The Design and Evaluation of 'MoM (Microbiome of Maternity)' Role-Playing Game (RPG) in Educating on the Importance of Diet and Lifestyle and Its Interactions with the Gut Microbiota During Pregnancy

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Abstract: Changes in antenatal gut microbiota (GM) have been associated with gestational diabetes and obesity which are influenced by diet and lifestyle. Gamification can be used as an interactive health education tool to convey this concept to the public. Thus, we designed an interactive story titled 'MoM: Microbiome of Maternity' highlighting the importance of diet and lifestyle during pregnancy. Using the 'RPG Maker MV' software, a branching narrative emphasizing flavour texts with a local flair was developed. The choice-based game narrative revolves around daily diet and lifestyle preferences in an engaging story throughout pregnancy. A graphical report is provided at predetermined intervals, highlighting the relevant details on their health and GM. A pilot evaluation was conducted using feedback surveys: Part A evaluated the knowledge on GDM, healthy diet and GM (13 items, score ≥ 8 ($\geq 60\%$) depicts adequate knowledge) and Part B evaluated the satisfaction on the game design and structure (24 items, score ≥ 38 depicts satisfaction and pleasant experience). We found that the initial knowledge on the introduced health concept were inadequate (Part A score 7.67 ± 2.97). After playing 'MoM', their understanding was improved and were satisfied with the design (Part B score 42.3 ± 6.49). In conclusion, 'MoM' is an effective educational game in promoting health awareness among women.

Keywords: Diabetes, Gamification, Gut Microbiota, Obesity, Pregnancy

1.   Introduction

The collection of microorganisms such as bacteria, archaea and eukarya in the human gastrointestinal tract (GI) is referred to as 'gut microbiota'. The density of gut microbiota has been estimated to be more than 10^{14} cells, encoding over 100 times the amount of genomic content (microbiome) compared to the human genome. The composition of gut microbiota represents a part of the health and lifestyle history of humans from an intricate and mutually beneficial relationship with the host (Thursby & Juge, 2017). Changes in antenatal gut microbiota have been associated with the development of gestational diabetes mellitus (GDM) and obesity which are influenced by diet and lifestyle (Li et al. 2021; Mullins et al. 2021; Ruebel et al. 2021; Hasain et al. 2021; Hu et al. 2021).

The use of gamification as an educational tool to convey scientific concepts on gut microbiota and health to the public could be explored as part of interactive health promotion initiatives (Coil et al. 2017; Suleiman-Martos et al. 2021; Deng et al. 2021). D'avilla et al. (2021) and Rothwell et al. (2018) demonstrated that educational games for pregnant women are successful in helping them learn in a fun manner. Via games, the knowledge is gained in a participative way and this aids the players in making well-informed decisions about issues related to pregnancy and motherhood in the real world.

Game-based learning is the process of learning a particular topic through the use of game mechanics. Simply put, it is the act of learning through playing (Ahmad Bakri et al., 2021). While this can be carried out in physical form, the advancement of technology in recent years has greatly boosted the presence of game-based learning (GBL) on mobile phones, in addition to personal computers. Studies have suggested that GBL is effective in educating players of varying ages through use of subtext and narrative in addition to gameplay (Ismail et al, 2019). According to Azhar and Jalil (2022), GBL enhances students' knowledge, problem solving, communication and critical thinking skills. Various types of games can be used to achieve this, ranging from simple interactive games to RPGs and simulators.

Currently, strategy and time management mobile games such as 'Pregnant Mommy Care Baby Game', 'Pregnant Mommy & Newborn Baby' and '9 minutes' provide a glimpse into motherhood routines. On the other hand, simulator game applications such as 'Baby and Mom 3D-Pregnancy Sim' and 'Pregnant Mom & Baby Simulator' are also gradually becoming popular in the Google Store. These games however do little to educate on good health and diet choices during pregnancy. It should also be noted that none of the existing games are within the context of the Malaysian population and culture.

In the context of interactive narrative games, 'global agency' is defined as the player's choices and actions having substantial influence on significant plot events. A dynamic, responsive system symbolises a player's influence towards the transitions within the game (Murray in Chauvin et al., 2014). Since player interaction can break the game narrative structure at any time, the only way to keep it intact is to remove or severely limit the player's capacity to change it. This effectively removes global agency, forcing the player to follow a predetermined course. As a result, ludologists claim that stories must imply a reduction in player agency and should not be used in game design. However, Mateas and Stern (2005) argues that in order to engineer a cohesive educational game loaded with scientific jargon, all characters need to use unrestricted natural language and expressive gestures as their primary form of expression. This contradiction explains the lack of such games in the pregnancy context.

Furthermore, despite the positive effort in promoting maternal health to society, these games are not designed to hone metacognitive skills such as reflecting, analysing and synthesising skills that are essential to the cyber generation today (Anderson & Barnett, 2013). From the vantage point of the microbiome field, a plethora of educational games on the gut microbiome and its purpose in health have been promoted to the public to a great extent (Coil et al., 2017; Brown, 2021;'Gut Check,' 2010). Most of the games are in physical forms for use in face-to-face activities. Due to this, the games are inapplicable for online learning which is trending, especially during the Covid-19 pandemic. Moreover, none of the games introduced is specifically designed to address both the issues of pregnancy and gut microbiome health. It is also discovered that there are minimal dietary health-themed games invented in the role-playing game (RPG) genre.

Although one of them; 'The Guts and Glory RPG' which entails a track and hunt adventure of seeking dangerous meals does revolve around making diet choices, it is not particularly relevant to pregnancies. Another factor to consider is the ability of these games to promote autonomous learning on maternal health. Roe and Perkins (2020) found only few studies were discovered to investigate tools to promote autonomy for learners despite the evidence of its effectiveness on students. It is vital that a game is informative and interactive, at the same time is able to provide self-directed learning experience to the learners as it is deemed more meaningful to them.

Therefore, we designed an interactive role-playing game (RPG) called 'MoM: Microbiome of Maternity'. The game emphasizes the importance of a diet and lifestyle for a healthy pregnancy, and its interaction with gut microbiota composition, particularly for GDM and obesity. The game is based on the dietary patterns, lifestyle and gut microbiota profile obtained from pregnant Malaysian women (Abdullah et al. 2021). This game development is part of an effort in harnessing frugal education by utilizing design thinking, leveraging available resources, and embracing sustainability to develop creative, practical, and sustainable education for all (Clarke et al. 2020). It is also designed to cater to multicultural Malaysian society, which is immersive in the collectivism element (Yusof et al., 2020). The present study aims to describe the design of 'MoM' as a choice-based narrative game that revolves around daily diet and lifestyle preferences given in an engaging story throughout pregnancy. The efficacy of 'MoM' as an educational game was assessed from a survey among women respondents.

2.   Methodology

2.1   Literature search

In order to determine the availability of games relevant to gut microbiome during pregnancies, a set of keywords were identified and searched using the Google search engine. The keywords 'pregnant', 'game', 'gut', and 'microbiome' were opted for the initial search and the resulting hits were recorded. The nature of the resulting games were scrutinized and its limitations in relevance to the intended context (gut microbiome during pregnancy) was highlighted.

2.2   Conceptualization

2.2.1   Identification of suitable metrics

Several steps were taken in the conceptualization of the game. First, measurable metrics were identified; these are the values used by medical experts in measuring Post-Prandial Fasting (PPF) and Gestational Diabetes Mellitus (GDM) in pregnant women. Initially, a flowchart was designed to determine the programmable flow of events that could be used in calculating cause-and-effect during gameplay; i.e. player choices affecting the outcome of the game (**Figure 1**).

As shown in **Figure 1**, the initial variable processing workflow involves; i) the player first inputs the relevant details (age and trimester) for the game to determine the generalized pregnancy status to be set at the start of the game as denoted by the 'Profiles' parallelograms T1, T2 and T3. After which, current GDM status is inputted. The game then decides the diabetes status (Indicated by the diamond shape). ii) If diabetes status is confirmed, the 'Profile GDM4' registers the GDM status and the game skips the Fasting Postprandial Glucose (FPG) calculation. The Body Mass Index (BMI) calculation is then calculated based on player choices throughout the game and is outputted as Profile B1, B2, or B3. The game then outputs the final profile for trimester (T_x), BMI (B_x) and GDM (GDM4). iii) If the calculation determines diabetes in the negative, the game will then calculate the BMI and FPG. Based on player decisions throughout the game, the 2-Hour Post Prandial (2HPP) will be calculated and identified whether to fall under two predetermined ranges (greater or lower than a score of 7.8). The game then determines the GDM Profile (Profile GDM 1) and finally outputs the final profile for trimester (T_x), BMI (B_x) and GDM (GDM_x).
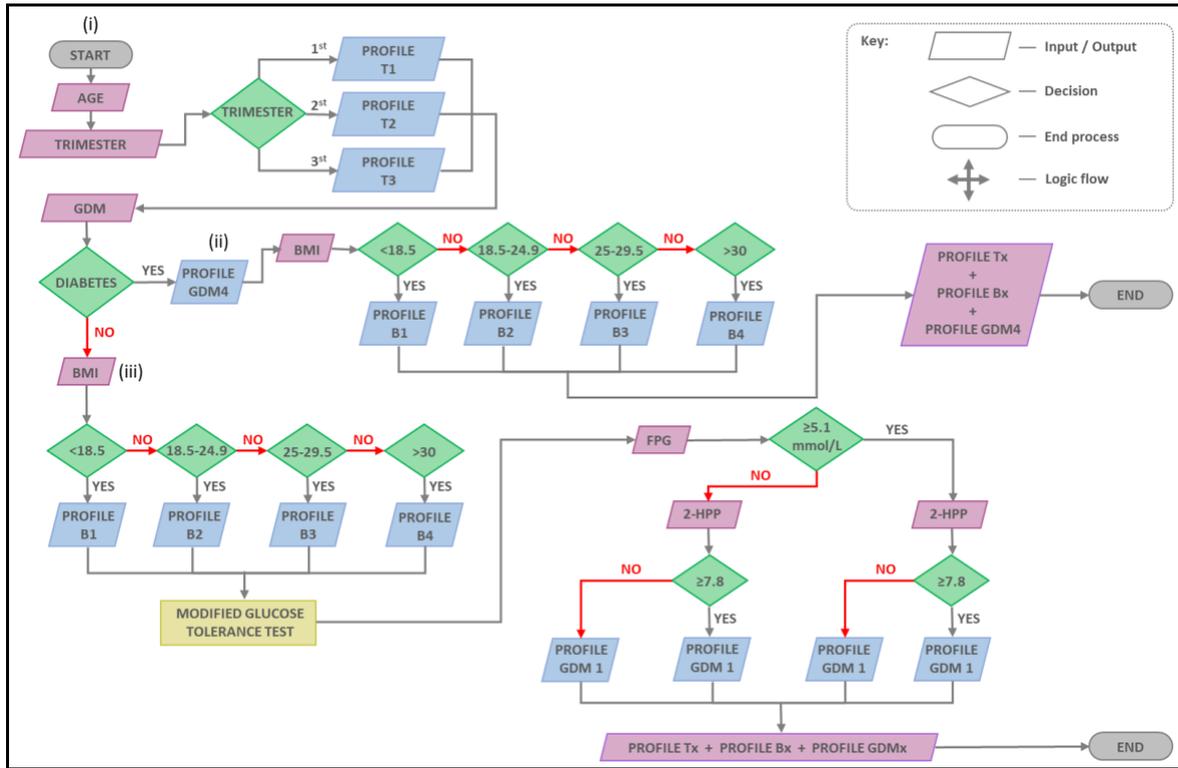
Fig. 1 Flowchart for the determination of variable processing workflow.

2.2.2   Identification of target output for the game design

Next, the target values for the game to output during gameplay is determined. The metrics (PPG and GDM values) were converted to variables that the game can understand, calculate, and output accordingly. To achieve this, the data needed were catalogued into four distinct categories; 'Outcome', 'Factors', 'Variables', and 'Inputs' (**Figure 2**). 'Outcome' refers to the information group that will be outputted (Lifestyle score; represented by BMI, and diet score; represented by GDM). 'Factors' refer to the group of variables that will be used to determine the final values outputted as the 'Outcome'. 'Variables' are the elements that will constantly fluctuate as a direct response from player choices. 'Input', as the name implies, are the choices that the player makes. Therefore; the player's 'input' will change the 'variable' values, and then calculated depending on the 'Factors', resulting in the final 'Outcome'. The basis of the game mechanics were established based on this initial concept.
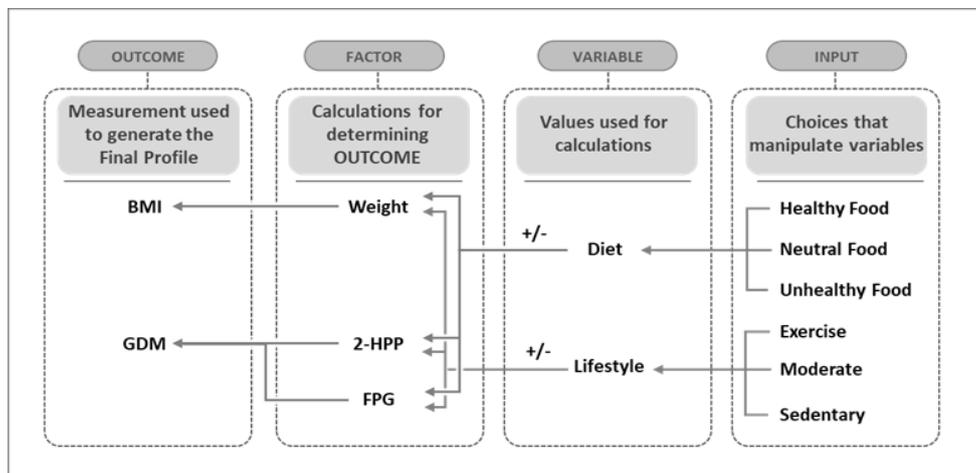

Fig. 2 Determination of parameters needed for game design.

2.2.3   Determination of measurable parameters

In order to standardize the "Input" based on player choices throughout the game, the input values were set into three categories; i) Positive values; where player choices lead to an increase in the associated variables, ii) Neutral values; where the choices do not alter the associated variables, and iii) Negative values; where the associated variables will be reduced. This is applied for both variables associated with BMI and GDM "Outcomes".

2.3   Determination of gut microbiome profile

The gut microbiome profile used as a clinical reference in the game was obtained from a prospective observational study carried out by Abdullah et al. (2021). A total of 38 Malay pregnant women who were attending Universiti Teknologi MARA Medical Centre, Sungai Buloh, Selangor, Malaysia were recruited in this study. Anthropometric measurements such as Body Mass Index (BMI), and also clinical information such as GDM status based on Modified Glucose Tolerance Test (MGTT) and 2-hour postprandial glucose test (2HPP) were recorded. BMI was stratified as underweight, normal, pre-obese and obese. Faecal samples were collected during the first trimester (T1) and third trimester (T3). The V3-V4 region of 16S rRNA gene amplicon libraries was sequenced and analyzed using QIIME (version 1.9.1) and METAGENassist. Univariate and multivariate statistics, PLSDA and Kendall rank correlation testing were used to identify key genera and associations with BMI and GDM status.

2.4   Narrative Design

2.4.1   Designing the core narrative structure

To ensure a coherent story, a core narrative structure was first designed where a general storyline was decided. This includes the persona of the main character, the associated circle of friends, occupation, household, social and marital status. Establishing these general narrative components helps to avoid any glaring inconsistencies in the story. To set the pacing of the story, the nine-month pregnancy period was adapted to nine associated chapters, providing the game with a clear timeline. The core narrative structure was then broken down to the three-month trimesters, where each group of chapters where given a pregnancy-related underlying narrative theme based on suggestions by experts in the development team. Following that, each month was isolated into its own chapter and was further fleshed out as described in the "Daily Narrative Structure Design" section below. To simplify the story-writing process, each chapter was set to take place in a single representative day, alternating between weekdays and weekends. Furthermore, the narrative was ensured to include six core questions to address three lifestyle variables and three diet variables (**Figure 3**).

2.4.2   Designing the daily narrative structure

The daily narrative structure was designed by first determining the "core issues" to address in the associated chapter. These "core issues" were selected based on medical data and were suggested and reviewed by a medical expert in the development team. Upon deciding on a pregnancy-related issue to focus on for the chapter, the daily narrative was constructed, and the relevant three lifestyle and three diet questions were designed (**Figure 3**).
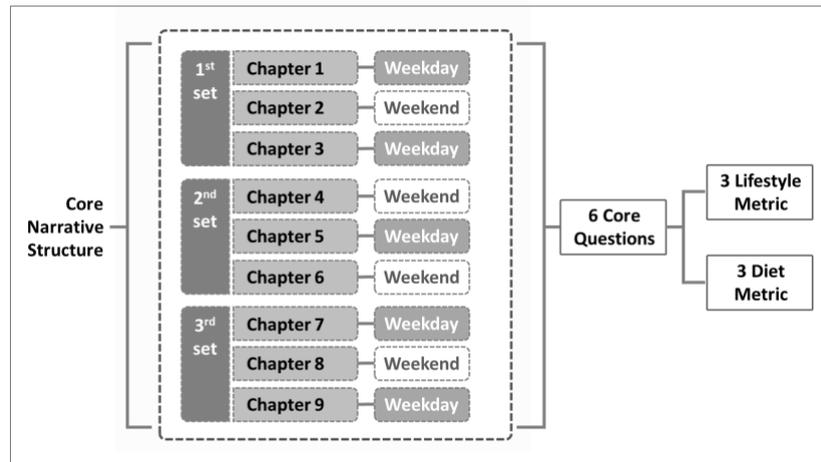
Fig. 3 Core game narrative structure

2.4.3 Inclusion of false agency

In addition, elements of false agency were also intentionally included to add variety to the story without affecting the metrics and core structure of the game. These choices were designed to allow for experiential learning of certain pregnancy related choices. At the same time, these choices provide insight into the consequences to their choices as well as the appropriate advice should they make an objectively 'wrong' choice. While these choices were designed to add variety to the game, the branches were ultimately redirected to the same ending in each chapter.

2.5 Game design

2.5.1 RPG Maker MV

The design of the game was done using 'RPG Maker MV', a commercially available software for making RPGs. The default settings were used as a basis for the preliminary game. 'Common Events' were utilized to enable 'global event' calling, aiding management of chapter stories. No external coding was done, and the designing mainly took place using what was provided by the software, with the exception of a few minor edits to the main script to achieve small quality of life adjustments. All mathematical calculations of the variables to achieve the intended 'Outcome' were carried out through variable manipulation in the 'Common Events'. The narrative storyline was drafted in a Google Sheet that went through several edits by the development team prior to being keyed into the game design software. The drafts were streamlined during the edits to cater to the four-line text limit set by the software.

Custom character designs were done using models of local women, which were all volunteers. This was intended to improve the relatability of the game to the target demographic; Malaysian women. For the pilot study, only one representative avatar is prepared for each character involved in the story. The game was deployed for two operating systems; Windows and Android. For the former, the readily available 'Deploy to Windows' function was sufficient. However, for Android, the APK file was built using Android Studio (Arctic Fox 2020.30.1 Patch 2) using the deployed file generated from the 'RPG Maker MV' software.

2.5.2 Report Card Design

The initial concept for the Report Card was drafted on paper to decide on a suitable User Interface (UI). Using the gut microbiome data, the microbes were categorized into the relevant groups; those affected by BMI and GDM. The groups were then further categorized based on whether they are directly or inversely proportional to the BMI or GDM values (**Figure 4**). This correlation is then used in the iterative design of the calculations as well as the Report Card.
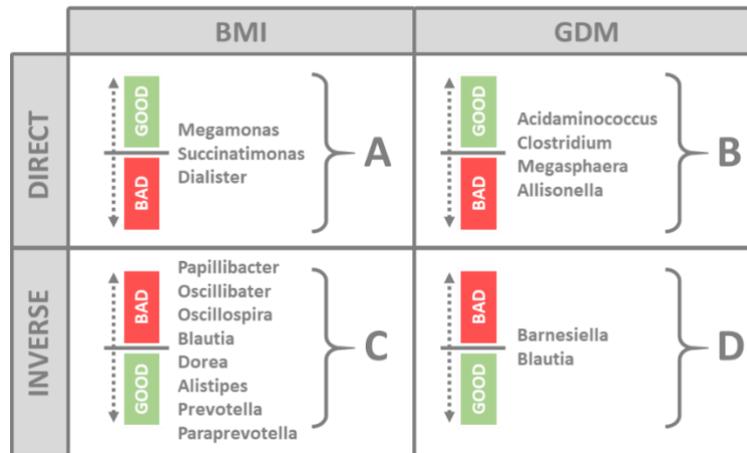
Fig. 4 Grouping of gut microbes according to their proposed association with perturbations in BMI or GDM, and their positive (direct) or negative (inverse) correlation.

The initial concept was first drafted using Adobe Photoshop CS6, acting as a mock-up. Upon completion of the rudimentary calculations as well as the BMI and GDM 'Outcomes', a test run of the Report Card was designed for the alpha and beta test periods (**Figure 7**).

2.6 Pilot Evaluation

A total of 15 women respondents were recruited for pilot evaluation via convenience sampling. The women respondents were introduced and explained about the game being a choice-based interactive narrative game revolving around daily diet and lifestyle preferences during pregnancy. The instructions on how to install and play the game on their mobile phones were given. After completion of the game, all respondents were requested to answer a validated feedback survey comprising two parts with a total of 37 items.

Part A of the survey with 13 items was used to evaluate the knowledge of the game player on the relationship between healthy food with the GDM and the composition of gut microbiota. The questions for Part A were adopted from the validated and established GDM Knowledge Questionnaire (GDMKQ) by Hussain et al. (2014). Three key information being assessed in Part A were:

  I. Knowledge about gestational diabetes mellitus (six items)
 II. Knowledge about healthy food nutrition (three items)
III. Knowledge on the relationship between food patterns and the composition of gut microbiota (four items)

A score of one will be given to every right answer or 'yes' and zero to every wrong answer, 'no' or 'I don't know'. Knowledge scores for individuals on GDM, diet, and gut microbiota will be calculated and summed up to give the total knowledge score. The scoring range is a minimum of zero to a maximum of 13. A higher score indicates better knowledge about GDM and the relationship between a balanced diet and gut microbiota during pregnancy. A cut-off level of score ≤ 7 ($<60\%$) will be considered to be inadequate knowledge while a score ≥ 8 ($\geq 60\%$) depicts adequate knowledge.

In Part B, 24 items of questionnaires were used as a feedback survey on the design of MoM which comprised of four key information as follows:

  I. Health knowledge feedback (three items)
 II. Narrative feedback (11 items)
III. Game design feedback (10 items)
 IV. Open suggestion (one item)

A score of three was given to every answer of 'Strongly Agree', score two for 'Agree', score one for 'Disagree' and score zero for 'Strongly Disagree'. The scoring range was between 0 and 63. A

higher score indicates high satisfaction and experience with the MoM. A cut-off level of score ≤37 (<60%) was considered to be unsatisfactory and an unpleasant experience while a score ≥38 (≥60%) depicts satisfaction and pleasant experience playing the MoM.

Data entry and statistical analysis were performed using the IBM® SPSS® Statistics (SPSS, IBM New York USA; version 27). Descriptive analysis was performed on the score obtained from Part A and B. Continuous data with a normal distribution was described as mean ± standard deviations (SD). Non-normal distribution data were described as Median and interquartile ranges (IQR). Categorical data was presented in frequencies and percentages

3. Results

3.1 Keyword search

The preliminary keyword search on Google turned up nine hits (**Table 1**). Of which, five resulted from the keywords 'Pregnant' and 'Game', one from 'Gut' and '(RPG)', and three from 'Gut' and 'microbiome'.

Table 1. Hits from the keyword search and their limitations.

NO	KEYWORD	FINDING/HITS	GAME TYPE	LIMITATIONS	REFERENCE
1	Pregnant, game	Baby and Mom 3D-Pregnancy Sim	Simulator	Does not focus on diet during pregnancy.	https://bit.ly/3wmDmqi
2	Pregnant, game	Pregnant Mommy Care Baby Game	Mobile game	Does not cater to knowledge during pregnancy.	https://bit.ly/3H1A3ts
3	Pregnant, game	Pregnant Mommy & Newborn Baby	Strategy and time management	Does not focus on the dietary habit of the mother and the effects of those habits.	https://bit.ly/2ZYEdl9
4	Pregnant, game	9 Minutes	Story-based game	Is not based on Malaysian context.	https://bit.ly/3ETXx1X
5	Pregnant, game	Pregnant Mom & Baby Simulator	Simulator	Is not based on Malaysian context.	https://apple.co/3CSsxyU
6	Gut (RPG)	The Guts & Glory RPG	RPG	Is only about types of meals.	https://bit.ly/3wlXqJs
7	Gut, microbiome	Gutsy: The Gut Microbiome Card Game	Card game	Physical game. Not catered towards pregnancies.	https://bit.ly/2ZVDalQ
8	Gut, microbiome	Gut Check: The Microbiome Game	Board game	Physical game. Not catered towards pregnancies.	https://bit.ly/3bLnMv7
9	Gut, microbiome	Gut Check: The Microbiome Game	Card game	Physical game. Not catered towards pregnancies.	https://bit.ly/301saUy

Categorization of the game types found yielded two card games, two simulators, and the remaining were a single hit under the category of mobile, RPG, strategy and time management, card game (physical) and board game (physical).

3.2   Survey output

The pilot evaluation study included 15 women with the mean age was 23.47 ± 6.60 years ranging from 19 to 40 years. All the respondents were Malay and only 13.3% (N=2/15) respondents are married and had a pregnancy experience. Responses for 13 items in Part A and 24 items in Part B of the survey were presented in Supplementary **Table 2** and **Table 3**, respectively. Knowledge on the relationship between healthy food with the GDM and the composition of gut microbiota was recorded in terms of right (or 'yes') and wrong (or 'no' or 'I don't know') answers and was presented in numbers and percentages (**Table 2**).

For knowledge about GDM, the highest number of right answers were recorded for questions 3 (86.7%) and 5 (86.7%), followed by question 3 (80.0%) (**Table 2**). The lowest number of right answers was recorded from questions 4 (13.3%) and 6 (53.3%). Whereas the majority of questions related to knowledge about healthy food nutrition (2 out of 3) recorded the highest right answers, questions 9 and 8 with 93.3% and 80.0% correct responses, respectively. In contrast, the 'no' or 'I don't know' answers were recorded highest in all questions related to knowledge on the relationship between food patterns and the composition of gut microbiota. The highest 'no' or 'I don't know' answers were recorded for questions 12 (86.7%) and 13 (86.7%) (**Table 2**). For the Part A feedback survey, the mean knowledge score of respondents on the GDM, healthy diet and gut microbiota was 7.67 ± 2.97 which indicates inadequate knowledge (score ≤7). The recorded score was lower as compared to Hussain and colleagues (2015) with a reported higher mean score of 10.01 ± 3.63.

Table 2: Responses of respondents for Part A of the feedback survey

No	Questions Part A	Right/Yes: N (%)	Wrong/No/ I don't know: N (%)
	Knowledge about GDM		
1	Gestational Diabetes Mellitus is a type of diabetes that occurs:	11 (73.3)	4 (26.7)
2	In uncontrolled Gestational Diabetes Mellitus, blood sugar levels are:	12 (80.0)	3 (20.0)
3	Your risk of developing Gestational Diabetes Mellitus increases if you:	13 (86.7)	2 (13.3)
4	You have an increased chance of developing Diabetes Mellitus Gestation if:	2 (13.3)	13 (86.7)
5	You are more likely to develop Gestational Diabetes Mellitus if you have:	13 (86.7)	2 (13.3)
6	The normal value of fasting blood sugar (FBS) is:	8 (53.3)	7 (46.7)
	Knowledge about healthy food nutrition		
7	If you have Gestational Diabetes Mellitus, you should control intake of foods with high content of:	11 (73.3)	4 (26.7)
8	Which of the following food can be eaten without restriction during Gestational Diabetes Mellitus:	12 (80.0)	3 (20.0)
9	What is the type of nutritional source mainly provided by rice?	14 (93.3)	1 (6.7)
	Knowledge on the relationship between food patterns and the composition of gut microbiota		
10	Did you know about the impact of daily food patterns on your intestinal microbiota composition?	6 (40.0)	9 (60.0)
11	Did you know about the importance of gut microbiota to the health of mother and child during pregnancy?	6 (40.0)	9 (60.0)
12	Did you know that the composition of the gut microbiota is different for pregnant women with diabetes mellitus?	2 (13.3)	13 (86.7)
13	Did you know that a well-balanced gut microbiota composition can reduce the risk of getting obesity and other diseases such as diabetes?	5 (33.3)	10 (66.7)

Score one was given to every right answer or "yes" and score zero to every wrong answer, "no" or "I don't know". The maximum score is 13 and the minimum is zero. The mean knowledge score of respondents on the GDM, healthy diet and gut microbiota was 7.67 ± 2.97.

The discrepancy between findings could be due to age factor, younger respondents in the present study (mean age was 23.47 ± 6.60 years) as compared to Hussain et al. (2015) with the mean age of 31.95 ± 5.35 years. Perhaps mature age may have a better understanding of the health issues related to pregnancy and GDM as compared to young adults. Thus, we could suggest that our respondents had good knowledge of GDM and healthy food nutrition. However, their knowledge of the relationship between the healthy diet with gut microbiota composition, and its interaction with the GDM and obesity during pregnancy remained low.

In terms of game design, we categorized the satisfaction and positive feedback into four levels which are 'strongly agree', 'agree', 'disagree' and 'strongly disagree', and was presented in numbers and percentages (**Table 3**). After playing 'MoM', the majority of respondents either strongly agreed or agreed that their health knowledge related to diet and gut microbiota during pregnancy and GDM were improved as observed from the responses of questions 1 and 2 (**Table 3**). All the respondents agreed that the MoM is a suitable gamification teaching tool to convey scientific concepts on gut microbiota and health to the public.

Further categorization of a degree of satisfaction on the storyline and game design shown in **Table 3** revealed that the majority of our respondents either strongly agreed or agreed that the narrative storyline and structure used in 'MoM' are suitable, accurate and relevant to the health concept and real-life situation (Questions 4 until 13).

The same positive feedback was obtained for the game design as we observed the majority of the respondents were either strongly agreed or agreed that the layout of the report card, duration of the game, the platform used, and graphics were suitable to them. The majority of the respondents spent between 30 minutes to 60 minutes to complete the game (66.7%) (**Figure 5A**). Impressively, some of the respondents completed the game within 30 minutes (26.7%). While playing the game, the majority of our respondents were showing either neutral (46.7%) or happy (33.3%) facial expressions (**Figure 5B**). Almost all of the respondents (93.3%) agreed that 'MoM' could be played independently, which is one of the key elements to ensure we developed a user-friendly game for health promotion. Overall, for Part B of the feedback survey on the game design, the mean score of satisfaction on the game design was 42.3 ± 6.49 (score ≥38).

Table 3: Responses of respondents for Part B of the feedback survey

No	Questions Part B	Strongly Agree: N(%)	Agree: N(%)	Disagree: N (%)	Strongly Disagree: N (%)
	Health knowledge feedback				
1	The 'MoM' game has increased my understanding of how daily food patterns affect gut microbiota composition:	5 (33.3)	8 (53.3)	2 (13.3)	0 (0.0)
2	The 'MoM' game has improved my understanding of how gut microbiota composition is different for pregnant women with diabetes mellitus?	3 (20.0)	11 (73.3)	1 (6.7)	0 (0.0)
3	Do you think MoM gamification is suitable to be used as a public health teaching tool?	7 (46.7)	8 (53.3)	0 (0.0)	0 (0.0)
	Narrative feedback				
4	The language used in this game is suitable for me	5 (33.3)	10 (66.7)	0 (0.0)	0 (0.0)
5	I can easily understand the terminologies used in the game narrative:	5 (33.3)	10 (66.7)	0 (0.0)	0 (0.0)
6	The plot for the story is interesting:	3 (20.0)	9 (60.0)	2 (13.3)	1 (6.7)
7	I understand the storyline for each chapter (month):	4 (26.7)	11 (73.3)	0 (0.0)	0 (0.0)
8	The characters in the game are accurate in providing the experience during pregnancy:	6 (40.0)	9 (60.0)	0 (0.0)	0 (0.0)

No	Questions Part B	Strongly Agree: N(%)	Agree: N(%)	Disagree: N (%)	Strongly Disagree: N (%)
9	The tone throughout the whole story fits the theme of the story which is on pregnancy experience of a mother:	5 (33.3)	9 (60.0)	1 (6.7)	0 (0.0)
10	The local foods highlighted in the story is relevant to me:	6 (40.0)	9 (60.0)	0 (0.0)	0 (0.0)
11	The local lifestyle elements highlighted in the story is relevant to me:	4 (26.7)	11 (73.3)	0 (0.0)	0 (0.0)
12	I have gained new knowledge about pregnancy through this game:	7 (46.7)	8 (53.3)	0 (0.0)	0 (0.0)
13	The facts included in the story are accurate:	5 (33.3)	10 (66.7)	0 (0.0)	0 (0.0)
14	What is your opinion on the narrative of the MoM game as a whole?	NA (Refer to **Table 4**)			
	Game design feedback				
15	The report cards (at the end of each day) help me understand how my choices affect my health:	3 (20.0)	11 (73.3)	1 (6.7)	0 (0.0)
16	The report cards (at the end of each day) help me understand how my choices affect my gut microbiome:	5 (33.3)	9 (60.0)	1 (6.7)	0 (0.0)
17	The duration of each chapter is acceptable for me	4 (26.7)	7 (46.7)	4 (26.7)	0 (0.0)
18	The duration of the entire game is acceptable for me	4 (26.7)	6 (40.0)	5 (33.3)	0 (0.0)
19	The platform used is suitable for me	5 (33.3)	10 (66.7)	0 (0.0)	0 (0.0)
20	The graphics used in the game is suitable for me	2 (13.3)	9 (60.0)	3 (20.0)	1 (6.7)
21	How much time has been spent playing this game	NA (Refer to **Figure 5**)			
22	Choose one facial expression that you do the most while playing the game	NA (Refer to **Figure 5**)			
23	Is this game can be played independently	NA (Refer to **Figure 5**)			
24	Overall, I enjoy the gameplay experience	7 (46.7)	7 (46.7)	1 (6.7)	0 (0.0)

Score three was given to every answer of 'Strongly Agree', score two for 'Agree', score one for 'Disagree' and score zero to every answer, 'Strongly Disagree'. The maximum score is 63 and the minimum is zero. The mean score of satisfaction on the design of the 'MoM' game was 42.3 ± 6.49.

Further analysis of test-player feedback revealed that participants mostly (10) spend between 30 to 60 minutes on the current version of the game (spanning four chapters), while only one participant took between 60 to 90 minutes to complete the entire storyline (**Figure 5a**). In terms of facial expression, a majority (seven) stated to have shown a neutral expression throughout playing the game, while five participants stated to have shown a happy expression. The remaining three participants admitted to expressing confusion while playing (**Figure 5b**). Interestingly, 14 of the participants agree that the game can be played independently, while one respondent states otherwise (**Figure 5c**).
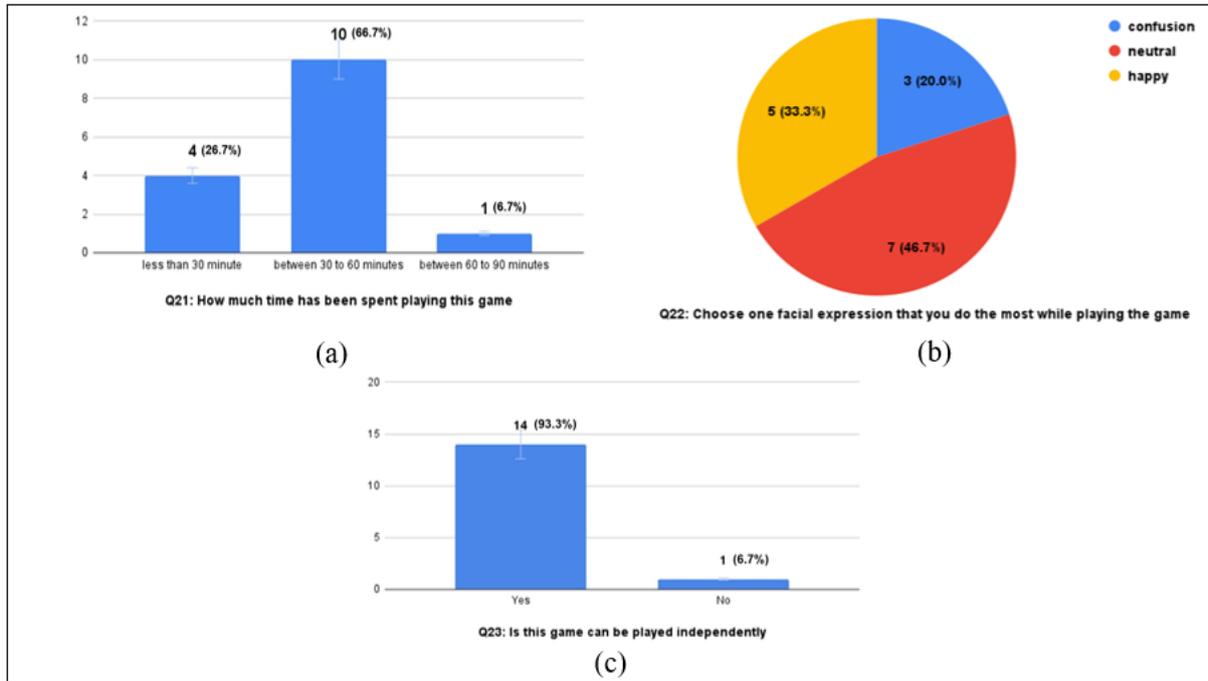
Fig. 5 The feedback on the total time spent (4a), facial expression (4b) and whether the MoM could be played independently (4c).

3.3 Game design output

A preliminary game of around 45 mins - 90 mins was developed. For test-play purposes, currently, only four out of the intended nine chapters were made available for test-players. The graphics for the game were kept to a minimum and were sufficient in exerting the intended feel of the game. While there was a long list of graphics planned to be added to the final product, it was deemed necessary to test out the end-user feedback before fully committing to any sort of graphic- or art-style (**Figure 6**).

Fig. 6 Screenshots of MoM showing choices during gameplay.

A rudimentary report card was designed to provide in-game feedback on the players' choices throughout the story (**Figure 7**). It essentially acts as a 'score screen' 'or result screen' that functions to i) wrap up a given chapter, and ii) provide information on the status of the players' gut microbiome.
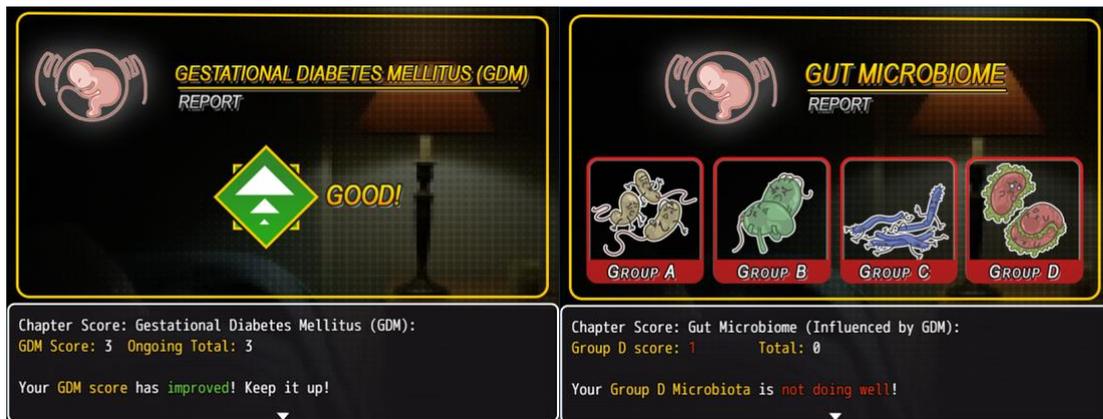
Fig. 7 Samples of the Report Card showing the effect of player choices on gut microbiome, generated at the end of each chapter

The screen is divided into four; i) GDM status, ii) Gut microbiome (influenced by GDM) status, iii) BMI status, and iv) Gut microbiome (influenced by BMI). A prompt stating 'Good' or 'Bad' was set to appear for the GDM and BMI statuses. While, for the gut microbiome statuses, the A, B, C, and D groups of bacteria for both GDM- and BMI-influenced was set to appear. For all four screens, a generalized text was programmed in to give players an overall idea of the four statuses.

3.4 Player Feedback

From the questionnaire, 10 out of the 15 test-players provided useful feedback. It should be noted that most of the comments provided were in the local language (Malay), and therefore some translation and interpretations were made to facilitate the feedback analysis. The remaining five either stated they had no opinion or simply commented 'good' (or equivalent) which did not leave much to extrapolate from. The comments mostly revolve around the story, where it can be interpreted to be 'Good' (six test-players), 'Good but needs improvement' (two test-players), and 'Bad' (two test-players) (**Table 4**). Overall, test-players agreed that the story is either relatable or of sufficient quality. However, as expected, the duration of the story did not appeal to some of the test-players, with one stating simply that the story is 'too long' or that the story is 'uninteresting'.

Table 4. Test-player feedback translation and interpretation.

No	Feedback (Translation, simplified)	Interpretation	Limitations	Proposed Improvements
1	Good story, but needs more focus on variety (in the story).	Good but needs improvements	Not enough variety	More choices or branching narratives
2	Easy to understand, and appropriate for the masses.	Good	n/a	n/a
3	The story is interesting, brief, and easy to understand.	Good	n/a	n/a
4	Good story. Needs more information on diet and recommended activities for pregnant mothers.	Good but needs improvements	Not enough information	More information on diet and suggested activities
5	Casual story and useful information.	Good	n/a	n/a
6	Story is too long.	Bad	Length of story is too long	Shorten the story, less text less branches
7	Story needs to be improved.	Bad	(Delivery of) story is uninteresting	Shorten the story, add drama or conflict,

No	Feedback (Translation, simplified)	Interpretation	Limitations	Proposed Improvements
				change game format
8	Relatable storyline.	Good	n/a	n/a
9	Story improves knowledge on pregnancy and GDM.	Good	n/a	n/a
10	Good story and relevant to Malaysians.	Good	n/a	n/a

4.   Discussion

4.1   Keyword Search

While some games with a narrative on pregnancies were available, they were mostly focused on simple interactive gameplay components. Moreover, the design of the games suggest that they are intended for a much younger target demographic and do not offer real-life applications. Arguably, certain aspects of the games do provide some degree of knowledge (e.g. the interactive sonogram in 'Pregnant Mommy Care Baby Game'), however simplistic they may be. More nuanced games such as the 'Guts (RPG)', 'Gutsy', and 'Gut Check' on the other hand, while providing experiential learning through gameplay mechanics, do not cater to pregnancy-related themes.

4.2   Survey output

The degree of player satisfaction towards the storyline suggests that the game was designed with the appropriate concepts, easily understood metrics (health issue), and game mechanics that were relatable to the respondents. Further, the overall design had successfully elicited satisfaction in players, as indicated by the facial expressions and time-to-completion. The players' ability to complete the game without assistance suggests that the game mechanics are sufficiently simple, even for players with little-to-no experience playing games. However, the underlying concept behind the mechanics and story may be unclear to some of the respondents (i.e. players simply playing for the sake of playing, without truly experiencing the subtle nuances of the design). This may likely be contributed by limited experience and game literacy part and will have to be factored in during the upcoming iterations of the game (Klimmt, 2009).

4.3   Game design

The initial conjecture when selecting RPG Maker MV software for the game development was that it possesses the necessary capabilities for making a visual novel game. In truth, the decision to use the software was simply due to prior experience and familiarity. Following the principle of 'minimum viable product', it was decided that the software was sufficient to create the end-product intended by the team without the need to slog through a steep learning curve. While other tools and software were explored (e.g. Twine), the inherent lack of programming skills rendered it nigh impossible to achieve the intended 'minimum viable product' within the decided production time. In short, RPG Maker MV's 'Event-Based Programming' allowed for a quick-and-dirty approach for creating the visual novel game and testing out the concept being explored.

Verbal feedback during alpha-tests suggests that test-players have difficulty comprehending a purely numerical score sheet. Therefore, a more graphics-heavy results screen was adapted. It is readily admitted that compressing the vast scientific findings into a graphical format that is easily digestible by the layman is no easy task (Agusalim, 2015). This is in large due to the complex nature of the gut microbiome profile, making them difficult to group in a conventional fashion. Ultimately, the microbiome groups were subdivided into simple categories based on direct or inverse proportions with BMI and GDM. Furthermore, the "Event-Based Programming" requires a relatively creative approach when handling variables for calculations to capitalize on graphical representation of the data. It is

assumed that any obvious use and display of numbers (i.e. in the form of scores or points) would devolve the gameplay, where players would simply aim for the options with bigger scores.

However, it is possible that a completely different approach will be more suitable, such as the incorporation of a permanent HUD during gameplay (Rosyid et al, 2021). This may be more effective at conveying the impact of a player' set of choices in real time, rather than at the end of a given chapter.

4.4   Player feedback

Verbal feedback and personal communications also revealed that test-players tend to have an aversion to reading long texts. Arguably, either this may be due to a lack of interest in reading in general, or the story provided lacks the necessary plot points to retain player interest. It is also possible that the aversion above is due to the game being in English rather than in the local language. It is frequently discussed during game development that the story may require further streamlining or simplifying. In addition, the possibility of providing a translation of the game is also considered. However, due to the time investment required to achieve this, it was decided to finalize the gameplay mechanics before embarking on such a daunting task (Winn, 2009).

Most of the test-players agree that the concept proposed in this game design is unique in that they feel relatable to the provided content. Noticeably, few comments suggests that the test-players wish to indulge in a more fantasy setting (e.g., they wished the husband character were Korean). It was decided that it did not entirely fit the narrative for the time being (Although admittedly, it would make an interesting plot point to build upon, but that would be counterproductive towards the 'reading aversion' mentioned above).

Arguably, the small sample size does not provide an accurate measurement of the entire Malaysian population's preference towards visual novels. However, as the game development is done with the intention of iterative design format, the information gathered is highly useful in finessing the development direction and avoid it from going off the rails. Further improvements will be made and more feedback will be gathered accordingly until a satisfactory finalized product can be achieved (Viudes-Carbonell et al., 2021).

5.   Conclusion

The preliminary findings suggest that the gameplay and design direction in 'MoM' has the potential to be used as an educational tool on gut microbiome. Test-players agree that to them, this is a novel approach to pregnancy health education. Understandably, the game design approach needs to be improved in order to retain player interest. Further, additional information needs to be carefully added to the game in order for players to benefit more from their experience. However, it can be concluded that the development direction of this game-based learning approach has potential.

6.   Suggestions

Notably, a majority of the potential test-players approached for the survey were iPhone users, and the initial deployment was done on Android. However, since deployment to iOS was not possible at the time of development and test-play, to compensate, an additional deployment was made to the Windows OS. It is also recommended that the survey be carried out to a larger sample size, with a broader age group and more identifiable game literacy.

7.   Co-Author Contribution

The authors affirmed that there is no conflict of interest in this article. Author 1 carried out the game development, graphics design and contributed to the write up of the article. Author 2 prepared and ran the survey, recruiting test-players, running analysis and contributed to the article write up. Author 3 contributed to the script writing, quality assurance of the game and preparing the literature review. Author 4 contributed to the script writing and literature review. Author 5, Author 6 and Author 7 provided input on medical information and reviewed the medical relevance involved in the game development.

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