

# Towards the Development of a Personalized Nutrition Knowledge-Based System: A Mixed-Methods Needs Analysis of Virtual Dietitian

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**Abstract**— Albeit the potent association between nutrition and health has been repeatedly corroborated in the field of nutrition science through evidence-based approaches, the prevalence of inadequate nutrition among Filipino households is still too high. Therefore, the goal of this study was to pinpoint nutrition challenges faced by Filipino young adults and evaluate whether a personalized nutrition knowledge-based system is a potential nutrition intervention tool. A mixed-methods needs analysis approach was operated to arrive at a panoramic profile of a nutrition knowledge-based system through the participation of respondents in an online survey ( $n = 85$ ) and focus groups ( $n = 4$ ). The assessment was grounded from the influencing factors of health and nutritional status such as food selection, nutrition barriers, poor eating habits, nutrition knowledge, and with the inclusion of nutrition application for technical feedback. The findings exploited the fact that people do not track what they eat, let alone the nutrients it contained, which eventually leads to undereating or overeating. There was also a commonness in lack of nutrition knowledge to make healthier food choices. Fortunately, the willingness of participants to point their directions towards a healthier lifestyle through the use of a nutrition knowledge-based system was evident. The paper then concluded with recommendations for future studies and how its findings might be utilized for the development of a personalized nutrition system.

**Index Terms**— Personalized Nutrition, Knowledge-Based System, Nutrition Tool, Dietetics, Needs Analysis, Nutrition Application.

## 1 INTRODUCTION

THE latest National Nutrition Survey (NNS) of the Food and Nutrition Research Institute (FNRI) revealed that there is a multitude of contemporary inadequate nutrition problems and challenges among Filipinos [1]. To date, NNS is the main source of data that classifies Filipino citizenry's nutritional and health status. As such, the realization of nutritional adequacy has been advocated under the Philippine Plan of Action for Nutrition (PPAN) 2017-2022 in agreement with the Philippine Development Plan (PDP) of the 10-point Economic Agenda of President Rodrigo Duterte [2]. In nutrition science research, an adequate nutrition means the full acquisition of the nutritional needs of the person with a proper macronutrient distribution based from the recommended daily allowances of all essential minerals and vitamins [3] relative to the recommended energy and calorie intakes per day (e.g., Philippine Dietary Reference Intakes [4]). Aside from the conclusions of NNS, a more recent study also publicized the inadequacy for most macro- and micronutrients among Filipino adolescents and schoolchildren [5]. During these age groups, poor nutrition is associated with an increased risk of diabetes, hypertension, coronary heart disease, and obesity, thus rendering a crucial role for childcare providers to guide children in inaugurating a healthy eating pattern and smarter food choices [6]. Labeled as a critical and neglected age group, young people also reached the epidemic levels of overweight and obesity [7], with about one in three adolescents affected worldwide. The current state of nutrition status is truly alarming and urgently needs to be solved.

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### 1.1 Background of the Study

In terms of nutrition interventions, or strategies to enhance the nutritional status of an individual, the health community has a myriad of experience in creating and evaluating intervention techniques [8] both implemented alone or in combination with other comprehensive nutrition care practices. As early as 1983, the Food and Agriculture Organization of the United Nations has already highlighted several nutrition interventions as well as a detailed set of criteria for selecting the most appropriate strategy for nutritional improvement [9]. To name a few, these nutrition interventions include school feeding, promotion of breastfeeding, nutritional rehabilitation, family planning, and face-to-face nutritional communication. Further, a novel breed of nutrition tool has also emerged due to computer revolution from web-based and mobile apps to wearable devices [10].

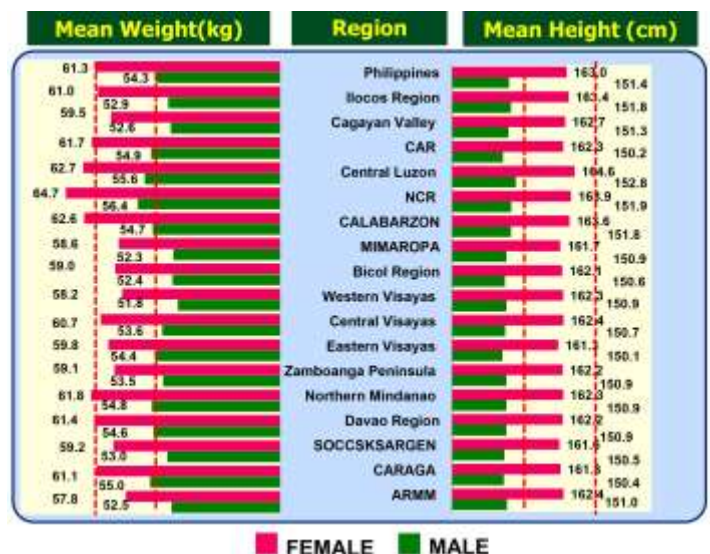


Fig. 1. Mean Height and Weight of Filipino Adults by Region.

Technology-based intervention tools are now gaining traction in the field of nutrition. For instance, Food-O-Meter [11] is an online nutrition intervention tool designed for adolescents to improve their dietary intake of specific nutrients such as fiber, vitamin C, iron, calcium, and fat. Based from both short-term (1-month) and medium-term (3-month) impact evaluations, however, there was no significant changes in fat intake for the intervention group. As such, Food-O-Meter was suggested to be developed further to improve its effectiveness as a nutrition intervention tool. Another technology-based intervention tool is the Quest to Lava Mountain – a computer game on dietary and physical activity behaviors [12]. After playing an average of 4.6 hours during the six-week intervention, decreased sugar consumption and a higher physical activity attitude among children were publicized. These computer-based intervention tools along with other examples in a recent systematic review [13] only revealed a preliminary evidence. It is still difficult to determine which type is more effective although any strategy with technology is more appealing among youths. The use of knowledge-based system is also underexplored.

## 1.2 Study Objectives

This study therefore is focused on identifying challenges faced by Filipino young adults in their nutrition as well as assess the applicability and suitability of a nutrition knowledge-based system as an intervention tool. This study is also an attempt to provide a panoramic profile of a nutrition knowledge-based system called “Virtual Dietitian” which was initially cited in the development of “Plan-Cook-Eat” – a progressive web meal planner application [14]. The panoramic profile is intended to lay the foundation for dietary change interventions along with the implementation of a theoretically-based approach. On the other hand, the inclusion of participants in this study serve as a participatory model prior to the final development of Virtual Dietitian making them as somewhat system co-designers and source of feedback. These variables are considered as effective components when implementing nutrition intervention [15].

TABLE 1  
FOCUS GROUP GUIDE QUESTIONS

Variables	Questions
Nutrition Knowledge	1. How do you think nutrition knowledge, or lack thereof, affects your food intake? 2. What comes into your mind when you hear or think of health foods or eating healthy? 3. What do you think is the effect of knowing the nutrition information of foods you eat?
Food Selection	1. How do you select your food daily? 2. Do you consider micro and macronutrients when choosing foods? Why or why not?
Nutrition Barriers	1. What are the reasons that prevent you from selecting and eating healthy meals? 2. Which foods are the most difficult to avoid?
Poor Eating Habits	1. Do you calculate the amount of calories in a meal and its total in a day? Why or why not? 2. How would you describe your eating habit or pattern in a daily basis?
Nutrition Application	1. In what way do you think a nutrition app can help you to consume healthier foods? 2. What features do you think are helpful for your nutritional status? Why?

## 2 METHODS

At its core, the study utilized a mixed-methods needs analysis approach using a focus group and online survey methodology to achieve a balanced quantitative and qualitative exploration. Simultaneous deployment of both quantitative and qualitative methods covers a deeper comprehension of a phenomenon, in which there exists too little prior research [16]. In this case, the development of a nutrition knowledge-based system was the phenomenon under study. The focus group design was used as the qualitative method to extract participants’ opinions and beliefs regarding their nutrition problems and how solutions could be aided by a nutrition system. Such method has been demonstrated as a useful tool in gathering exploratory data in the initial phase of a research study [17]. In addition, an online survey was also utilized to offer a complementary perspective of the nutrition systems development, which was executed in parallel with the focus group. Quantitative data was fixated on the evaluation of nutrition knowledge-based system features to arrive at a description of the proposed solution. Data from both methodologies was analyzed independently.

### 2.1 Participants in Focus Groups and Online Survey

For the focus groups, participants were recruited over a six-week period through the employment of multiple community-based recruitment strategies which are considered as standard methods in the field of health and medical research [18]. These include internet postings, direct recruitment of potential study participants, referrals from non-investigators, and a snowball sampling. A set of eligibility and selection criteria was placed to ensure that the results are caused by the intervention and not by other factors. The criteria for focus groups were: (1) Filipino, (2) male and female young adults (ages 18-35 years old), (3) who are in good health, (4) could provide informed consent, and (4) two days of food record. Young adults were specifically chosen as they are at the forefront of the obesity epidemic and in need of public health interventions [19]. On the other hand, the online survey was distributed using social networking websites. The only eligibility criterion was that the participants should be a Filipino to match the ethnographic profile of the focus group and the background of the study.

### 2.2 Data Collection and Analysis

The focus groups method was participated by four groups with five participants each who underwent the same content and structure. Each participant gave an informed consent and the nature of the study was explained prior to the session. All interviews were held in a private conference room inside an academic institution and facilitated by the same person for consistency purposes. Responses to the questions (see Table 1) were audio-recorded and transcribed in full. Statements were extracted and clustered according to nutrition app features via a document analysis technique. On the other hand, the link to the private server (where the survey was stored) was sent via electronic messaging and social networking sites. The survey was available online for four weeks. Moreover, the questions and statements about the nutrition app features were rated using a 5-point Likert scale. These nutrition app features were based from the qualitative data from the focus groups.

**TABLE 2**  
**FREQUENCY DISTRIBUTION OF DEMOGRAPHIC, SOCIOECONOMIC, AND ANTHROPOMETRIC VARIABLES OF PARTICIPANTS**

Variables	Focus Groups (n = 4, t = 20)			Online Survey (n = 85)			Total n (%)
	f	%	95% CI	f	%	95% CI	
<b>Age</b>							
18yrs - 25yrs	13	65.00	62.1 - 68.3	53	62.35	58.3 - 65.1	66 (62.86)
26yrs - 30yrs	7	35.00	31.9 - 38.2	23	27.06	24.4 - 29.9	30 (28.57)
31yrs - 35yrs	0	0.00	-	9	10.59	8.2 - 12.5	9 (8.57)
<b>Living Condition</b>							
With Family	15	75.00	70.4 - 78.9	39	45.88	40.1 - 49.3	54 (51.43)
With Roommates	3	15.00	13.1 - 16.9	24	28.24	24.3 - 31.1	27 (25.71)
Alone	2	10.00	8.5 - 11.1	22	25.88	21.2 - 28.4	24 (22.86)
<b>Monthly Household Income</b>							
Poor (< PHP 9,520)	0	0.00	-	2	2.35	1.9 - 2.8	2 (1.90)
Low Income (PHP 9,520 - PHP 19,040)	0	0.00	-	6	7.06	5.1 - 8.9	6 (5.71)
Lower Middle Income (PHP 19,040 - PHP 38,080)	0	0.00	-	51	60.00	56.2 - 64.3	51 (48.57)
Middle Middle Income (PHP 38,080 - PHP 66,640)	17	85.00	82.1 - 88.2	25	29.41	26.4 - 33.3	42 (40.00)
Upper Middle Income (PHP 66,640 - PHP 114,240)	3	15.00	12.9 - 17.5	1	1.18	0.8 - 1.4	4 (3.81)
<b>Current Physical Activity</b>							
Sedentary (Little or no exercise)	5	25.00	23.4 - 26.9	41	48.24	47.2 - 50.1	46 (43.81)
Light (Exercise 1-3 times/week)	7	35.00	32.2 - 38.3	13	15.29	13.1 - 17.2	20 (19.05)
Moderate (Exercise 4-5 times/week)	2	10.00	8.5 - 12.1	12	14.12	11.8 - 15.1	14 (13.33)
Active (Daily exercise or intense exercise 3-4 times/week)	3	15.00	13.2 - 17.6	16	18.82	15.9 - 21.2	19 (18.10)
Very Active (Intense exercise 6-7 times/week)	3	15.00	13.1 - 17.1	3	3.53	2.1 - 5.0	6 (5.71)
Extra Active (Very intense exercise daily)	0	0.00	-	0	0.00	-	0
<b>Nutritional Status</b>							
Underweight (BMI < 18.5 kg/m <sup>2</sup> )	4	20.00	18.6 - 21.2	12	14.12	11.9 - 16.2	16 (15.24)
Normal (BMI >= 18.5 and < 25 kg/m <sup>2</sup> )	8	40.00	38.2 - 41.8	36	42.35	41.1 - 44.2	44 (41.90)
Overweight (BMI >= 25 and < 30 kg/m <sup>2</sup> )	3	15.00	13.2 - 16.9	27	31.76	29.7 - 33.2	30 (28.57)
Obese (BMI >= 30 kg/m <sup>2</sup> )	5	25.00	24.1 - 26.5	10	11.76	9.2 - 13.1	15 (14.29)
<b>Average Number of Meals a Day</b>							
Two	1	5.00	3.5 - 5.4	12	14.12	12.1 - 16.0	13 (12.88)
Three	12	60.00	54.1 - 65.5	39	45.88	43.2 - 48.1	51 (48.57)
Four	4	20.00	18.2 - 22.5	23	27.06	24.1 - 29.9	27 (25.71)
More than Four	3	15.00	12.1 - 17.5	11	12.94	9.2 - 15.1	14 (13.33)
<b>Energy Consumption</b>							
< 1000 kcal	1	5.00	3.9 - 5.5	0	0.00	-	1 (0.95)
>= 1000 kcal and < 2000 kcal	7	35.00	32.1 - 38.2	21	24.71	21.2 - 26.5	28 (26.67)
>= 2000 kcal and < 3000 kcal	11	55.00	32.1 - 38.2	26	30.59	27.5 - 33.1	37 (35.24)
>= 3000 kcal and < 4000 kcal	1	5.00	3.5 - 5.4	34	40.00	37.2 - 42.1	35 (33.33)
>= 4000 kcal	0	0.00	-	4	4.71	3.1 - 5.8	4 (3.81)

### 3 RESULTS AND DISCUSSION

The primary objectives of the study were to identify nutrition challenges faced by Filipino young adults, and assess whether a nutrition knowledge-based system is a prospective nutrition intervention tool. To do this, the variables sought in the profile of respondents must establish a clear picture that paints their nutrition challenges. First, the robust connection of household income with adequate nutrition has been established, where low socioeconomic status limits the access to high quality food and adequate diets [20]. That is, low income status is related to non-adherence to science-based recommendations, or known as food-based dietary guidelines, which adversely influences health [21]. On the other hand, individual physical activity has been connected to food intake as working body requires more energy to burn [22]. Meaning, a person who undergoes intense training is likely to eat more than a person who has short term physical activity. The meal spacing is also an important factor to consider when looking at a nutrition profile. The strategic use of meal spacing could compensate the urge of people who eat more food in a day. For instance, a person who is used to eat a lot in a day could divide meals and calorie requirements depending on the preferred meal spacing. On that way, there

is a guarantee that calorie requirement is being met regardless of how many times they eat in a day. The calorie requirement is commonly based on Total Daily Energy Expenditure (TDEE) which was explained on Plan-Cook-Eat [14]. Depending on body goals, an individual may select either a calorie surplus, calorie deficit, or the exact value of TDEE. Based from this, the weight of an individual will either be increased, decreased, or maintained. Lastly, BMI illustrates an image of participants' nutritional status as key determinant on predicting chronic diseases [23]. It is also considered as a good indicator of excess adiposity and an inexpensive method for assessing body fatness along with other anthropometric measurements [24].

Table 2 presents the frequency distribution of participants in terms of demographic, socioeconomic, and anthropometric variables for both focus groups and online survey. The study found a high number of people living either with their family (51.43%) or roommate (25.71%) and have a monthly income household of lower middle income (48.57%). Their physical activity is sedentary (43.81%) with a normal BMI (41.90%) and usually need to consume daily calories from 2000 to 3000 kcal (35.24%). Their meal spacing is three meals a day (48.57%).

The first goal of the data gathering was to elicit opinions and views concerning nutrition challenges and how it could be aided by a nutrition knowledge-based system. Through a focus group design, the guide questions revolved around the following concepts: nutrition knowledge, nutrition barriers, food selection, poor eating habits, and nutrition application. Some excerpts of the qualitative data from the focus group sessions were presented on each UI. Second, system features emerged from the sessions were rated in an online survey to gauge the acceptability of other potential users. High fidelity prototype designs were created as well to represent the user interface before the final system exists. Results were shown on Table 3. Finally, a functional architecture for the system was developed initially as a basis for Virtual Dietitian.



Fig. 2. App UI Screens: Meal Plan and Nutrition Facts Label.

Nutrition knowledge has been credited for providing the necessary power for people to be a smarter decision-maker when it comes to food selection and dietary choice [25]. It is also evident nutrition knowledge affects attitudes, which has been a useful construct for food evaluations [26]. However, sessions from the focus groups revealed that people lack the needed nutrition knowledge to make healthier food choices. Figure 1 shows the app screens that generates a personalized meal plan with the nutrition information to inform users on the nutrients contained on each ingredient and meal.

*In my opinion, eating healthy means eating vegetables and fruits, and avoiding fatty foods like Lechon and fried foods. [P2]*

*It is difficult to track nutrients because I don't even know how to that's why I eat food whatever is available in the table. [P4]*

*Because I don't know what kind of foods to eat and what not to eat, I just eat whatever is delicious and affordable. [P5]*

*My knowledge in terms of nutrition is limited. I stay healthy by following suggestions from other people whom I know is healthy themselves. I want to consult with dietitians or nutritionists but it will be expensive for me especially that I want to have a regular meeting so that I can achieve my fitness goals in life. [P10]*

*In my opinion, yes, an app that generates meal plan will be very helpful for me because I don't have to think, plan, or calculate the nutrients, the fat, those kind of data, and other stuff. [P11]*



Fig. 3. App UI Screens: Food Tracker and Grocery List.

People have generally different motivations behind what they eat everyday such as habit, variety, convenience, price, preferences, and hunger [27]. It is evident that people do not look at the nutrition contents when choosing foods – a clear manifestation of the nutrition problem emerged from NNS. Focus group sessions also exposed that people do not track what they eat, let alone the nutrients it contained. Given the fact that dietary tracking is essential for consistent long-term weight loss success [28], it is clear that people should have a way of doing so. Hence, food tracker was also considered as a feature for the nutrition knowledge-based system. Grocery list generator was also added based on the meal recipes on the system to simplify the preparation process.

*I just eat whatever my mom cooks for the whole family. We do not actually look at the nutrition contents. When she cooks eggs or Adobo, we all eat it in the family. Besides, our food is reliant on the budget given by our dad. [P5]*



*I want to have a personal diary where I can log my food, or an app to do that for me automatically. [P7]*

*I just eat whenever I want and whatever food is available and what I can buy which is why I am not sure how many times I eat in a day or how much in terms of calorie stuff. [P19]*

*Calculating the data every day is tedious so I don't do it. I also do not know where and how to start. [P20]*

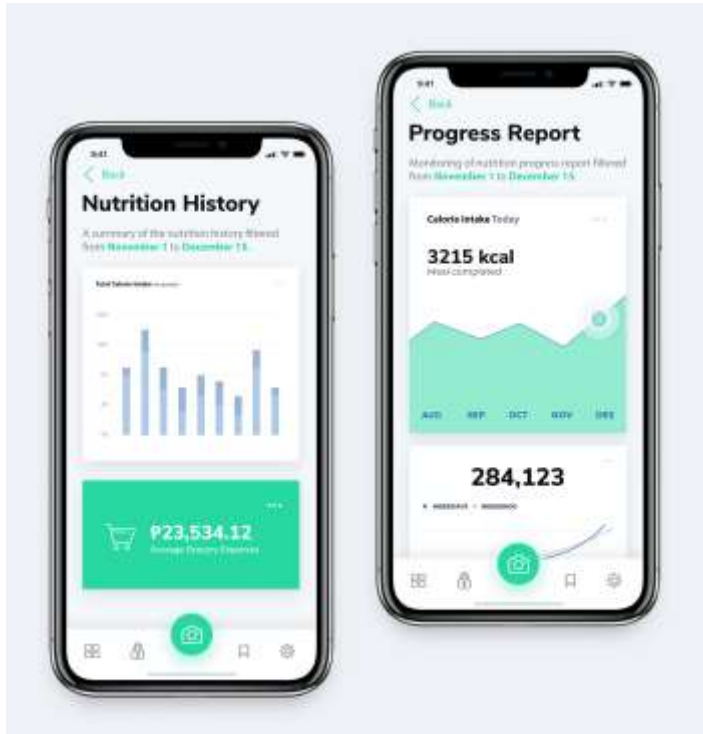


Fig. 4. App UI Screens: Nutrition History and Progress Report.

Tracking and monitoring nutrition progress is also vital in painting a picture of dietary habits. Identifying this eating habit, although tedious when done manually, could deliver a better well-being especially that it is associated with health-related quality of life [29] and school performance [30]. The challenging task of monitoring nutrition progress could be ease by automating the task using an application. Therefore, nutrition history and progress report were included in the list of features (See Figure 3). It also includes interactive charts as graphical representations of data for easier understanding.

*Tracking nutrition is already available in other apps so I think automatically selecting meals for me based from what I should eat will be helpful for me. [P6]*

*I want to lose weight but I don't know how much to eat or what should I eat to achieve my goal. [P7]*

*I like to keep track of my calories and to be warned if I am about to eat more than I should have. [P11]*

*There should be a list of recipes, the nutrients per meal, and recommendations if it should be my meal. [P13]*

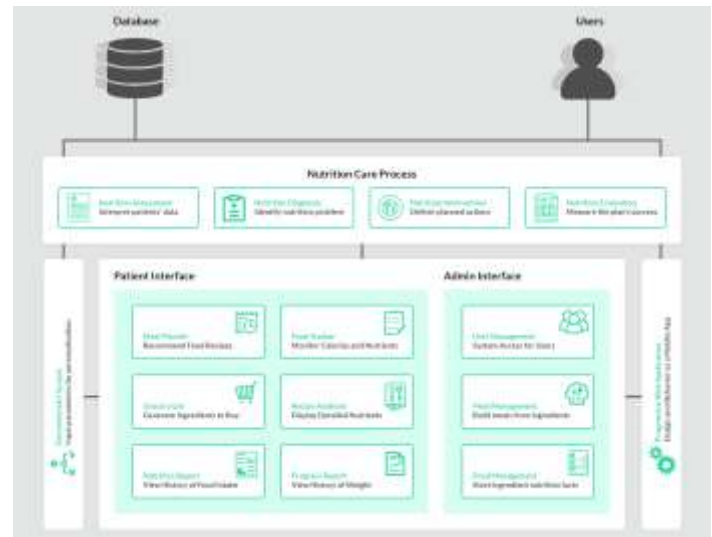


Fig. 5. Proposed Nutrition System Architecture.

The system architecture (See Figure 5) was grounded on processes and features that emerged from the focus group sessions, and evaluated on the online survey. The interface includes modules such as meal planner, food tracker, recipe analyzer, grocery list, nutrition report, and progress report. Personal information was also added such as age, height, weight, and physical activity for the calculation of TDEE, and restrictions (allergies, religion) and preferences (dietary type, body goal) as recommended in Plan-Cook-Eat [14].



Fig. 6. Meal Plan with Equivalent Nutrition Facts per Meal.

Based on the responses from the online survey and focus group sessions, it was evident that there are nutrition trials and challenges that impede a quality well-being, which then supports the results of NNS. Respondents generally lack the needed nutrition knowledge to make smarter food choices. Hence, they only eat whatever is available and accessible, or whenever there is a meal prepared by family members (e.g., mother). Furthermore, tracking food nutrients are considered a daunting task as well as the daily calculations of nutrition

data. Fortunately, they expressed willingness not only to eat healthier foods but also to track their nutrition as long as it is automated and easy to use. Respondents find it important to monitor their nutrition but will only do so if it is easy to do. Hence, the emerged features and system architecture along with the added designs of meal plan and equivalent nutrition facts (Figure 6) and conceptual data model (Figure 7) were identified to fulfill the ease in monitoring and diet planning.

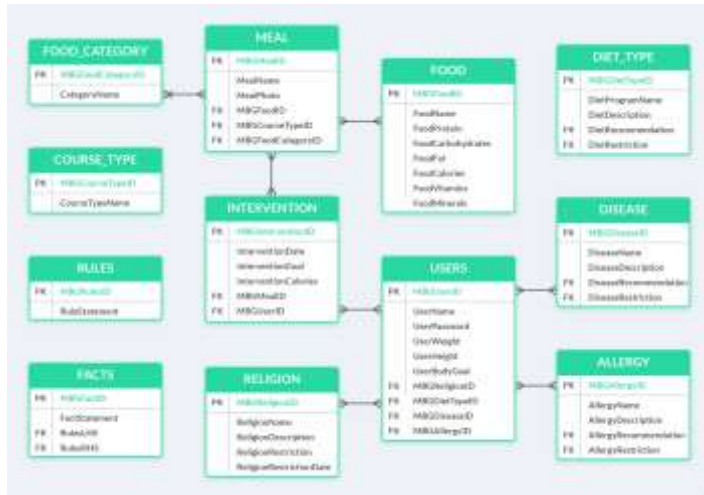


Fig. 7. Proposed Conceptual Data Model.

Table 3 illustrates the most rated nutrition system features that must be first considered in developing a nutrition knowledge-based system as an intervention tool such as meal planner (M=4.87, SD±0.12), food tracker (M=4.91, SD±0.11), grocery list (M=4.23, SD±0.34), nutrition fact (M=4.56, SD±0.41), nutrition history (M=4.31, SD±0.19), as well as progress report (M=4.69, SD±0.22). The result of the quantitative exploration was in line with the findings of Plan-Cook-Eat [14] where an application is suggested to integrate nutrition knowledge throughout the modules. The use of nutrition facts in meals, for instance, help users to assist in selecting food while learning the nutrients of each ingredient although the meal selection is automatically performed by the meal planner module. The inclusion of more nutrition-related modules were also warranted. Fortunately, food tracker was emerged from participants' selected features. This module is the food diary version of the nutrition system. The importance of nutrition history and progress report were also evident on the study. It only means that although people do not generally track what and the amount of food they eat; they are still willing to monitor their nutrient intake.

TABLE 3  
EVALUATION OF THE PROPOSED NUTRITION SYSTEM FEATURES

Features	Purpose	Mean
Meal Planner	Recommend food recipes	4.87
Nutrition Fact	Display nutrition information	4.56
Food Tracker	Monitor calories and nutrients	4.91
Grocery List	Generate ingredients to buy	4.23
Nutrition History	View history of food intake	4.31
Progress Report	Monitor weight progression	4.69

#### 4 CONCLUSION

Adequacy of nutrient intake is a cornerstone of leading a healthy lifestyle as lack thereof is associated with increased morbidity and mortality, and an overall decreased quality of life. Therefore, it is important to ensure the maintenance of a good nutritional status. Unfortunately, the findings exploited the fact that people do not track what they eat, let alone the nutrients it contained, which eventually leads to undereating or overeating. There is also a prevalence in lack of nutrition knowledge to make healthier food choices which is usually dependent on family members' preferences [31]. Affordability [32] and accessibility [33] are also essential factors in making food choices. Fortunately, the willingness of participants to point their directions towards a healthier lifestyle through the use of a nutrition knowledge-based system is evident on the findings. Therefore, this study is a confirmation that such computer-based application is needed not only as a nutrition intervention tool but also as part of the overall health sector.

On a side note, there are study limitations that should be reported and addressed. First, perceptions of the participants with regards to existing nutrition tools were not gathered. As such, a comparison was not made between the existing apps to the proposed nutrition knowledge-based system. Further, data gathered from the online survey was self-reported. It is also important to note that the topics discussed on the focus groups were limited on the following concepts: poor eating habits, nutrition knowledge, nutrition barrier, food selection, and nutrition application. There is a possibility that there are still other variables and concepts that needs to be exploited to fully comprehend the nutrition challenges of Filipino young adults. And in terms of age, the results might also differ when the age bracket is changed, i.e., infants, adolescents, adults [34]. It is also worth exploring other factors such as pregnancy, athleticism, nutritional disorders and chronic diseases.

Nevertheless, the findings of the study will be integrated in the next phase of the project which is the development of the final version of the nutrition knowledge-based system called "Virtual Dietitian". Future nutrition applications, systems, and tools could also take advantage from the findings of this study by ensuring that their system is compliant to the needs of their users and could provide a straightforward solution to their nutrition challenges. As mentioned in literature, the inclusion of participants through a participatory model is essential to the effectiveness of a nutrition intervention strategy along with its theoretical basis. In the case of Virtual Dietitian, the grounding framework of the knowledge-based system will use Nutrition Care Process as the systematic approach to ensure the quality and consistency of individualized nutrition care. Implemented by dietitians and nutritionists to their patients, this approach includes four stages such as nutrition assessment, diagnosis, intervention, and monitoring and evaluation. Good nutrition is an important criterion of leading a healthy lifestyle which is why it is important to maximize technology in achieving it.

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