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Empowering indigenous families through a card-based serious game for household outbreak preparedness: Development and usability

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ABSTRACT

Recent global epidemics have called attention to how vulnerable communities are to outbreaks, particularly those involving novel diseases. Due to underlying social and health disparities, the Indigenous Orang Asli Community are more susceptible to severe impact from outbreaks. However, preparedness levels in this community remain low, and there is a lack of culturally tailored programs that effectively engage them. The objective of this study is to develop and test the usability of *Wabak X*, a serious card game designed to educate Orang Asli in Selangor, Malaysia, on household outbreak preparedness. *Wabak X* was developed and evaluated through five stages: predevelopment and storyboarding, alpha 1, alpha 2, beta and final build. Findings demonstrated that *Wabak X* was well-accepted by the community, with majority reporting high perceived knowledge and confidence in applying what they learned. *Wabak X* exhibits considerable potential as an evidence-based, culturally appropriate tool to enhance outbreak preparedness in Orang Asli households.

Keywords: outbreaks, epidemic preparedness, indigenous peoples, serious games, health education

INTRODUCTION

Disease X is a placeholder established by the World Health Organization to refer to a hypothetical disease not yet observed in humans but that has the potential to cause a global pandemic [1], and it is predicted to be triggered by a zoonotic spillover [2]. Experts had long anticipated the emergence of a novel disease that could result in a deadly pandemic; however, COVID-19 nonetheless caught the global community off guard.

A critical lesson of the recent COVID-19 pandemic is that a novel outbreak can rapidly propagate beyond national borders. However, the combination of preparedness and effective response can mitigate its negative impacts [3]. Though the reality is that individuals at the grassroots are always the first to be impacted by health crises, preparedness initiatives have primarily focused on higher levels, such as at institutional, national, and international settings, with a lesser emphasis on the community, household, or individual levels [4, 5].

Globally, between 50% to 92% of households are inadequately prepared for disasters [6]. Only 3.4% of households in Hong Kong have fully prepared for an influenza pandemic, while the majority have not taken any steps [7]. There is limited data on household preparedness for outbreaks in Malaysia. However, evidence indicates that only 20% of the general population are fully prepared for flood disasters [8], and the proportion is even lower among indigenous groups, with only 10% of them having life-safety measures planned [9].

The Indigenous population of Peninsular Malaysia is known as the Orang Asli. Their primary ethnic groups are the Negrito, Senoi, and Proto-Malay. The Negrito mainly reside in the northern region, while the Senoi inhabit the forested central highlands. The Proto-Malays on the other hand, primarily live in the western and southern regions, closer to urban centers. Among the three ethnic groups, the Proto-Malays share certain customs and cultural similarities with the Malays [10].

While Malaysia experiences robust economic growth and offers universal healthcare to its citizens, disparities continue to exist among different demographics attributed to the underlying social determinants of health [11]. Underserved population like the Orang Asli experience inferior health outcomes due to lower socioeconomic status, limited education, poor housing conditions, and barriers to health care access [12, 13]. Many Orang Asli communities in Selangor live along forest fringes suffering environmental degradation, that are adjacent to urban areas [10]. Combined with their reliance on forest foraging for livelihood, these features increase their vulnerability to zoonotic spillovers, including emerging threats such as disease X [14]. If a novel outbreak were to occur in this community, it could rapidly spread to the highly populated

A preliminary version of this study was previously presented in the 12th National Public Health Conference, held in conjunction with the 26th NIH Scientific Conference on 8th July 2025.

urban areas, potentially resulting in high mortality rates, as was the case during the COVID-19 pandemic [15].

Although information on outbreak preparedness levels among the Orang Asli is limited, evidence indicates that Orang Asli families are not only inadequately prepared for flood disasters but also not even interested in participating in preparedness programs [16]. This is likely due to the fact that the programs are not culturally tailored and traditional lecture-based education is ineffective in engaging them. Therefore, it is reasonable to infer that they have a general lack of preparedness, including for outbreaks. Consequently, it is necessary to address this issue by introducing a more innovative approach to education, such as a game-based learning approach, as an effort to reduce health disparities due to education and improve health outcomes.

Serious games are game-based learning approaches with defined learning objectives, with learning built into the gameplay to make learning more interesting and more effective [17, 18]. Serious games have been utilized in disaster preparedness education. However, the majority focus on natural disasters and are in digital format [19], and those in non-digital format, specifically in the form of board games, are more targeted for decision makers or require facilitators [20-22]. While serious games have been applied in various preparedness interventions, existing games targeting Indigenous populations have primarily focused on mental health and language learning and have been developed for Indigenous communities in Canada and New Zealand [23-25].

There is currently no known serious game for outbreak preparedness that is culturally relevant and accessible to the Indigenous Orang Asli Community. Specifically, there is a lack of such games that can be used in a low-resource setting, self-paced, suitable for families and in a language that is understood by the Indigenous community. Therefore, the objective of this study is to develop and test the usability of a serious game, named *Wabak X*, that is tailored for the Orang Asli in Selangor, Malaysia, to educate on household outbreak preparedness.

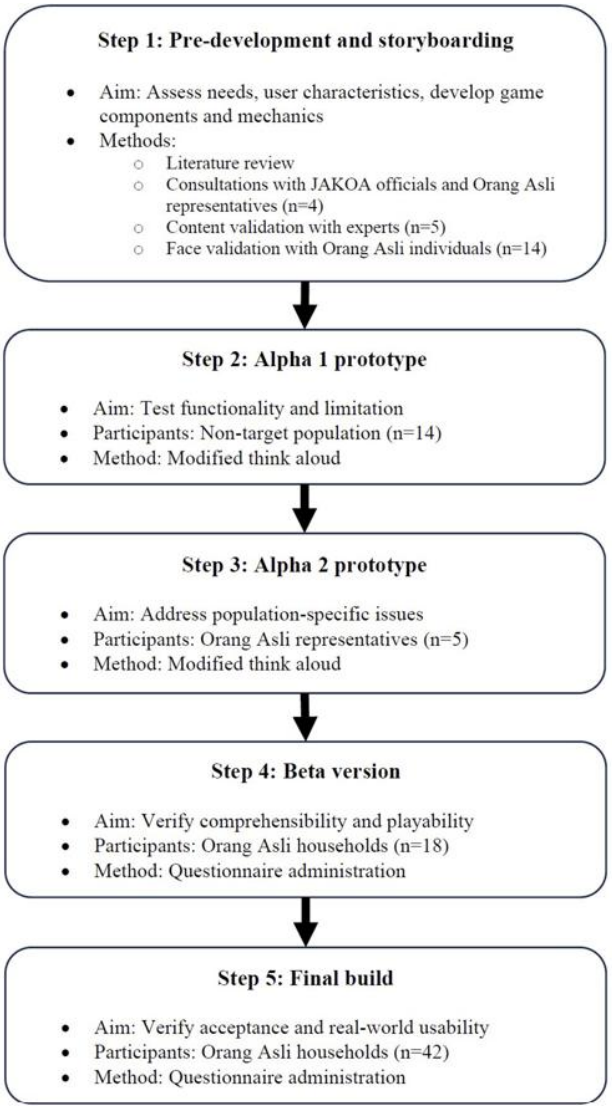

Figure 1. *Wabak X* card game development and testing process (Source: Authors' own elaboration)

MATERIALS AND METHODS

The framework proposed by Olsen et al. [26] was adapted to develop, validate, and evaluate *Wabak X* for usability. The framework can be divided into five stages, including:

(1) pre-development and storyboarding,

(2) alpha 1 prototype,

(3) alpha 2 prototype,

(4) beta version, and

(5) final build [26].

Pre-development started in September 2023. It began with a review of the literature and basic demographic data for the target population. Storyboarding and the following stages were carried out between October 2024 and January 2025. An overview of the study methods is presented in **Figure 1**.

Pre-Development and Storyboarding

Prior to the development of *Wabak X*, the research gaps, target population, and their needs were identified through a review of literature and the basic demographic data of the population. The health belief model (HBM) was found to be commonly used theory in developing disaster and emergency health preparedness programs [27]. Therefore, the HBM was used to guide the interpretation of insights and in establishing the learning objectives of *Wabak X*.

Following this, interviews were conducted with subject matter experts (SMEs), including three representatives from the department of Orang Asli development (JAKOA) and one Orang Asli representative who had experience in providing health services to the Orang Asli Community. SMEs were recruited through nomination by higher-level officials at JAKOA headquarters. The aim was to learn more about the user characteristics that could potentially influence their engagement with the game. The information included literacy levels, prior knowledge and experience with outbreaks, familiarity with card games and other user skills or limitations that could potentially impact gameplay engagement. The art style was also discussed with the SMEs to ensure that the *Wabak X* artwork is culturally sensitive and accurate. The insights gained contributed to the storyboarding of the game.

During storyboarding, the game components and art concepts were developed and then evaluated by experts and Orang Asli community members for content validity and face validity, respectively, across four components:

(1) the instructional leaflet,

(2) game mechanics,

(3) lessons learned from gameplay, and

(4) design and artwork.

Experts were recruited through nomination by their departmental heads and included individuals with expertise in communicable disease control, Orang Asli healthcare, Orang Asli behavioral research, veterinary public health, and the implementation of programs for the Orang Asli Community. For the recruitment of the Orang Asli Community, villages were first randomly selected using computer-generated numbers. Village leaders, committee members, and community members were then invited to participate with the help of JAKOA officials. Participation was voluntary.

For content validity, five experts rated each component on three scales:

(1) relevance to the intervention objectives,

(2) clarity, and

(3) comprehensibility.

Ratings were given on a four-point scale (1 = disagreement, 2 = agreement with major revision, 3 = agreement with minor revision, 4 = full agreement). For face validity, 14 Orang Asli Community members assessed the same four components with respect to their relevance to community needs, clarity and comprehensibility, also using the four-point scale.

The definitions and formulas for validity indices were guided by previous studies [28, 29]. The component-level content validity index (C-CVI) was defined as the proportion of raters who assigned a rating of 3 or 4, calculated as the number of raters scoring 3 or 4 divided by the total number of raters. The scale-level content validity index (S-CVI/ave) was defined as the mean of the scale-level C-CVI values across the four components, calculated as the sum of all C-CVI values in that scale (e.g., relevance) divided by the number of components (i.e., 4). The same procedure was applied for face validity, yielding the component-level face validity index (C-FVI) and the scale-level face validity index (S-FVI/Ave). With five expert raters, the acceptable S-CVI/Ave value is 1.00 [30, 31], while with 14 Orang Asli Community members, the acceptable S-FVI/ave threshold is at least 0.83 [32].

Alpha 1 Prototype

In this stage, the game is complete in function but lacks any form of finished art. The aim of the alpha 1 prototype testing is to evaluate the game's functionality and limitations. Firstly, an in-house "game-breaking" session was conducted with two individuals from the research team to review the game mechanics.

Then, an initial usability test was conducted with 14 individuals who are not members of the target population. Health professionals, doctoral students in public health, and their family members were recruited through snowball sampling, with all participation being voluntary. The aim was to identify apparent usability issues, such as whether players understand the game, find it easy to play, and enjoy it. This will enable subsequent testing to concentrate on more succinct, population-specific issues.

This usability testing involved a diverse set of age groups and educational backgrounds, ranging from five to 40 years old. It was conducted in two sessions, each lasting between 15 and 30 minutes, with 5 to 8 participants per session, using the modified think-aloud method. In this method, players verbalize their views on the game only when they encounter difficulties or have thoughts to share, moderated by the researcher to minimize disruption to the gameplay. The researchers observed and documented the expressed opinions and sentiments, which helped to gain insights into the gameplay for improvements.

Alpha 2 Prototype

Alpha 2 incorporates the modifications identified in alpha 1, and following that, a second round of usability testing is conducted. The modified think-aloud method was also employed, in addition to unstructured interviews.

The usability testing involved four Orang Asli individuals and one JAKOA representative. The Orang Asli participants were recruited from two different villages selected by simple random sampling using computer-generated numbers. Participation was voluntary and involved village leaders and committee members.

The aim was to identify and address any population-specific usability issues. It was conducted in two sessions, followed by face-to-face interviews to verify the participants understood the learning objectives and to gather feedback on cultural representation in the preliminary artwork sketches. Consultation for design, artwork and cultural appropriateness also continued iteratively through text messaging until consensus was reached.

Beta Version

The majority of intense development occurs during this stage. In this stage, all the feedback from the previous stages is accounted for, and all elements of *Wabak X* are completed, including game mechanics, design and artwork. This round of usability testing aims to ensure it is comprehensible and playable for regular Orang Asli Community members.

Households were recruited from the same Orang Asli villages involved in the alpha 2 stage, but participants were individuals who had not taken part in earlier stages. Village leaders and committee members assisted in approaching households, and participation was voluntary.

Usability testing involved 18 Orang Asli households. A self-administered questionnaire on understanding and enjoyment was used. Trained research assistants were available to help if needed or to conduct interviewer-administered sessions for those who preferred them.

Final Build

No changes were made at this stage. An in-house final check of *Wabak X* was conducted, including double-checking the spelling, design and artwork for the final build. The final build of *Wabak X* was subjected to a final round of usability testing involving 42 households. The aim is to verify that the game is acceptable to the target population and functions as intended in the real world. Households were recruited from different Orang Asli villages not involved in the earlier stages. Villages were randomly selected using computer-generated numbers, and recruitment was voluntary with the assistance of village leaders and committee members.

Usability of the final build was assessed by eight domains: affective attitude, burden, ethicality, cultural appropriateness, perceived effectiveness, self-efficacy, visual and themes, and general acceptability, using a self-administered adapted

Table 1. Game mechanics that reflect the learning objectives, HBM constructs, and corresponding cards

LO	Game mechanics	IBHBM	Cards
1. To make people remember the items needed in an outbreak preparedness kit	Players collect five key items essential for household outbreak preparedness: (1) fever medications, (2) disinfectants, (3) personal protective equipment, (4) wound care items, and (5) important household documentation, which includes household preparedness plans and a list of essential service contacts and family members. Each set of the five items can be exchanged for one preparedness card. Each preparedness card carries the possibility of 1 or 2 scores. Collected preparedness cards are placed face-down in front of the player and made visible to all other players. At the end of the game, players flip open their preparedness cards, and the player with the highest accumulated preparedness score wins.	• Perceived benefits • Self-efficacy	• Item cards • Preparedness cards
2. To inform people that animals can transmit disease X to humans	Players who have an animal action card in hand can use it to bring the disease X card into gameplay. This signifies the predicted zoonotic transmission of disease X. The disease X card is then placed in front of the next player, visible to all other players, to indicate that they have been infected with disease X, and they will not be able to make any moves or collect preparedness cards.	Perceived severity	• Action card (animal) • Disease X card
3. To make people aware that the occurrence of disease X and outbreaks are unpredictable	Players who have the animal action card in hand can use it to bring the disease X card into gameplay at any point during the game. More than one disease X card is allowed in gameplay at a time. This signifies that disease X can occur unpredictably and can infect anyone. However, each player can only be infected with one disease X card. If the player who is supposed to receive the disease X card already has one in front of them, the card should be passed to the next player.	Perceived susceptibility	• Action card (animal) • Disease X card
To highlight that disease X can be passed to others, especially those nearby	If a player who is supposed to receive the disease X card uses an item card or hand hygiene action card to protect themselves, the disease X card is instead passed to the next player. This signifies transmission of infectious disease through close contacts.	Perceived susceptibility	• Disease X card • Item cards • Action card (hand hygiene)
To show that preparedness can protect from disease X and outbreaks	Players can protect themselves from the disease X card by using any one of the item cards or a hand hygiene action card and passing the disease X card to the next player. Players can also use the health authority action card to remove one disease X card from gameplay, even from other players, but this must be done during their own turn. These actions signify how having preparedness items in hand, practicing good hygiene, and quick response in contacting health authorities can provide protection.	Perceived benefits	• Disease X card • Item cards • Action card (hand hygiene, health authority)

Note. LO: Learning objectives & IBHBM: Individual beliefs of the HBM

questionnaire [33]. Trained research assistants were available to offer help if needed or to carry out interviewer-administered sessions for participants who preferred this option.

RESULTS

Pre-Development and Storyboarding

The first stage identified the need for a serious game in a non-digital format that can educate and empower Orang Asli families on outbreak preparedness. The game should be playable by a wide age group and both genders, regardless of educational background. It must be in Malay, yet inclusive of illiterate individuals, as long as they are able to understand the game rules. It must not require internet access, electronic devices or prior gaming experience. The game also needs to be a type familiar to the Orang Asli and capable of incorporating cultural elements. Consequently, a card game that attempts to fulfill all of the aforementioned criteria was conceptualized and named *Wabak X*.

The established learning objectives of *Wabak X* are

(1) to make people remember the items needed in an outbreak preparedness kit,

(2) to inform people that animals can transmit disease X to humans,

(3) to make people aware that the occurrence of disease X and outbreaks are unpredictable,

(4) to highlight that disease X can be passed to others, especially those nearby, and

(5) to show that preparedness can protect from disease X and outbreaks.

The game consists of four types of cards: item card, action card, preparedness card, and disease X card.

The goal of *Wabak X* is simple: players need to collect five key items to be able to exchange them for one preparedness card. Each preparedness card carries the possibility of 1 or 2 scores. The player with the highest preparedness score collected at the end of the game is the winner. **Table 1** describes the game mechanics, which represent the learning objectives and individual beliefs of the HBM on which it is grounded, as well as the corresponding cards.

The majority of the Orang Asli ethnic group in Selangor is Proto-Malay, with the main sub-group being Temuan. While each ethnic group have some cultural differences, most aspects are similar. Thus, *Wabak X* artworks incorporated Temuan features while still designed to be inclusive of Orang Asli culture as a whole. Additionally, the SMEs strongly advised that the disease X card should not be depicted as a spiritual entity, to avoid superstitions that might discourage people from playing.

Additionally, validation showed that all four components of the game were rated by experts as highly relevant to the objectives (S-CVI/ave = 1.00), clear (S-CVI/ave = 1.00), and comprehensible (S-CVI/ave = 1.00). Similarly, assessments by Orang Asli community members indicated that the components were relevant to community needs (S-FVI/ave = 0.98), clear (S-FVI/ave = 0.96), and comprehensible (S-FVI/ave = 0.96). These values demonstrate excellent content and face validity [30-32].

Figure 2. Early concept design showing numbered icons on the lower right of the item cards (Source: Authors' own elaboration)

Alpha 1 Prototype

Initial usability testing (n = 14) suggested that the game is ideally played with three to six players, is best suited for ages 7 and above, and the total game duration will take approximately 30 minutes. It was also determined that an extra action card was needed to make the game dynamics more enjoyable.

One of the learning objectives of *Wabak X* is for players to recall the essential items needed to assemble an outbreak kit. The alpha 1 prototype's design included numbered icons on the item cards intended to aid in memory retention (**Figure 2**). However, it was observed that the players were more focused on collecting the numbers rather than memorizing the items. Hence, it was decided that the numbered icons on the cards should be removed.

Alpha 2 Prototype

Alpha 2 usability testing (n = 5) confirmed the game is usable for the Orang Asli Community, culturally-appropriate and able deliver the five learning objectives. Suggestions for artwork included those related to both cultural and real-world accuracy. Selected early sketches and the revisions are shown in **Figure 3**.

For cultural accuracy, suggestions included depicting the *Tok Batin* (village head) as older with a darker skin tone and changing the *tempok* (headgear) to a more accurate style for the Temuan. The hunter using the *sumpit* (blowpipe) should be shown actually performing the act of blowing the *sumpit*, rather than just holding it. Additionally, the *anyam* (weaving) design was revised to feature a weave style and colors authentic to the Temuan.

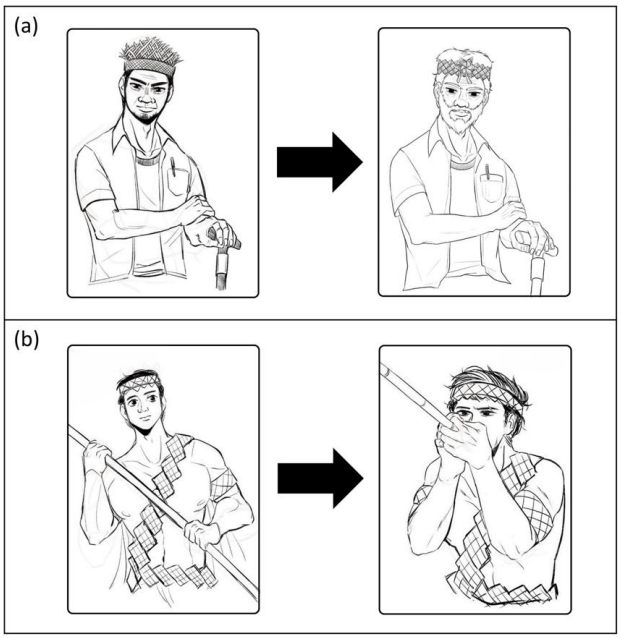

Figure 3. Examples of early sketches and their revisions: (a) Tok Batin, (b) Sumpit (Source: Authors' own elaboration)

For real-world accuracy, suggestions included depicting animals as neutral rather than malicious, illustrating characters undergoing quarantine with a pink bracelet similar to those used during home quarantine in Malaysia's COVID-19 response, and having health authority characters wear masks to model good practices during outbreaks.

Beta Version

The beta version stage had complete game mechanics and artwork. Detailed game rules and instructions are provided in the **Supplementary File**. Beta usability testing (n = 18) demonstrated comprehensibility and playability of *Wabak X*. Results revealed that 83.3% of Orang Asli families regarded the game as fun and 88.9% understood the learning objectives.

Final Build

The final build featured the completed design, ready for commercial printing. Final build usability testing (n = 42) demonstrated positive findings. 85.7% of the Orang Asli families found *Wabak X* card game overall acceptable and no ethical concerns were reported. 92.9% reported gaining new knowledge, and 88.1% expressed self-efficacy in applying what they learned after playing *Wabak X*. 76.2% agreed the instructions were clear, however, 7.1% found the game to be difficult, highlighting the potential for improved instructional clarity. **Table 2** shows the detailed results. The gameplay setup of *Wabak X* final build is shown in **Figure 4**.

Card piles are placed in the center of the table as shown in **Figure 4**: item and action cards draw pile (upper left), item and action cards discard pile (upper right), disease X card draw and discard pile (lower left; draw from the top and discard to the bottom), and preparedness card draw pile (lower right).

Table 2. Usability testing of *Wabak X* final build (N = 42)

Domain/item	M-I	FA	*P
1. Affective attitude			
1.1 Do you like or dislike the *Wabak X* card game? (1: Strongly dislike, 5: Strongly like) *1.1 Adakah anda suka atau tidak suka permainan kad Wabak X?*	5 (0)	37	88.1
1.2 Do you want to play the *Wabak X* card game again? (1: Not at all, 5: Really want to play again) *1.2 Adakah anda mahu bermain permainan kad Wabak X lagi?*	5 (1)	37	88.1
1.3 Would you recommend others to play the *Wabak X* card game? (1: Not recommend at all, 5: Highly recommend) *1.3 Adakah anda akan rekomen/syorkan orang lain main permainan kad Wabak X?*	5 (1)	36	85.7
2. Burden			
2.1 Is the *Wabak X* card game difficult to play? (1: Not difficult at all, 5: Very difficult) *2.1 Adakah cara main kad Wabak X susah?*	2 (2)	3	7.1
2.2 Are the instructions for the *Wabak X* card game clear? (1: Not clear at all, 5: Very clear) *2.2 Adakah arahan main kad Wabak X jelas?*	5 (1)	32	76.2
2.3 Is the *Wabak X* card game balanced between challenge and fun? (1: Not balanced at all, 5: Very balanced) *2.3 Adakah permainan kad Wabak X seimbang mencabar dan seronok?*	5 (1)	34	81.0
3. Ethicality			
3.1 Does *Wabak X* card game have a negative impact on Orang Asli community? (1: No negative impact, 5: Major negative impact) *3.1 Adakah permainan kad Wabak X memberi kesan buruk kepada masyarakat Orang Asli?*	1 (0)	0	0.0
4. Cultural appropriateness			
4.1 Is the *Wabak X* card game appropriate for the Orang Asli culture? (1: Not appropriate at all, 5: Very appropriate) *4.1 Adakah permainan kad Wabak X bersesuaian dengan budaya masyarakat Orang Asli?*	5 (0)	36	85.7
4.2 Is the artwork of the *Wabak X* card game appropriate for the Orang Asli culture? (1: Not appropriate at all, 5: Very appropriate) *4.2 Adakah lukisan permainan kad Wabak X sesuai dengan budaya masyarakat Orang Asli?*	5 (1)	36	85.7
5. Perceived effectiveness			
5.1 Is *Wabak X* card game effective in educating about disease X and outbreak preparedness? (1: Not effective at all, 5: Very effective) *5.1 Adakah permainan kad Wabak X berkesan dalam mendidik tentang persediaan Penyakit X dan wabak?*	5 (1)	36	85.7
5.2 Did you learn something new about Disease X and outbreak preparedness from the *Wabak X* card game? (1: Learned nothing at all, 2: Learned a lot) *5.2 Adakah anda ada belajar benda baru tentang persediaan Penyakit X dan wabak daripada permainan kad Wabak X?*	5 (0)	39	92.9
6. Self-efficacy			
6.1 Are you confident in applying knowledge and skills learned from *Wabak X* card game? (1: Not confident at all, 5: Very confident) *6.1 Andakah anda yakin anda mampu menggunakan pengetahuan dan kemahiran yang dipelajari daripada permainan Wabak X?*	5 (1)	37	88.1
7. Visual and themes			
7.1 Is the artwork of the *Wabak X* card game attractive? (1: Not attractive at all, 5: Very attractive) *7.1 Adakah lukisan permainan kad Wabak X menarik?*	5 (1)	36	85.7
7.2 Is the artwork of the *Wabak X* card game appropriate for the topic of outbreak preparedness? (1: Not appropriate at all, 5: Very appropriate) *7.2 Adakah lukisan permainan kad Wabak X sesuai dengan topik persediaan wabak?*	5 (1)	37	88.1
8. General acceptability			
8.1 Overall, how acceptable is the *Wabak X* card game? (1: Very bad, 5: Very good) *8.1 Secara am, bagaimanakah penerimaan anda terhadap permainan kad Wabak X?*	5 (1)	36	85.7

Note. M-I: Median (IQR); FA: Frequency of agreement; *P: Percentage agreement (%); & *Represents the percentage of participants who gave ratings of 4 or 5 on the questionnaire's 5-point Likert scale

Figure 4. Gameplay setup of the final build of Wabak X for four players. Card piles are placed in the center of the table as shown: item and action cards draw pile (upper left), item and action cards discard pile (upper right), Disease X card draw and discard pile (lower left; draw from the top and discard to the bottom), and preparedness card draw pile (lower right) (Source: Authors' own elaboration)

DISCUSSION

The fundamental objective of serious games is to facilitate knowledge transfer and skill building [17]. However, usability issues can significantly affect user experience and, consequently, learning outcomes. Therefore, a structured approach is crucial in the development and evaluation of serious games. The framework established by Olsen et al. [26] offers serious game developers a systematic and practical approach for incorporating usability testing into their development processes. Numerous studies have adapted this framework for the development and evaluation of serious games, but the focus has primarily been on electronic formats aimed at healthcare professionals or patients to improve care and the management of chronic diseases [34-36]. *Wabak X* is the first non-digital serious game known to be developed and tested using this framework.

Educating and empowering the Orang Asli in disease prevention represents an ongoing public health challenge due to their unique circumstances and cultural context [12]. This

study demonstrates that an innovative approach such as *Wabak X* has the potential to overcome this barrier. Participants from Orang Asli families in this study believed *Wabak X* is effective for educating on outbreak preparedness, and they expressed confidence in applying the knowledge acquired from the game. Card games, while rarely utilized in preparedness education initiatives, have demonstrated efficacy in education of factual subjects and as a supplement to lectures [37-39]. This study illustrates that *Wabak X* can facilitate the transfer of knowledge and skills related to outbreak preparedness at the household level, serving as a supplementary tool for current community preparedness initiatives.

Wabak X stands out as a pioneering serious card game for the underserved Orang Asli Community. The design is grounded in evidence, community needs, and capabilities. The initial stage identified the need for a serious game intervention that is accessible and specifically tailored to the unique circumstances of the Orang Asli. Although serious mobile games have potential for reaching underserved populations, a systematic review highlighted significant challenges to their application in rural settings. These challenges include prohibitive costs, limited internet access and reliance on the English language [40]. Despite significant advancements and a spotlight on digital interventions, such approaches are not ideal for indigenous populations like the Orang Asli. Hence, delivering *Wabak X* in a low-tech format was an appropriate decision to maximize accessibility in low-resource settings and rural communities.

Additionally, this study reveals that a significant proportion of Orang Asli families regarded *Wabak X's* game mechanics as clear, comprehensible, engaging and well balanced between challenge and enjoyment. A minority of participants reported finding the game challenging, but since the proportion is less than 10%, this suggests that the difficulty level is appropriate for serious games [41]. To further improve clarity, a video in casual Malay could be produced to explain the game instructions.

This study presents several limitations. Firstly, *Wabak X* was specifically developed and tested with the Orang Asli in Selangor, which may restrict its generalizability to other populations, including Orang Asli from different regions or other Indigenous communities with different sociocultural contexts or health system access. Secondly, adaptations may be needed to address differences in subgroup ethnicities, language, and cultural practices. While *Wabak X* attempts to cover infectious disease and potential novel outbreaks, its concepts are based on the presumption that disease X will be zoonotic; hence, outbreaks from other causes, such as vector-borne or food- and water-borne diseases, may not be sufficiently addressed by this game. Moreover, the relatively small sample size further limits the extent to which the findings can be generalized. Furthermore, this study evaluated only perceived effectiveness, which may not reflect statistically robust, measurable outcomes. Future studies should therefore assess its impact through controlled intervention studies and explore tailoring the game for different Orang Asli subgroups, the broader Malaysian population and a wider range of outbreak scenarios.

CONCLUSIONS

Wabak X is a card-based serious game that is well-accepted by Orang Asli families in Selangor, culturally appropriate, and user-friendly, with high perceived knowledge and self-efficacy for outbreak preparedness at the household level. It is well suited for remote and low-resource communities. While further refinement of the instructions could enhance usability, *Wabak X* is nevertheless an innovative initiative that serves as a valuable educational tool for disease X and outbreak preparedness for the Indigenous Orang Asli Community.

Author contributions: ASAS, MM, KI, & IMS: methodology and writing–review & editing; **ASAS & MM:** conceptualization; **ASAS:** visualization, data curation, formal analysis, and writing–original draft; & **MM:** supervision. All authors have agreed with the results and conclusions.

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AI statement: The authors stated that generative AI was used only for language editing. All analysis, interpretation, and content decisions were made solely by the authors. All artworks were conceptualized by the authors and illustrated by a human artist. No AI-generated images were used.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

1. WHO. Prioritizing diseases for research and development in emergency contexts. Shortlist of blueprint priority diseases 2018. World Health Organization; 2023. Available at: https://www.who.int/activities/prioritizing-diseases-for-research-and-development-in-emergency-contexts (Accessed: 6 November 2023).
2. Simpson S, Kaufmann MC, Glozman V, Chakrabarti A. Disease X: Accelerating the development of medical countermeasures for the next pandemic. Lancet Infect Dis. 2020;20(5):e108-15. https://doi.org/10.1016/S1473-3099(20)30123-7 PMid:32197097
3. Nuzzo JB, Ledesma JR. Why did the best prepared country in the world fare so poorly during COVID? J Econ Perspect. 2023;37(4):3-22. https://doi.org/10.1257/jep.37.4.3
4. Chiossi S, Tsolova S, Ciotti M. Assessing public health emergency preparedness: A scoping review on recent tools and methods. Int J Disaster Risk Reduct. 2021;56:102104. https://doi.org/10.1016/j.ijdrr.2021.102104

5. Lorenzoni N, Kainrath S, Unterholzner M, Stummer PH. Instruments for disaster preparedness evaluation: A scoping review. Aust J Emerg Manag. 2022;37(3):56-64. https://doi.org/10.47389/37.3.56
6. Levac J, Toal-Sullivan D, O'Sullivan TL. Household emergency preparedness: A literature review. J Community Health. 2012;37:725-33. https://doi.org/10.1007/s10900-011-9488-x PMid:21984406
7. Tam G, Huang Z, Chan EYY. Household preparedness and preferred communication channels in public health emergencies: A cross-sectional survey of residents in an asian developed urban city. Int J Environ Res Public Health. 2018;15(8):1598. https://doi.org/10.3390/ijerph15081598 PMid:30060535 PMCid:PMC6121418
8. Diyana FAN. Attitude and flood preparedness of households in Pasir Mas, Kelantan, Malaysia. IOP Conf Ser Earth Environ Sci. 2022;1091:012022. https://doi.org/10.1088/1755-1315/1091/1/012022
9. Sadeka S, Mohamad MS, Sarkar MSK, Al-Amin AQ. Conceptual framework and linkage between social capital and disaster preparedness: A case of Orang Asli families in Malaysia. Soc Indic Res. 2020;150:479-99. https://doi.org/10.1007/s11205-020-02307-w
10. Jabatan Kemajuan Orang Asli. Suku kaum Orang Asli semenanjung Malaysia [Indigenous tribes of peninsular Malaysia]. JAKOA; 2022. Available at: https://www.jakoa.gov.my/umum/suku-kaum/ (Accessed: 23 July 2025).
11. WHO. Malaysia's commitment to the right to health. World Health Organization; 2024. Available at: https://www.who.int/malaysia/news/detail/07-04-2024-malaysia-s-commitment-to-the-right-to-health (Accessed: 25 July 2025).
12. Mohd Rosman MHW, Yong CL, Azman MU, Mohd Ishar MI. The health issue in Orang Asli Community. Malay J Soc Sci Human. 2020;5(2):36-41. https://doi.org/10.47405/mjssh.v5i2.360
13. Jamal M, Ganapathy M. Framing the actors though thematic structures: The case of the Malaysian Orang asli. Acad J Interdiscip Stud. 2021;10:249-58. https://doi.org/10.36941/ajis-2021-0055
14. Neiderud C-J. How urbanization affects the epidemiology of emerging infectious diseases. Infect Ecol Epidemiol. 2015;5(1):27060. https://doi.org/10.3402/iee.v5.27060 PMid:26112265 PMCid:PMC4481042
15. Shakor ASA, Samsudin EZ, Chen XW, Ghazali MH. Factors associated with COVID-19 brought-in deaths: A data-linkage comparative cross-sectional study. J Infect Public Health. 2023;16(12):2068-78. https://doi.org/10.1016/j.jiph.2023.10.016 PMid:37950972
16. Sadeka S, Mohamad MS, Sarkar MSK. Disaster experiences and preparedness of the Orang Asli families in Tasik Chini of Malaysia: A conceptual framework towards building disaster resilient community. Prog Disaster Sci. 2020;6:100070. https://doi.org/10.1016/j.pdisas.2020.100070
17. Becker K. What's the difference between gamification, serious games, educational games, and game-based learning? Acad Letters. 2021:209. https://doi.org/10.20935/AL209
18. Schrader C. Serious games and game-based learning. In: Zawacki-Richter O, Jung I, editors. Handbook of open, distance and digital education. Singapore: Springer Nature Singapore; 2023. p. 1255-68. https://doi.org/10.1007/978-981-19-2080-6_74
19. Findlay B. Digital games in disaster preparedness education [Master's thesis]. University of Auckland; 2017.
20. Chew KS, Wong SS-L, Tarazi IS binti, Koh JW, Ridzuan NA 'Ain binti, Wan Allam SAS bin. Tutorless board game as an alternative to tabletop exercise for disaster response training: Perception of interaction engagement and behavioral intention. BMC Med Educ. 2023;23:432. https://doi.org/10.1186/s12909-023-04356-4 PMid:37308907 PMCid:PMC10262424
21. Naeemi P, Asgary A, Arabi M, Taghi-Molla A, Wu J. Pandemic resilience serious game: Crafting an educational strategy board game. J Public Health (Berl.). 2024. https://doi.org/10.1007/s10389-024-02305-z
22. Mossoux S, Delcamp A, Poppe S, Michellier C, Canters F, Kervyn M. *Hazagora: Will you survive the next disaster?*–A serious game to raise awareness about geohazards and disaster risk reduction. Nat Hazards Earth Syst Sci. 2016;16:135-47. https://doi.org/10.5194/nhess-16-135-2016
23. Sound D. B.C. First nation's app revitalizes old Indigenous language in a new way. CtvnewsCa; 2021. Available at: https://www.ctvnews.ca/canada/article/bc-first-nations-app-revitalizes-old-indigenous-language-in-a-new-way/ (Accessed: 21 August 2025).
24. Bohr Y, Litwin L, Hankey JR, et al. Evaluating the utility of a psychoeducational serious game (SPARX) in protecting inuit youth from depression: Pilot randomized controlled trial. JMIR Serious Games. 2023;11:e38493. https://doi.org/10.2196/38493 PMid:36892940 PMCid:PMC10037175
25. Shepherd M, Fleming T, Lucassen M, Stasiak K, Lambie I, Merry SN. The design and relevance of a computerized gamified depression therapy program for indigenous Māori adolescents. JMIR Serious Games. 2015;3:e1. https://doi.org/10.2196/games.3804 PMid:25736225 PMCid:PMC4392467
26. Olsen T, Procci K, Bowers C. Serious games usability testing: How to ensure proper usability, playability, and effectiveness. In: Marcus A, editor. Design, user experience, and usability. Theory, methods, tools and practice. DUXU 2011. Lecture notes in computer science, vol 6770. Springer; 2011. p. 625-34. https://doi.org/10.1007/978-3-642-21708-1_70
27. Ejeta LT, Ardalan A, Paton D. Application of behavioral theories to disaster and emergency health preparedness: A systematic review. PLoS Curr. 2015;7. https://doi.org/10.1371/currents.dis.31a8995ced321301466db400f1357829 PMid:26203400 PMCid:PMC4494855
28. Yusoff MSB. ABC of response process validation and face validity index calculation. Educ Med J. 2019;11(3):55-61. https://doi.org/10.21315/eimj2019.11.3.6
29. Yusoff MSB. ABC of content validation and content validity index calculation. Educ Med J. 2019;11(2):49-54. https://doi.org/10.21315/eimj2019.11.2.6
30. Polit DF, Beck CT. The content validity index: Are you sure you know what's being reported? critique and recommendations. Res Nurs Health. 2006;29(5):489-97. https://doi.org/10.1002/nur.20147 PMid:16977646
31. Polit DF, Beck CT, Owen S V. Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. Res Nurs Health. 2007;30(4):459-67. https://doi.org/10.1002/nur.20199 PMid:17654487

32. Mohamad Marzuki MF, Yaacob NA, Yaacob NM. Translation, cross-cultural adaptation, and validation of the Malay version of the system usability scale questionnaire for the assessment of mobile apps. JMIR Hum Factors. 2018;5(2):e10308. https://doi.org/10.2196/10308 PMid: 29759955 PMCid:PMC5972216
33. Sekhon M, Cartwright M, Francis JJ. Development of a theory-informed questionnaire to assess the acceptability of healthcare interventions. BMC Health Serv Res. 2022;22:279. https://doi.org/10.1186/s12913-022-07577-3 PMid:35232455 PMCid:PMC8887649
34. Diehl LA, Souza RM, Gordan PA, Esteves RZ, Coelho ICM. InsuOnline, an electronic game for medical education on insulin therapy: A randomized controlled trial with primary care physicians. J Med Internet Res. 2017;19(3):e72. https://doi.org/10.2196/jmir.6944 PMid:28279950 PMCid: PMC5364323
35. Johnsen HM, Fossum M, Vivekananda-Schmidt P, Fruhling A, Slettebø Å. Developing a serious game for nurse education. J Gerontol Nurs. 2018;44(1):15-9. https://doi.org /10.3928/00989134-20171213-05 PMid:29355884
36. Ghodousi Moghadam S, Mazloum Khorasani Z, Sharifzadeh N, Tabesh H. A mobile serious game about diabetes self-management: Design and evaluation. Heliyon. 2024;10(18): e37755. https://doi.org/10.1016/j.heliyon.2024.e37755 PMid:39364243 PMCid:PMC11447347
37. Muthiyan G, Kasat P, Vij V, Solanki RS, C K, Sontakke B. Effectiveness of an innovative card game as a supplement for teaching factual content to medical students: A mixed method study. Cureus. 2023;15(10):e47768. https://doi.org /10.7759/cureus.47768
38. Gutierrez AF. Development and effectiveness of an educational card game as supplementary material in understanding selected topics in biology. CBE Life Sci Educ. 2014;13(1):76-82. https://doi.org/10.1187/cbe.13-05-0093 PMid:24591506 PMCid:PMC3940466
39. Su T, Cheng M-T, Lin S-H. Investigating the effectiveness of an educational card game for learning how human immunology is regulated. CBE Life Sci Educ. 2014;13(3):504-15. https://doi.org/10.1187/cbe.13-10-0197 PMid:25185233 PMCid:PMC4152211
40. Ouedraogo I, Some BMJ, Oyibo K, Benedikter R, Diallo G. Using serious mobile games to improve health literacy in rural sub-Saharan Africa: A literature review. Front Public Health. 2022;10. https://doi.org/10.3389/fpubh.2022. 768252 PMid:36466518 PMCid:PMC9717679
41. Calderón A, Ruiz M. A systematic literature review on serious games evaluation: An application to software project management. Comput Educ. 2015;87:396-422. https://doi.org/10.1016/j.compedu.2015.07.011