also demonstrated the attractiveness of digital games as a learning environment to support social, emotional and cognitive outcomes in young people [11,12], with evidence illustrating their influence on the long-term retention of knowledge [5,12]. Serious games appear to be well suited to specific mandated curriculum learning areas like Science, Technology, Engineering and Mathematics (STEM) [13-15] and offer additional learning opportunities to engage adolescents in new emerging fields of study [16].

Given their growing appeal, serious games are increasingly being explored as a novel alternative to the traditional classroom delivery of health promotion messages to adolescents [2,4,17,18]. Serious games for health promotion can stimulate real-life situations providing adolescents with explorative learning environments Field [19]. They can be adapted to the developmental stage, educational level, and personal interest, allowing the player to self-manage their educational goals [20]. Moreover, serious games can offer support for delivering health education around issues that may be challenging for teachers to address due to time, stigma and their lack of knowledge [20,21]. A large body of research exists to illustrate how serious games can be designed specifically for topics such as nutrition [14,22,23], sexual health [24,25], substance use [26], and mental health [27], among others. This ranges from understanding strategies that can be used to explain complex concepts to pedagogical approaches that capture the social and cultural nuances of communities and age-related groups. Yet despite two meta-analyses suggesting serious games represent promising learning tools [4,6], limited and inconsistent evidence of serious game efficacy in delivering health education content remains an issue [25,28].

For digital games to become a vital tool for the support of traditional modalities of teaching and learning, there is a need to evaluate the efficacy of these games. The challenge for teachers is to ensure the serious game is curriculum-aligned, fit-for-purpose, effective as a resource to meet the needs of a range of student ages and settings and can extend or complement learning. Developing serious games for health education, however, is both time-consuming and challenging as it requires multidisciplinary team members to address stated objectives, encompassing elements of design, content, format, and pedagogy to the psychology of behavioural change [29]. The need to adapt complex health information for suitability with younger audiences within an educational environment can pose several further challenges for game developers. These challenges include maintaining player engagement and ensuring the game effectively reflects national curriculum standards and learning goals and outcomes.

MIApp is a serious game that was developed in Western Australia to deliver education via a digital platform about meningococcal transmission and protection to adolescents aged between 12 and 15 years. MD, caused by bacteria called *Neisseria meningitidis*, is a severe, vaccine-preventable infectious disease that is rare but life-threatening [30]. MD can result in ongoing disability ranging from major neurological complications, including hearing loss, cognitive deficit, and seizure, to severe non-neurological effects, such as the amputation of a limb and death [31]. Adolescents are at increased risk of meningococcal carriage, a pre-cursor for the development of invasive disease [32]. Multi-level public health measures to reduce the risk of MD include vaccination, minimisation of behaviours known to increase transmission, and education for the early identification and treatment of suspected cases. Anecdotal experience of educators suggests teachers in Western Australia are hesitant to introduce the subject of MD to students without adequate support from a reliable information source. Current educational strategies for MD are limited by the availability of (often volunteer) staff to provide face-to-face presentations to school-aged children and by the coordination of organising these, especially in rural and remote areas.

This study aimed to evaluate the efficacy of the severe game MIApp on knowledge about meningococcal carriage, disease signs and symptoms and vaccination among adolescents. The secondary aims of the research were to assess the acceptability, usability, and overall student experience of MIApp. The overall purpose of the investigation was to determine whether the delivery via an iPad of a fun, engaging age-appropriate, self-navigating MIApp could be used as a valuable pedagogical tool to help educators better engage with young people around health issues they may find challenging to address.

Methods

Design

The current study stems from a project jointly funded by Lotterywest, the Western Australian Department of Health, the Amanda Young Foundation (AYF) and Edith Cowan University (ECU) between 2019 2022 to develop, deploy and evaluate an educational application (app) created to increase awareness and prevention of MD in a high-risk group, adolescents. As a serious game, MIApp incorporates various gamification elements where the player is tasked with solving the source of a meningococcal infection (MI) outbreak as a junior detective with work experience in the Detect and Protect Agency. In helping to solve the outbreak, the player receives work experience points and interacts with the dog character Buddy, who in real life was the pet of Amanda Young, a Western Australian who tragically died at the age of 18 from MD. Amanda's legacy lives on through the establishment of the AYF.

A steering committee that included experts in MD, public health, and serious game development from AYF, ECU, and the Department of Health participated in the formative development of MIApp. Pilot testing was conducted at two sites across Years 7, 8, 9, and 10, of which 68 pre-post survey dyads from the two-pilot study secondary schools were included in the analysis. Feedback from the pilot study informed minor refinements of the game application and associated survey instruments for the formal evaluation of MIApp.

Following the launch of MIApp in mid-2021, formal evaluation began in August 2021 and was completed in December 2021. Two education delivery models were compared in the study: the intervention group, MIApp, and the active control (comparison) group, which is an in-class educational presentation. Pre- and post-intervention questionnaires were conducted to examine student responses to nine key knowledge areas of MD (Table 1). The MIApp research design was a cluster randomised controlled trial (RCT), following data analysis from the pilot. Students were recruited across four-year groups from a range of secondary schools. The number of participating schools recruited was adjusted depending on the number of enrolled students per school and, consequently, the consent rate at each site.

Table 1: Key nine knowledge areas that were assessed before and after the intervention

Key knowledge areas to be assessed
1. Meningococcal infection is life-threatening but rare.
2. The early symptoms can be similar to a cold or flu. HOWEVER, you will feel extremely unwell and continue to decline even after standard interventions (e.g., taking Panadol, resting etc.).
3. Some of the most common symptoms include: fever, vomiting, diarrhea, headache, pain in your arms and legs, drowsiness, and confusion.
4. If you have these symptoms seek immediate medical help and tell someone you trust of the symptoms you are experiencing.
5. The best way to protect yourself from MD infection is to be vaccinated.
6. Vaccines protect against the 5 strains of Meningococcal infection (A, C, W, Y, and B). Check first and if you are not vaccinated, talk to your parents or a school health nurse about vaccination.
7. Some people in the population are healthy carriers of meningococcal bacteria. This means the organism lives at the back of their nose and throat without causing harm. These carriers may pass it onto someone else without realising and make them sick.
8. The meningococcal bacteria is spread through mucus and respiratory droplets from the throat, including via: kissing, sharing things that you put in your mouth like a water bottle, and openly sneezing and/or coughing.
9. Avoid behaviours that can spread saliva/mucus if you want to stop the spread.

Participants

Adolescents at increased risk for meningococcal carriage were the target demographic for this study. Participants were high-school students in year levels 7, 8, 9 and 10, aged 12 to 15 years. Schools were purposely selected using an online directory of the School Index of Community Socio-Educational Advantage (ICSEA) [33]. The ICSEA is a scale of socio-educational advantage computed for each school, allowing comparisons between schools based on the level of educational advantage or disadvantage that students bring to their academic studies. School facilities, resources, or staffing do not influence ICSEA. Sampling and recruitment aimed to acquire an equal proportion of male and female students between years 7 and 10 and across the ICSEA school values in the intervention and control groups. It should be noted that 3.8% of those students sampled identified as ‘other', as shown in Table 3. A total of six secondary schools across metropolitan Perth, Western Australia, gave consent and participated in the research study (Table 2).

Table 2. Demographics of participants

Table 3. Demographic characteristics and self-reported pre-knowledge of meningococcal disease in the MIApp vs Control presentation groups

		School 1	School 2	School 3	School 4	School 5	School 6	Total
ICSEA		**1100**	**1013**	**1032**	**1110**	**1120**	**890**	
		N=173	**N=56**	**N=138**	**N=198**	**N=214**	**N=9**	**N=788**
Year	**7**	111 (64.2%)	26 (46.4%)	0 (0.0%)	46 (23.2%)	214 (100.0%)	0 (0.0%)	**397 (50.4%)**
	8	62 (35.8%)	5 (8.9%)	0 (0.0%)	31 (15.7%)	0 (0.0%)	6 (66.7%)	**104 (13.2%)**
	9	0 (0.0%)	25 (44.6%)	138 (100.0%)	24 (12.1%)	0 (0.0%)	3 (33.3%)	**190 (24.1%)**
	10	0 (0.0%)	0 (0.0%)	0 (0.0%)	97 (49.0%)	0 (0.0%)	0 (0.0%)	**97 (12.3%)**
Gender	**M**	67 (38.7%)	31 (55.4%)	76 (55.1%)	93 (47.0%)	91 (42.5%)	3 (33.3%)	**361 (45.8%)**
	F	102 (59.0%)	21 (37.5%)	56 (40.6%)	97 (49.0%)	116 (54.2%)	5 (55.6%)	**397 (50.4%)**
	O	4 (2.3%)	4 (7.1%)	6 (4.3%)	8 (4.0%)	7 (3.3%)	1 (11.1%)	**30 (3.8%)**

		MIApp N=442	Control N=346	Total N=788	p-value†
Year	**7**	215 (48.6%)	182 (52.6%)	**397 (50.4%)**	0.193
	8	60 (13.6%)	44 (12.7%)	**104 (13.2%)**	
	9	118 (26.7%)	72 (20.8%)	**190 (24.1%)**	
	10	49 (11.1%)	48 (13.9%)	**97 (12.3%)**	
Gender	**M**	200 (45.2%)	161 (46.5%)	**361 (45.8%)**	0.938
	F	225 (50.9%)	172 (49.7%)	**397 (50.4%)**	
	O	17 (3.8%)	13 (3.8%)	**30 (3.8%)**	
Baseline Knowledge*	**Nothing**	218 (49.3%)	177 (51.2%)	**395 (50.1%)**	0.617
	Some	217 (49.1%)	166 (48.0%)	**383 (48.6%)**	
	A lot	7 (1.6%)	3 (0.9%)	**10 (1.3%)**	
	Median ICSEA	1100 (IQR 1032-1120)	1100 (1100-1120)	-	0.02

† Pearson's chi-squared for categorical variables, Kruskal-Wallis test for continuous variables

* Students were asked to nominate which of these three statements was the most accurate:

I don't know anything about meningococcal disease

I know a little about meningococcal disease

I know a lot about meningococcal disease

Ethics approval for the study obtained from the Human Research Ethics Committee at ECU initially included the potential to conduct the study in metropolitan and regional areas. Due to mandatory lockdowns and COVID-19 rules, there was no capacity for the study team to travel to regional areas within the time of the study, and consequently only metropolitan schools were included. Recruited schools were asked to provide an aggregate number of classes per year group (years 7, 8, 9 and 10) and students per class that were eligible to participate. Despite differences for student ICSEA scores between the MIApp and control groups, with the MIApp group having greater variation in socio-educational backgrounds, the median was the same for each group.

Instrumentation

All participating students were required to complete a pre- and post-intervention questionnaire designed to measure the primary outcomes; changes in knowledge of MD. To assess the nine key knowledge areas, a total of 16 questions were developed. These included questions on the symptoms on MD, where it lives in/on the body, how to prevent transmission and what to do if you suspect you or someone you know may have MD. The participants in the intervention group were also asked to rank on a 5-point scale a series of questions about their perception of usability and engagement with the game, and more generally about the delivery of educational messages using serious games as a platform [34]. Data on knowledge acquisition, timing and behaviour was also obtained to gain further insight into overall usability, learnability, and experience of the MIApp game.

Validity and reliability of the research instrument were established in several ways during the project. First, the instrument was closely examined by the research team and the steering committee to ensure alignment to formative research, curriculum text, clarity, and ease of language for the age group and the functioning and facilities within the instrument such as response mechanisms. Then the instrument was pilot tested for construct validity of the topics included. Minor revisions were made to discordant wording. A test-retest reliability was not performed for the questionnaire items.

Procedure

Following agreement to take part in the MIApp study and written informed consent provided by the school Principal, schools were asked to provide an aggregate number of classes per year group (years 7, 8, 9 and 10) and students per class that were eligible to participate. A parent/carer and student (participant) Information Sheet and Consent Form was disseminated from the schools, prior to the provision of consent and delivery of content. This information sheet outlined the rationale for the study, the risks and benefits to participants and the proposed activity undertaken as part of the research.

The educational content of both the intervention and control group was based on the AYF guidelines to support safer, healthier, and more physically active living in young Australians by creating meaningful, valuable, and strengths-based learning focused on MD awareness and prevention. They reflect the Health and Physical Education (HPE) learning outcomes for WA via the WA P-10 Syllabus for HPE and Australian Curriculum for HPE [35]. The intervention, MIApp, is a new software application developed by ECU. MIApp is a self-directed, serious game that has been designed to be completed in 30 minutes. It targets students in Years 7 to 10, to raise awareness and bring to life the realities of meningococcal infection. At the Detect and Protect Agency, players investigate a case to solve the source of a mystery infection. Players engage with the learning content and key messages delivered in the AYF presentation through a combination of games, quizzes, simulations, and interactive activities. The control is a face-to-face educational presentation delivered by a presenter from the AYF. This is the primary mode of education developed by the AYF and includes a secondary school PowerPoint presentation adapted to fit the allocated research time of 30 minutes. The presentation delivers nine key messages about MD including prevention and identification of symptoms, and preventative health care strategies (see Table 1). Embedded in the presentation is a short interactive quiz and a video, highlighting real life stories of young people who have caught and survived the disease.

Classes within each participating school were randomised to the intervention or control arms, stratified by year group, with half the classes at each school receiving either the app or the face-to-face presentation. At the discretion of individual schools, classrooms or locations were set up for the research trials. A requirement was that rooms be separate, so no interference was experienced with either mode of delivery. All questionnaires were completed using the Qualtrics survey platform [36].

Tablets were distributed to all the participants, followed by a briefing on the scope of the research and instructions for the session. Each session (control and intervention) took 50 minutes comprised of 5-10 minutes for the pre-intervention questionnaire, 30 minutes for either intervention (MIApp) or control (presentation), and a further 5-10 minutes for the post-intervention questionnaire. Participants were first asked to create a unique identifier (ID) that could be used to link the questionnaire data collected before and after their session, and again at the three-month follow up. MIApp cohort participants also used this unique ID to link survey responses to in-app data gathered by MIApp. Participants were not required to remember the username they created for the follow up survey, and no identifying information about the student was collected by the app.

Data Analysis

Statistical analysis was conducted using R version 4.0.3 [37]. 'Differences in correct' scores / 16 pre and post was used to compare the MIApp and control cohorts. Comparative sub-analysis of the differences was conducted by age and sex to assess differences in median score improvement between groups. The Kruskal-Wallis test was used for continuous variables (ref). Differences in proportion for baseline median included a Pearson's chi-squared for categorical variables. Statistically significant differences were considered at p <0.05.

Statistical equivalence testing was also performed using the method by Rusticus and Lovato [38]. First, 95% CIs were calculated using Games-Howell post hoc tests (which account for unequal group sizes and violations in homogeneity of variance). The equivalence interval was defined as ±2 points in pre-post score difference, which we considered to represent a similar level of improvement.

Results

A total of 788 participants from the six trial schools completed both the pre- and post-intervention questionnaire and were eligible for inclusion in the primary analysis. The demographics of participants by school are shown in Table 2. Although different demographic patterns were observed across the six participating schools, approximately half of the students were in year 7 (397, 50.4%), were female (397, 50.4%), and self-reported not knowing anything about meningococcal disease at the start of the trial (395, 50.1%). The demographic and self-reported pre-knowledge characteristics of the study population are shown in Table 3. There were no statistically significant differences between the groups, which suggests good balance of these properties following group randomisation.

Thirty-three participants of the control group (9.5%) and 18 of the MIApp group (4%) had a score of zero for the pre-intervention survey as they answered "I'm not sure/I don't know" to all the questions on the survey. The median pre-intervention correct score in both the MIApp and control cohorts was 6/16 (MIApp IQR 4 – 8, control IQR 3 - 9), and the median post-intervention correct score in both the MIApp and control cohorts was 14/16 (MIApp IQR 12 – 15, control IQR 13 - 15). The median improvement in score for the total cohort was 7/16 (IQR 5 – 10). The median improvement in score for the MIApp arm was 7/16 (IQR 5 – 9), and 8/16 in the control arm (IQR 5 – 11) (p<0.01). Statistical equivalence in mean improvement between arms was demonstrated, with the confidence intervals for the mean difference falling within 2 points (MIAPP vs control;

mean difference = -1.036, lower limit =-1.569, upper limit = -0.503). Improvement in score differed by year group, with students in year 9 and 10 having slightly lower median improvements in score (7 and 6, respectively) than those in years 7 and 8 who both had median improvements of 8 ($p < 0.01$). There were no statistically significant differences in median score improvement noted by gender ($p=0.195$) (Table 4).

Table 4: Median correct scores pre-and post-intervention and changes in median score, by year and gender

		MIApp N=442			F2F N=346			Total N=788			
		Pre-int. (Median, IQR)	**Post-int. (Median, IQR)**	**Δ Median score (IQR)**	**Pre-int. (Median, IQR)**	**Post-int. (Median, IQR)**	**Δ Median score (IQR)**	**Pre-int. (Median, IQR)**	**Post-int. (Median, IQR)**	**Δ Median score (IQR)**	**p-value†**
Year	**7**	6 (3.5 - 8)	14 (12 - 15)	7 (5 - 9.5)	6 (3 - 8)	14 (13 - 15)	8 (6 - 11)	**6 (3 - 8)**	**14 (13 - 15)**	**8 (5 - 10)**	<0.01
	8	6 (3.75 - 8)	14 (13 - 15)	7 (4.75 - 10)	6 (2 - 8)	15 (14 - 15)	9 (6 - 12)	**6 (3 - 8)**	**14 (13 - 15)**	**8 (5 - 10.25)**	
	9	7 (4 - 8)	14 (13 - 15)	7 (5 - 10)	6 (4 - 9)	14 (13 - 15)	8 (5 - 11)	**6 (4 - 8)**	**14 (13 - 15)**	**7 (5 - 10)**	
	10	7 (6 - 9)	14 (12 - 15)	5 (4 - 8)	7 (5.75 - 9.25)	15 (14 - 15)	7 (4 - 9)	**7 (6 - 9)**	**14 (13 - 15)**	**6 (4 - 8)**	
Gender	**M**	7 (4 - 9)	14 (12 - 15)	7 (4 - 9)	6 (3 - 8)	14 (13 - 15)	8 (5 - 11)	**6 (3 - 8)**	**14 (13 - 15)**	**7 (5 - 10)**	0.195
	F	4 (4 - 8)	14 (13 - 15)	7 (5 - 10)	6 (3 - 9)	14 (13 - 15)	8 (5 - 11)	**6 (4 - 9)**	**14 (13 - 15)**	**8 (5 - 10)**	
	O	6 (5 - 8)	13 (8 - 14)	5 (2 - 8)	6 (2 - 7)	14 (13 - 15)	8 (6 - 11)	**6 (4 - 7.75)**	**13 (11 - 14)**	**6.5 (2.5 - 9)**	

†Kruskal-Wallis test
Pre-int. – total number of correct answers out of a total possible score of 16, pre-intervention survey
Post-int. – total number of correct answers out of a total possible score of 16, post-intervention survey

Table 5 shows the percentage of MIApp participants attitudes to and engagement with the game. Most participants responded positively: "I thought MIApp was easy to use" (83%); "It was clear when I was playing what I was supposed to do next" (80%); "MIApp was more enjoyable than a presentation" (77%); "I felt very confident using MIApp" (74%); and "I would like to use educational games like this more often" (74%). There were few who found it difficult to use or who needed help: "I needed to learn a lot more before I could understand MIApp" (14%); "Finding things in MIApp was too hard" (11%); "I found using MIApp a bit overwhelming" (9%); and "I needed help from my teacher to be able to use MIApp" (6%).

Table 5. Student attitudes about MIApp, by year

Statement	Proportion agree Year 7	Proportion agree Year 8	Proportion agree Year 9	Proportion agree Year 10	Proportion agree TOTAL
I would like to use educational games like this more often	79%	76%	64%	70%	**74%**
Finding things in MIApp was too hard	11%	5%	9%	19%	**11%**
It was clear when I was playing what I was supposed to do next	80%	81%	80%	79%	**80%**
I needed help from my teacher to be able to use MIApp	7%	3%	4%	11%	**6%**
MIApp was more enjoyable than a presentation	77%	78%	75%	76%	**77%**
I thought the features of on the screen on MIApp were confusing	13%	5%	6%	26%	**12%**
I thought MIApp was easy to use	82%	81%	81%	85%	**82%**
I found using MIApp a bit overwhelming	8%	5%	11%	11%	**9%**
I felt very confident using MIApp	74%	75%	76%	75%	**74%**
I needed to learn a lot more before I could understand MIApp	14%	15%	12%	13%	**14%**

A total of 255 participants from both groups completed, non-duplicated (by unique ID) responses for the three-month follow up survey (97 MIApp, 158 control). Of these, 89 responses were able to be linked to the primary questionnaire results using the unique study identifier (50 MIApp, 39 control). The three-month follow-up survey asked participants to answer the same set of questions related to the nine key knowledge areas and indicate if they participated in the MIApp or control arm on the day of the trial. The median total correct score at the three-month follow-up was 11/16 and 12/16 for the MIApp vs control arms respectively, (MIApp IQR 9 – 13, control IQR 9 – 13, p=0.86). Although there was a slight decline in knowledge at the three-month mark, this again demonstrates that there was similar knowledge retention in both groups three months after the initial lesson. Overall, these results suggest very similar improvements in the pre-post intervention scores by intervention group, year, and gender. This suggests that students receiving either an educational session via an AYF presenter, or those who play MIApp can expect to improve their knowledge of MD in the nine key areas outlined above.

Discussion

Serious games are attracting significant attention for the promotion of health education among children and adolescents [4-6,39], yet there is still a need to understand their effectiveness [20,25,28]. This study compared the efficacy of the serious game MIApp on knowledge about MD, with a traditional classroom health education model, in a sample of secondary school students. Results demonstrated this serious game: 1) significantly improved knowledge about the disease among adolescents; 2) had an outcome statistically equivalent to that of the current face-to-face educational approach; and 3) was easy to use and more enjoyable. Importantly, the study showed gains in knowledge from playing the serious game MIApp were sustained three months on.

In line with recent research, this study supports the notion that age-appropriate, self-navigating serious games may be considered a positive learning tool to deliver school-based health education [23,24,40,41]. One fundamental feature of serious games is that they are 'fun' as well as pedagogically sound [7-9]. As illustrated by the MIApp study, adolescents find digital-game based learning more enjoyable than a traditional classroom presentation; characteristics acknowledged as essential for effective engagement [42]. By providing a captivating learning environment, serious games can intrinsically and extrinsically motivate adolescents promoting active learning to provide a deeper understanding of health issues [16,28,43]. Research also suggests that through the provision of interactive engagement and immediate feedback, serious games can maintain students' involvement for a longer period of time [44-46], supporting higher level thinking and increasing learner independence [10].

With increasing numbers of children and adolescents in Australia using digital games [1], together with the immediate transition to digital learning during the COVID-19 pandemic [47], serious games offer a unique educational platform to improve the reach of health education [4,26,48]. As a self-guided resource not limited to staff facilitating an education session, serious games can support teachers to provide health education around topics they have limited knowledge about or may find difficult to discuss [7]. Moreover, this study revealed students using MIApp also retained their MD knowledge over a three-month period, as did those students who attended a face-to-face educational presentation. While research has suggested serious games might be more beneficial for long-term retention of health information due to their enjoyable format [5], to-date most studies have focused primarily on short-term pre- and post- tests [23].

Although this study was conducted with schools with mostly medium to high ICSEA areas of Perth, Western Australia, as shown in Table 3, its relevance needs to be assessed in rural settings where cases of MD are higher, the preliminary findings of this study suggest MIApp could represent an emerging resource in the space of meningococcal education for adolescents and young adults in Australia. Key features underlying MIApp are known to promote motivational learning, improve knowledge, and promote engagement, which can increase educational achievement, and is likely responsible for the positive findings observed in the present study [40,46,49]. MIApp is freely downloadable from the App store on personal devices or is available on the AYF website [50] as a desktop version, accessible to all, including those regional and rural communities that previously would not have had the resources or access to receive the face-to-face presentations. Findings of this study can help teachers to feel more assured that students are gaining the same learning opportunity through an interactive and engaging app, as they would receive from a qualified presenter.

As shown in previous research [24,29,41,51], engaging key stakeholders in the co-design, development, testing and refining of the serious game MIApp was essential. Collaboration of stakeholders has been shown to be useful in promoting health communication interventions, and for enhancing acceptability, usability, and utility of the serious game [24]. For MIApp, collaborators included an interdisciplinary team of researchers, experts, and community partners with varied expertise in education, health and computer science and game development. This collaboration facilitated important development and design improvements on the game interface, mechanism, health content and pedagogy for students, and ensured that the social and cultural interests of the targeted adolescent group were included.

For greater influence serious games for health education and promotion should be designed in a way that enables them to be embedded in national curriculum, as this gives teachers the opportunity to combine gameplay with the mandated curriculum to address learning outcomes [13,15]. MIApp was aligned specifically to the teaching and learning HPE in Australian schools and was targeted to lower secondary school year-level syllabuses. The game was sequential and designed to cognitively build and support student understanding of concepts and health enhancing-skills and dispositions related to meningococcal awareness and prevention. The package draws on five interrelated ideas underpinning the pedagogy in the delivery of HPE in Australia. The broader dissemination of this tool by teachers as a public health intervention could support the digital implementation of national efforts to reduce MD among adolescents.

Limitations

There was a relatively low rate of complete responses (32%) for the three-month follow up, the response rate was lower for the MIApp group (22%) than the control group (48%). Attrition for this follow-up survey was expected to be low and was factored into sample size calculations, however, future projects may consider methods to improve response rates. Further, only 35% of completed surveys were able to be linked to IDs for the pre-post intervention arm. Despite these limitations, the completed surveys did suggest that many of the key messages delivered via either MIApp or in a face-to-face presentation are retained three months after a single 30-minute session.

Conclusions

Overall findings of this study suggest that serious games, such as MIApp, represent an effective strategic avenue for the use digital technology to engage adolescents in learning about key health issues. The research found both methods of delivery to be similar in improving knowledge and attitudes towards meningococcal carriage, disease signs and symptoms and prevention. Coupled with greater reported enjoyment, if well-designed, serious games have the potential for use in national health education. The strengths of this study included the engagement of a range of key stakeholders in its planning and design with the goal to improving outcomes and ensuring specificity of knowledge relating to the curriculum and possibilities for content inclusion in teaching and learning of HPE in Australia. While further investigations are needed to explore any minor changes required for the delivery in diverse socioeconomic, cultural, and geographic settings of Australia, this study has illustrated the efficacy of the MIApp game. Moreover, data generated in this study can support evidence on the development of future serious games for adolescent health education worldwide. Today in our digital landscape, greater understanding of the game learning interests of adolescent students is paramount to actively promote their active engagement in health education.

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Conflicts of Interest

None declared. The authors declare that they have no competing interests.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Abbreviations

MD: Meningococcal disease
MIApp: Meningococcal Infection Awareness, Prevention and Protection
STEM: Science, Technology, Engineering and Mathematics
AYF: Amanda Young Foundation
ECU: Edith Cowan University
MI: meningococcal infection
ICSEA: Index of Community Socio-Educational Advantage
HPE: Health and Physical Education

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